## 4.6 INVENTORY OF DISTRIBUTION PIPE *

### 4.6.1 PURPOSE

Precise details of the distribution network are not known and many cross-connection details are unclear.

A correct inventory of the pipelines, showing the exact alignment, size, year of installation, pipe material, depth etc. should be maintained in an appropriate format. Similarly an inventory has to be prepared for valves, indicating the type, diameter, exact location, direction of rotation for closing and opening, number of turns, etc. Inventory containing the location of hydrants and house connections should also be available.

A start was made with the use of metallic pipe locators and non-metallic pipe locators to trace pipe alignment and location in three pilot areas.

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 initiated to resolve them. This may involve trial pitting to determine pipework details.

This information will be utilized to identify characteristics of the distribution pipes in the Dar-es-Salaam water supply system, based on investigation results.

### 4.6.2 PROCEDURE

In order to update information about distribution pipes, maps (1:2500 or 1:5000) were distributed to the five sub-branches during the first on-site study. The sub-branches returned these maps after filling in the location, size, installation year and material of pipes and valves. During the second on-site study period, based on these maps, confirmation and additions were made with the help of NUWA engineers and technicians.

### 4.6.3 RESULT

The distribution pipes drawings are shown in Figure C.4.15.

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* The results of this inventory survey which results are summarized in section 4.3.1 "outline", Main Report, are used in section 5 "network analysis", Appendix C.

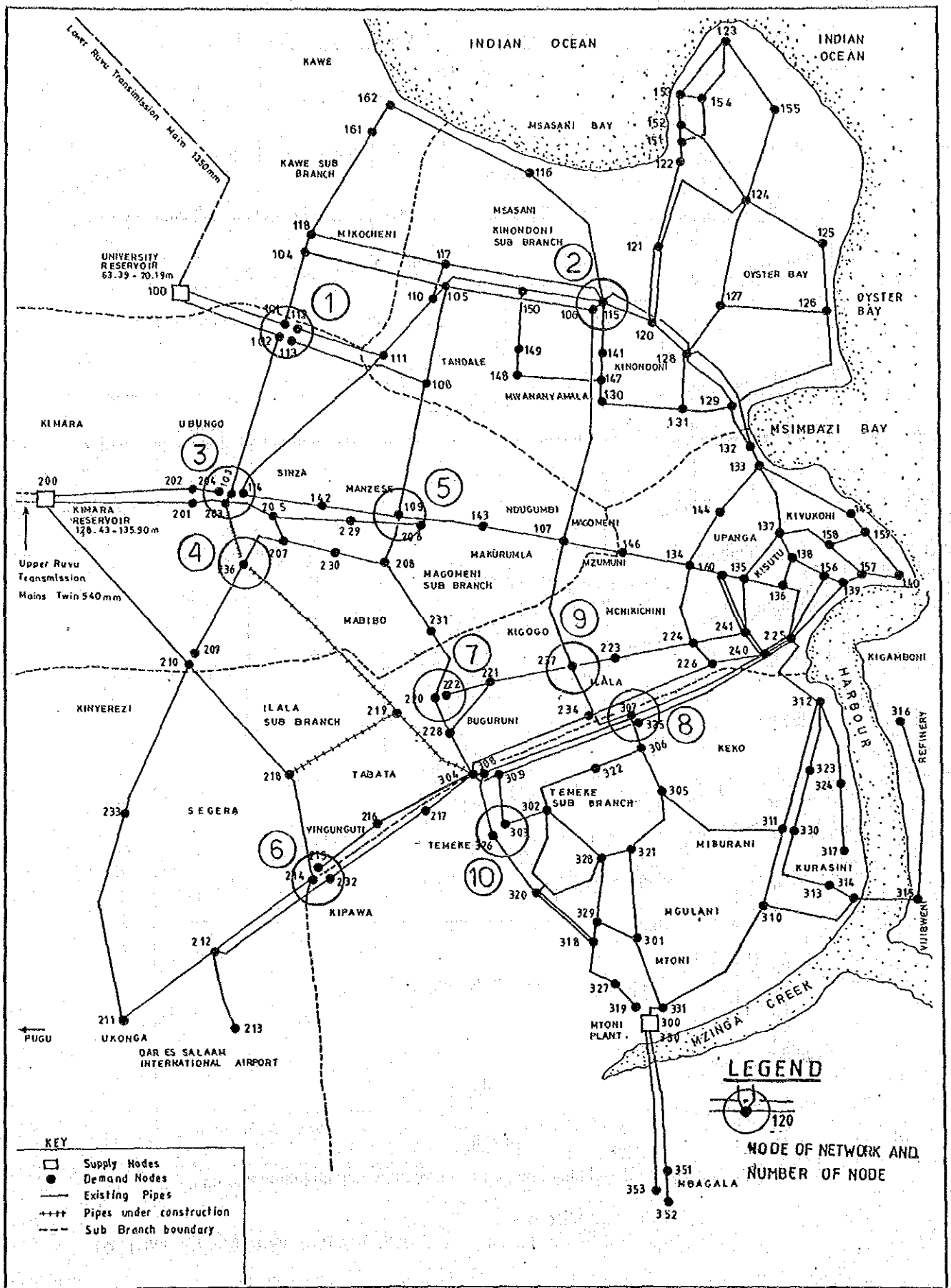
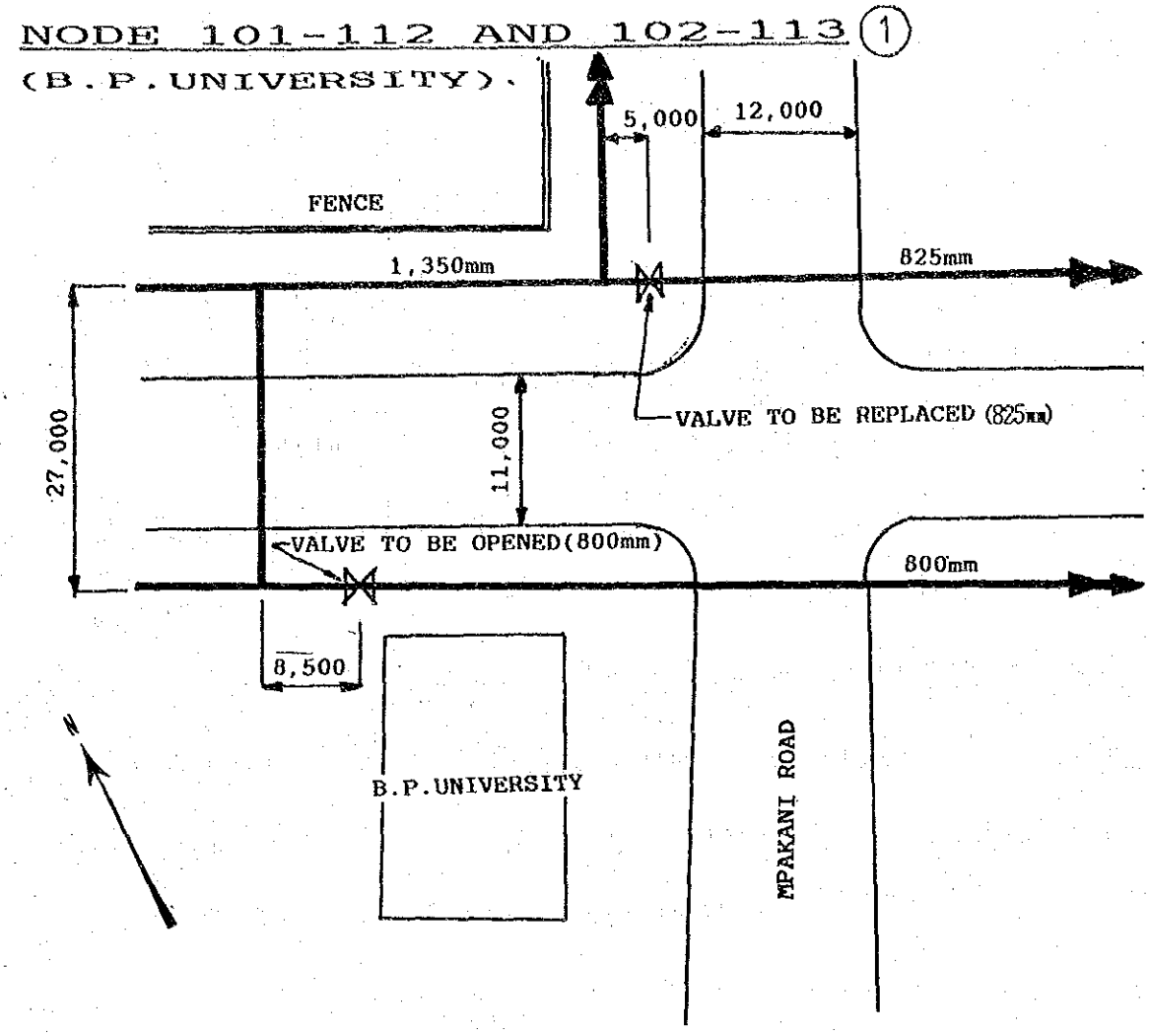
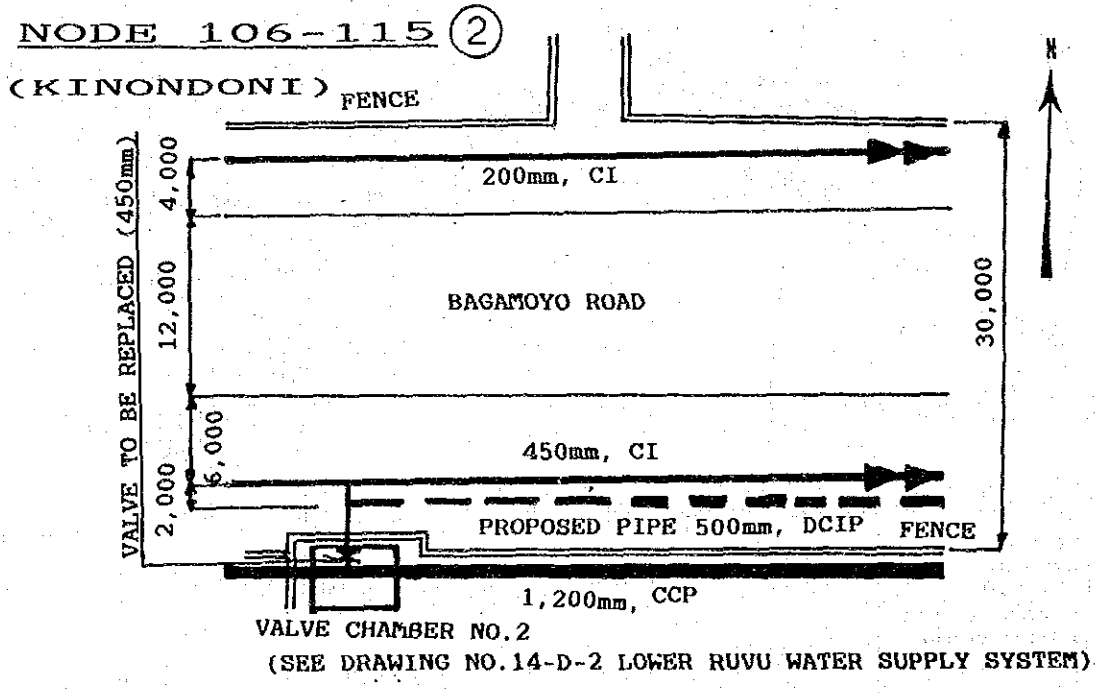



FIG. C.4.15 CONFIRMATION OF CONNECTION POINTS FOR DISTRIBUTION MAINS

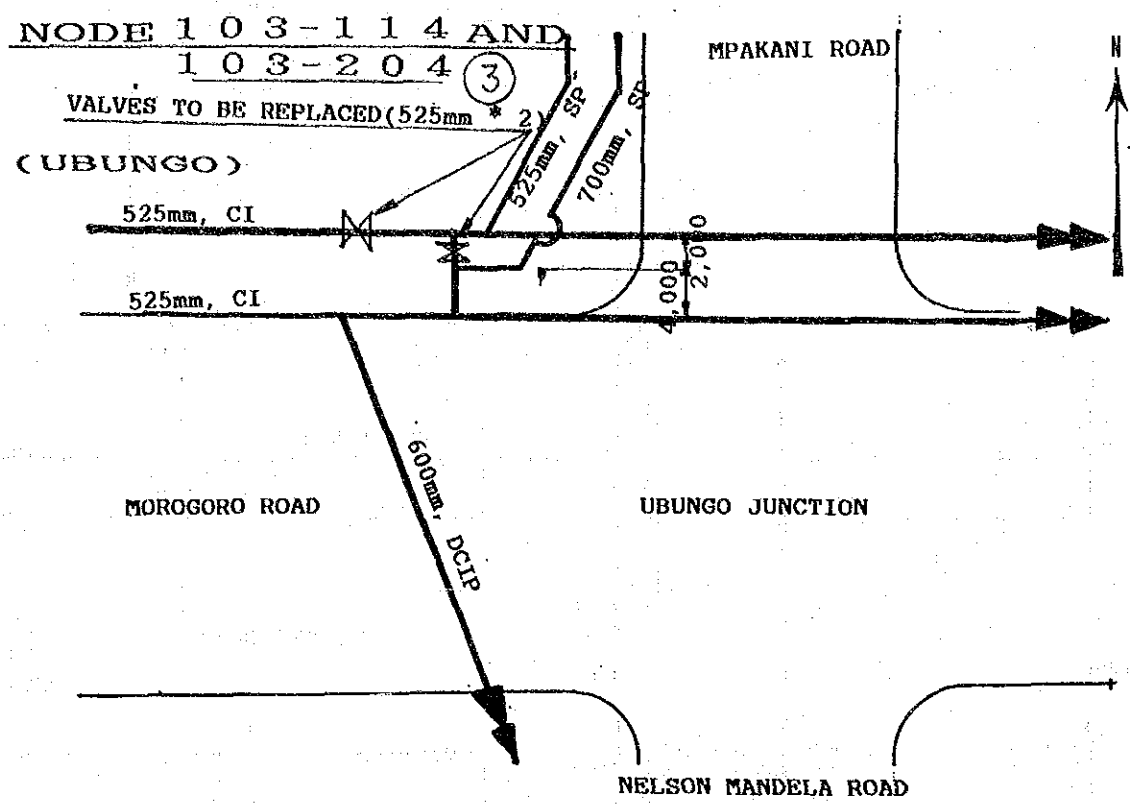
THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

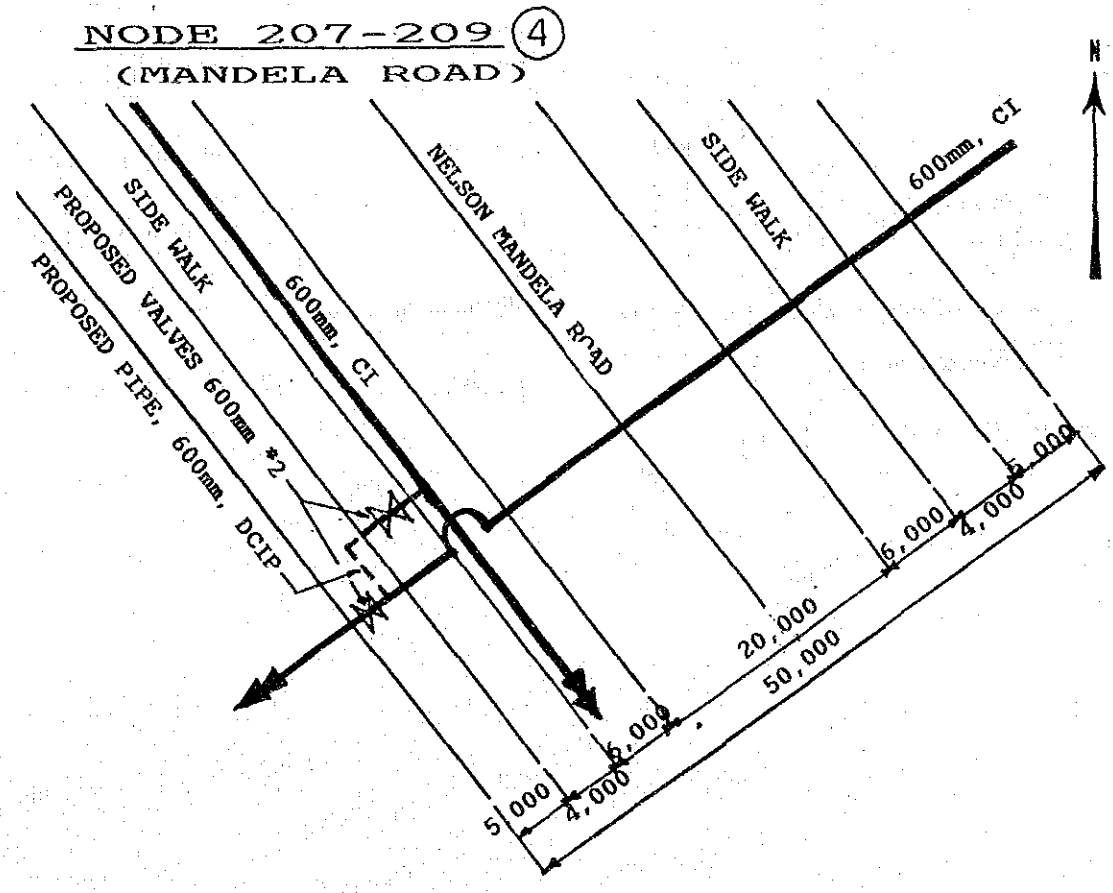



| | |
|---|---|
| FIG. C.4.16 | NODE 101-112 AND 102-113 (B. P. UNIVERSITY) NODE 106-115(KINONDONI) |

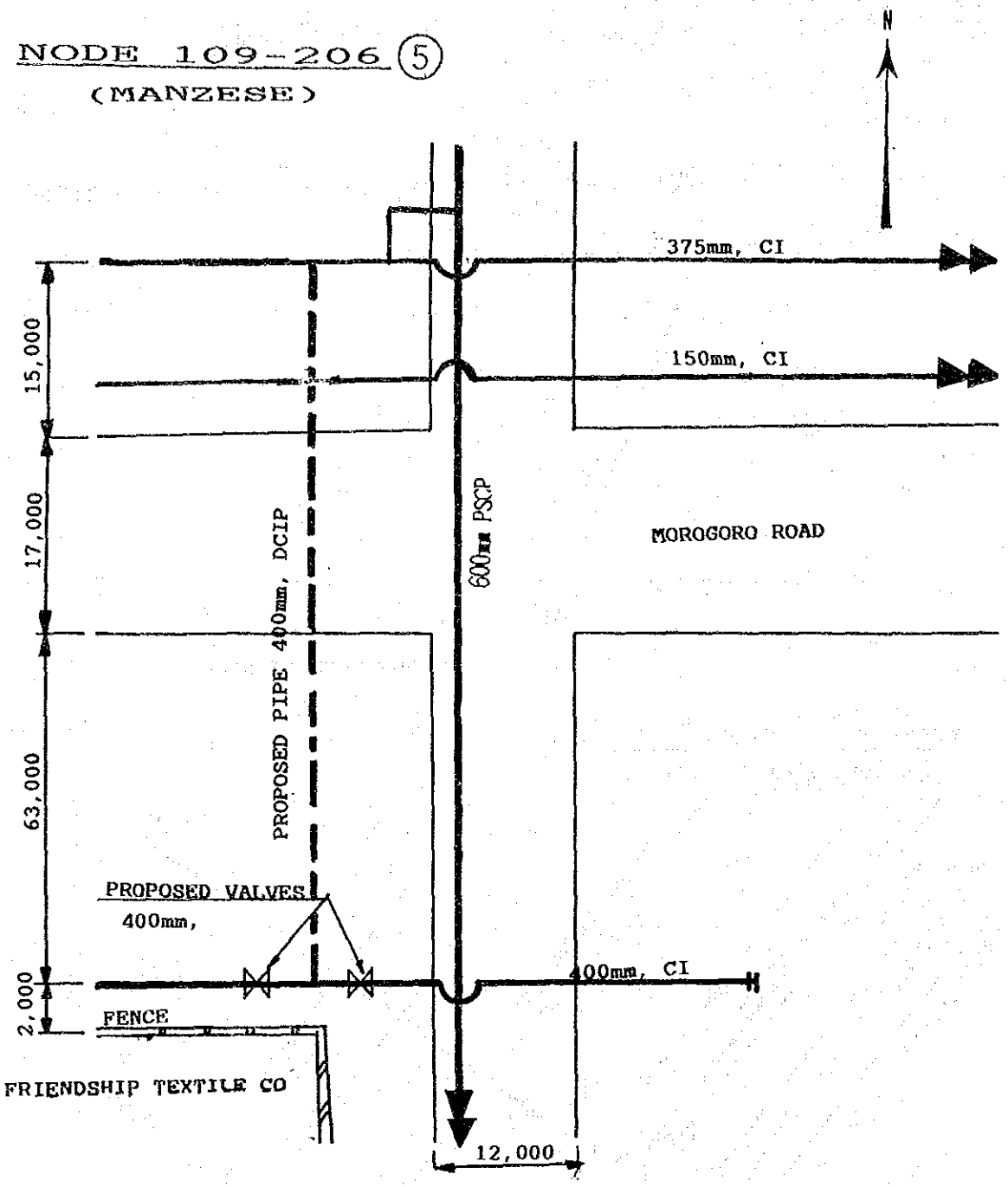
THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY




| | |
|---|---|
| FIG. C.4.16 | NODE 103-114 AND 103-204 (UBUNGO)<br>NODE 207-209 (MANDERA ROAD) |

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

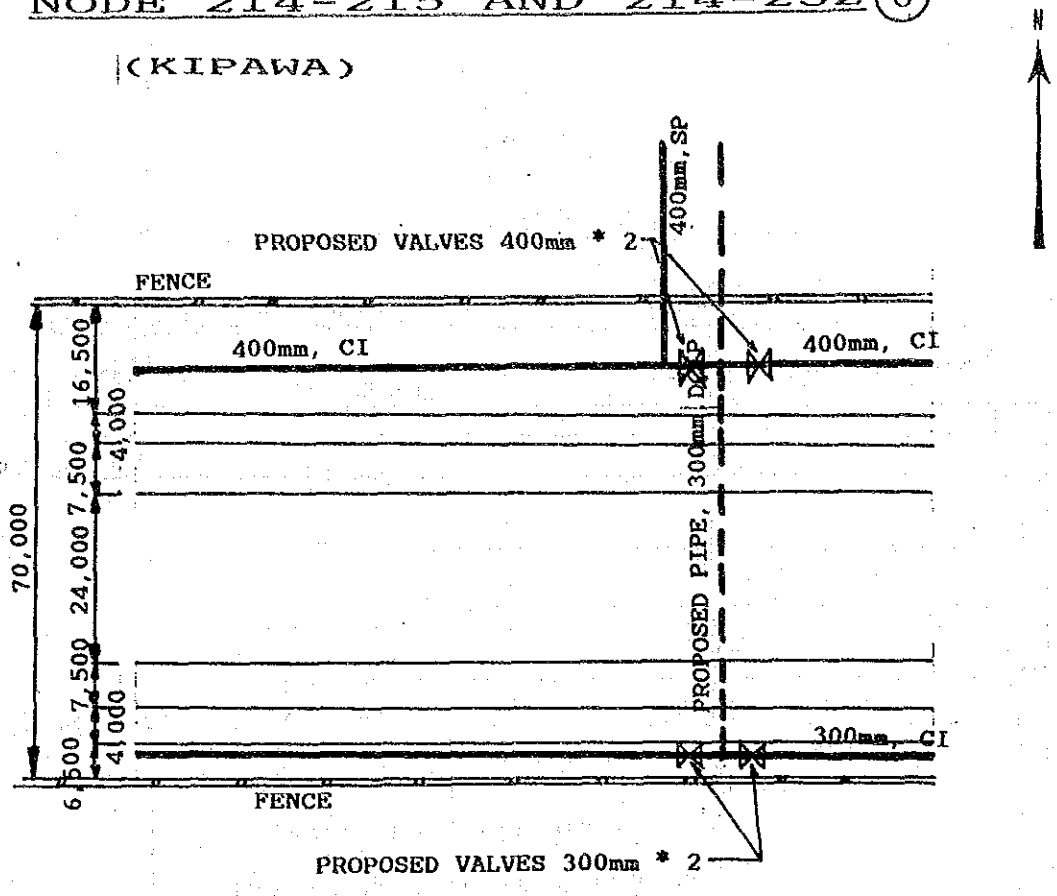



| FIG. C.4.16 | NODE 109-206 (MANZESE) |
|---|---|

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

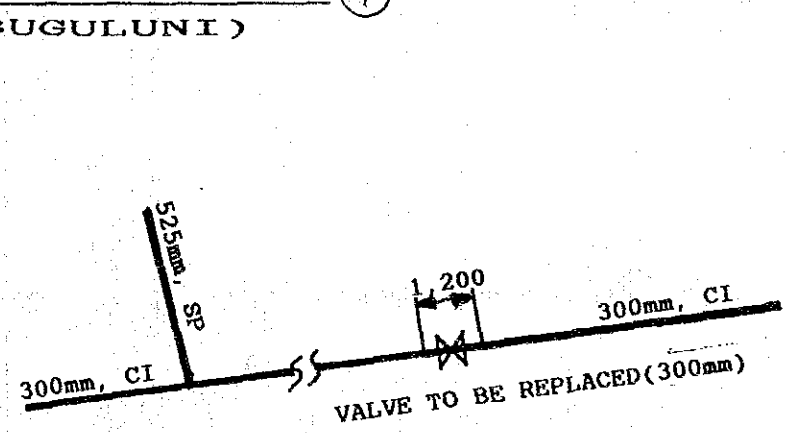
## NODE 214-215 AND 214-232 (6)

(KIPAWA)



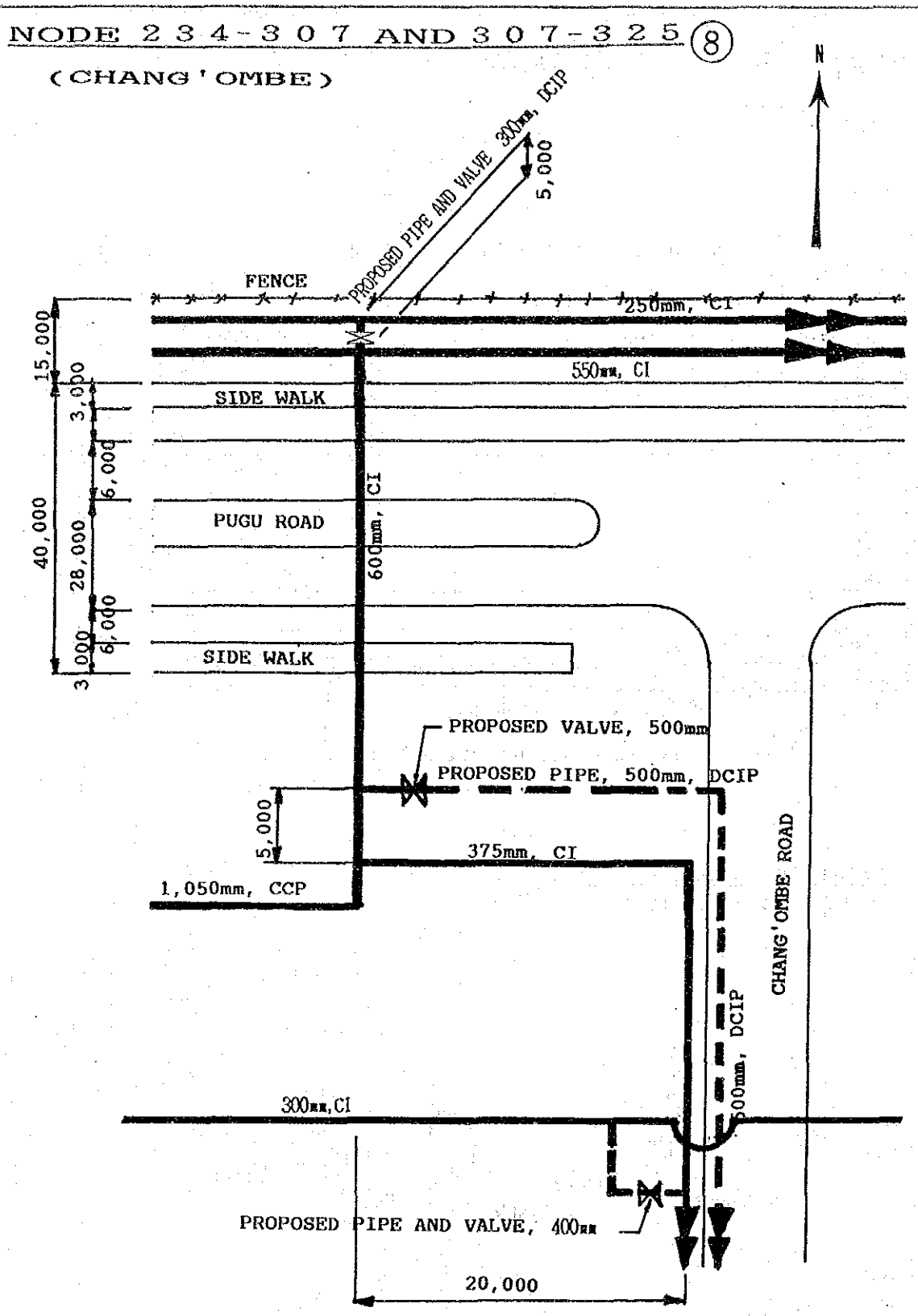

## NODE 220-222 (7)

(BUGULUNI)



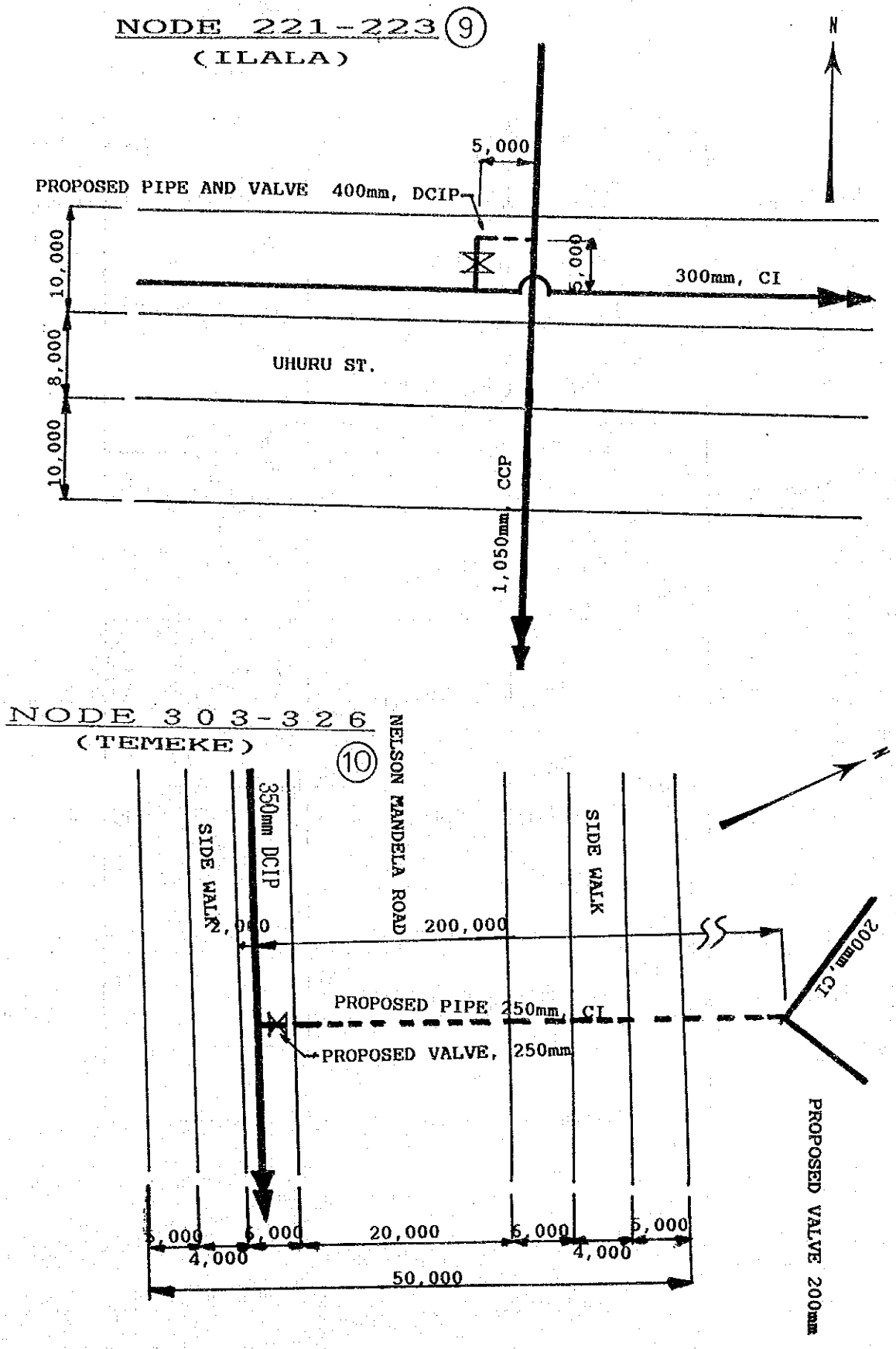

| | |
|---|---|
| FIG. C.4.16 | NODE 214-215 AND 214-232 (KIPAWA)<br>NODE 220-222 (BUGURUNI) |

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY




| FIG. C.4.16 | NODE 234-307 AND 307-325 (CHANG'OMBE) |
|---|---|

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY




| FIG. C.4.16 | NODE 221-223 (ILALA) :<br>NODE 303-326 (TEMEKE) |
|---|---|

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

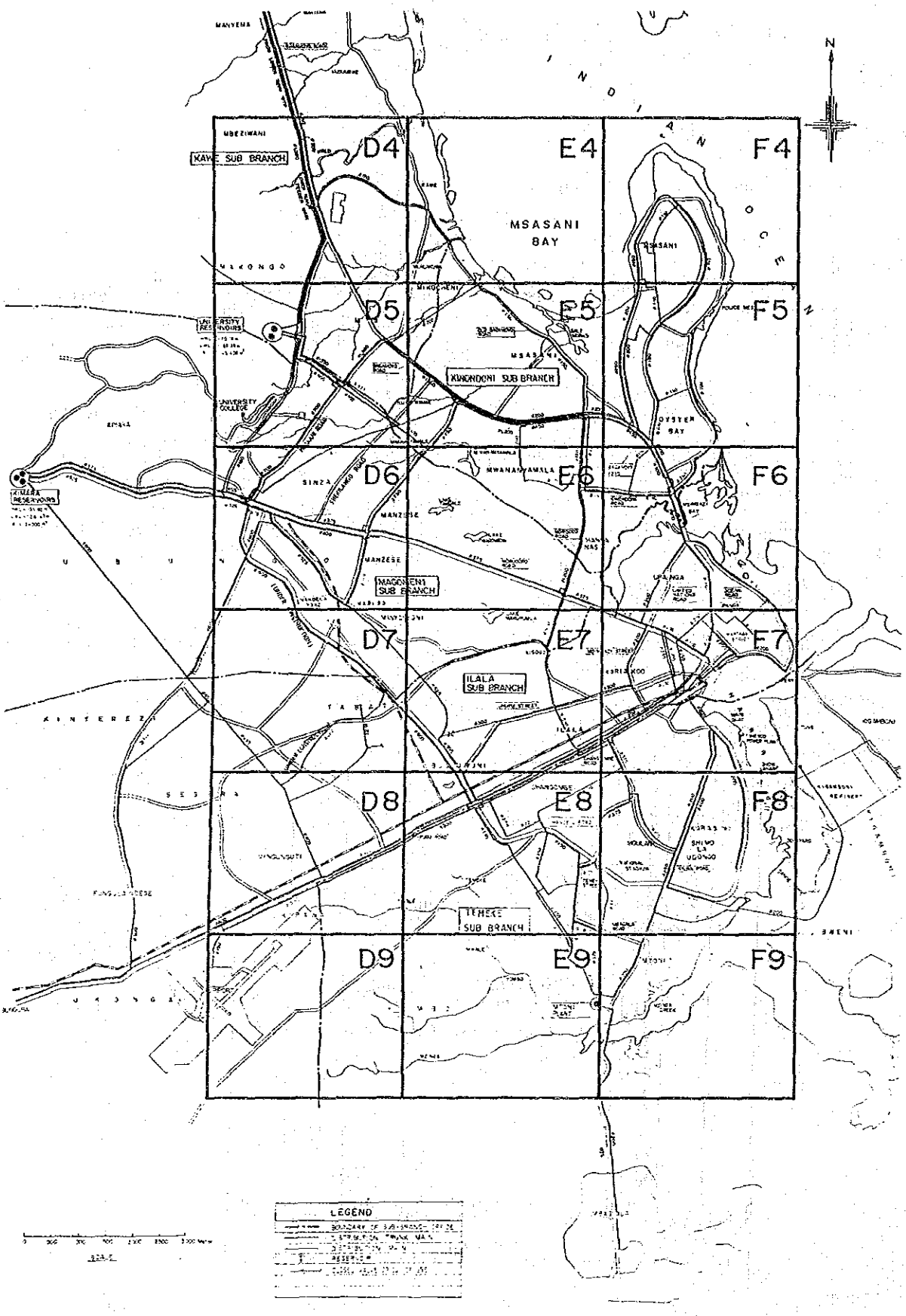



FIG. C.4.17 | INDEX FOR DISTRIBUTION PIPE DRAWINGS

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

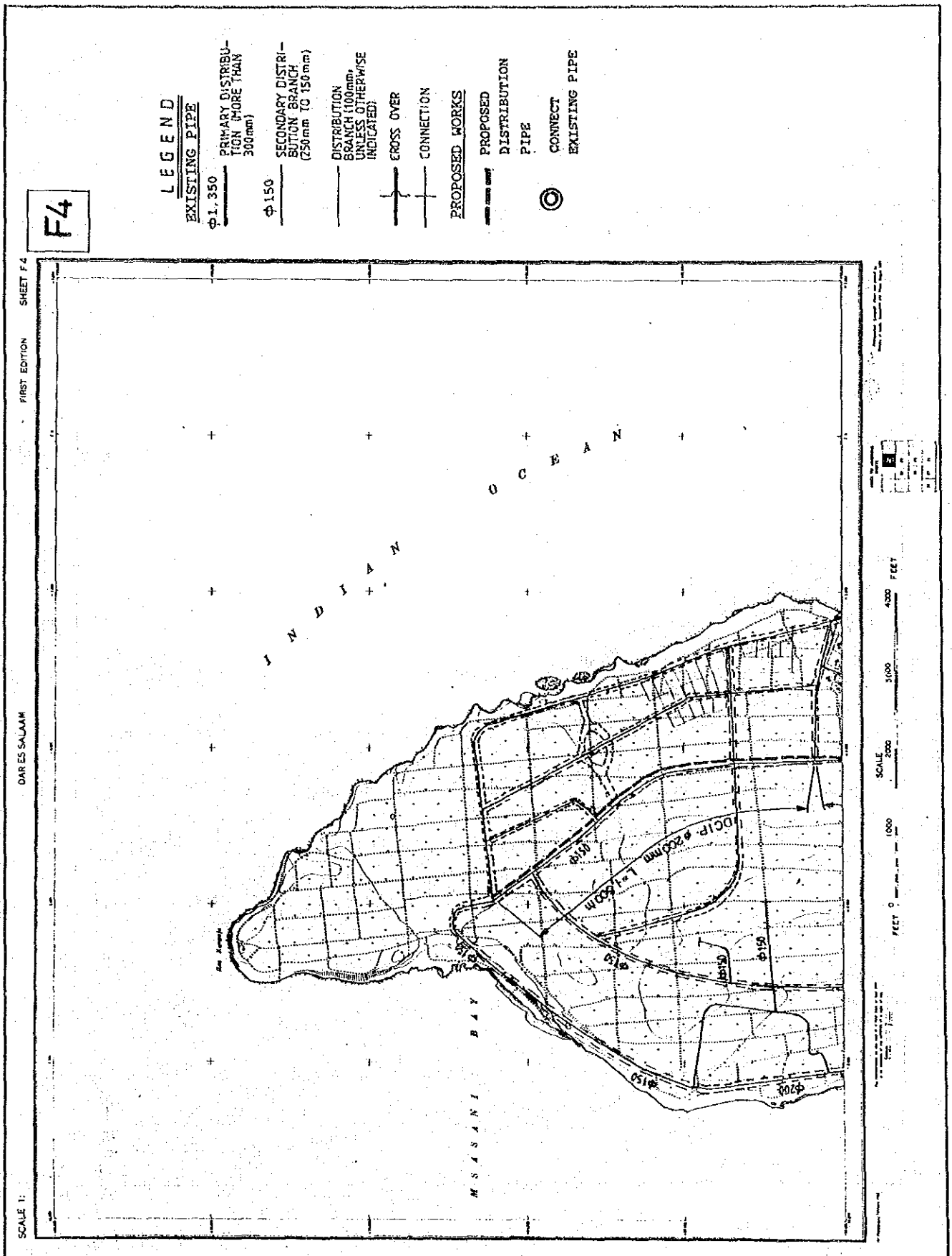



FIG. C.4.17 DISTRIBUTION PIPE DRAWING (1/18)

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

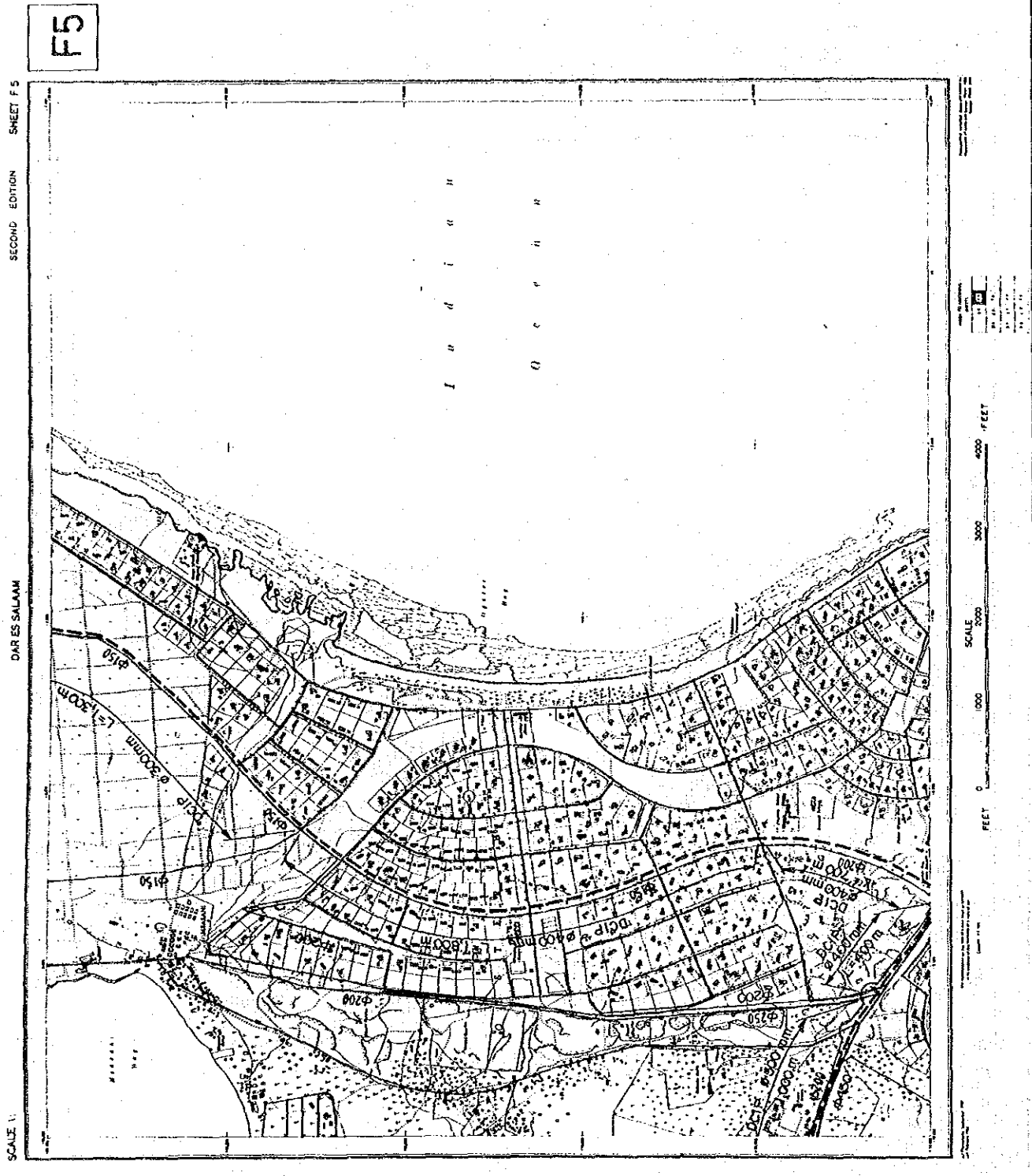



FIG. C.4.17 DISTRIBUTION PIPE DRAWING (2/18)

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

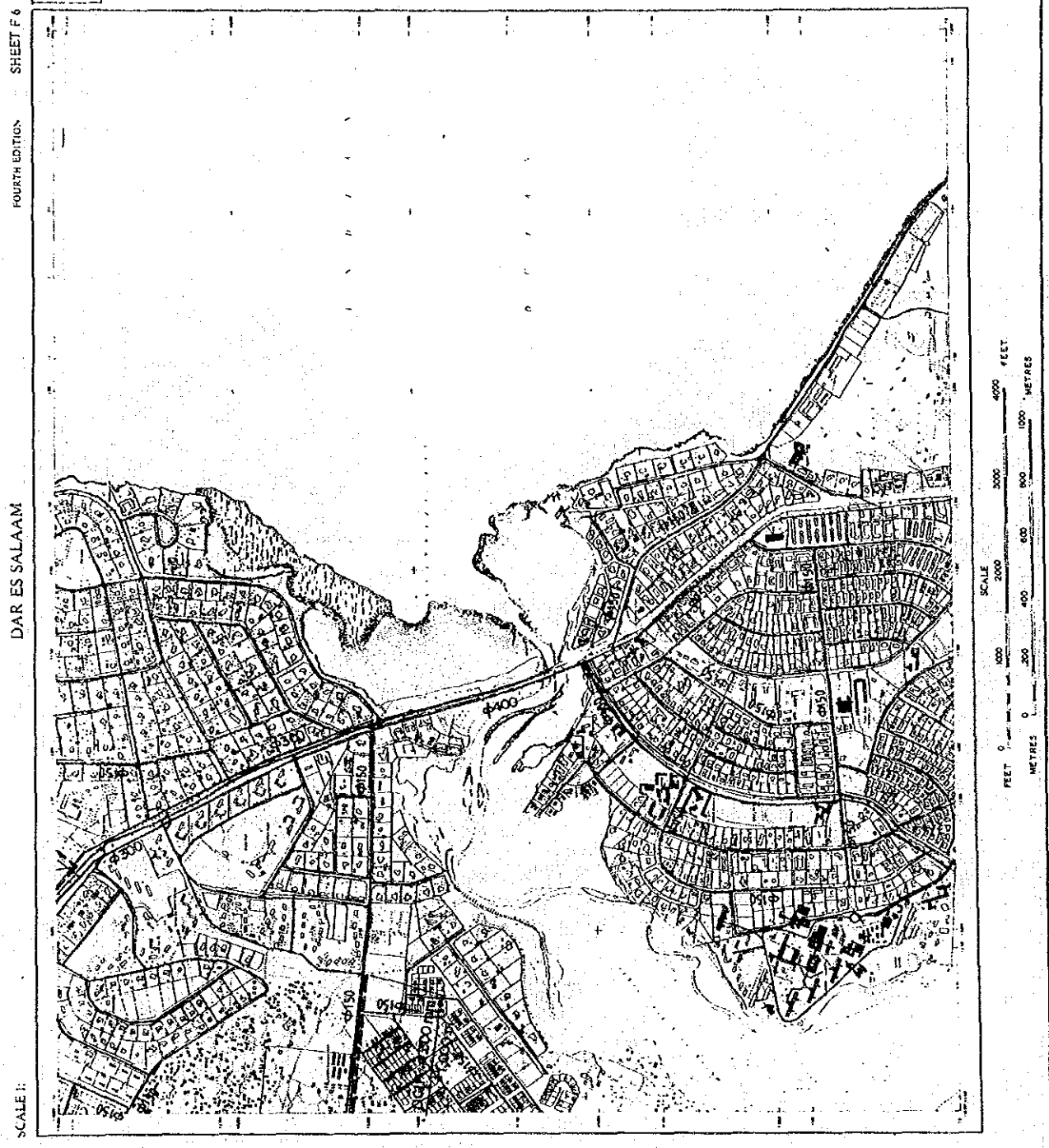



FIG. C.4.17 DISTRIBUTION PIPE DRAWING (3/18)

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

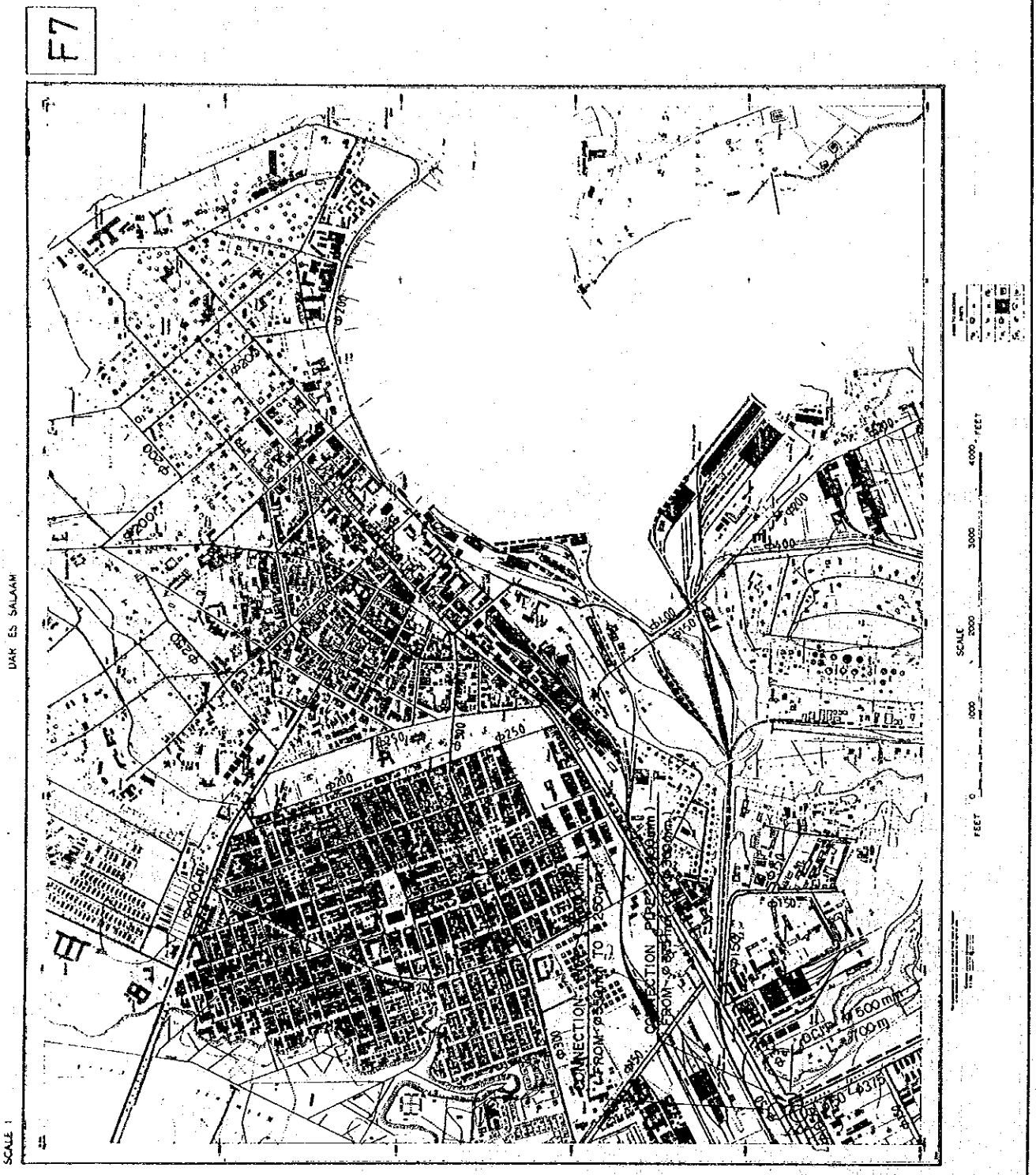



FIG. C.4.17 DISTRIBUTION PIPE DRAWING (4/18)

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

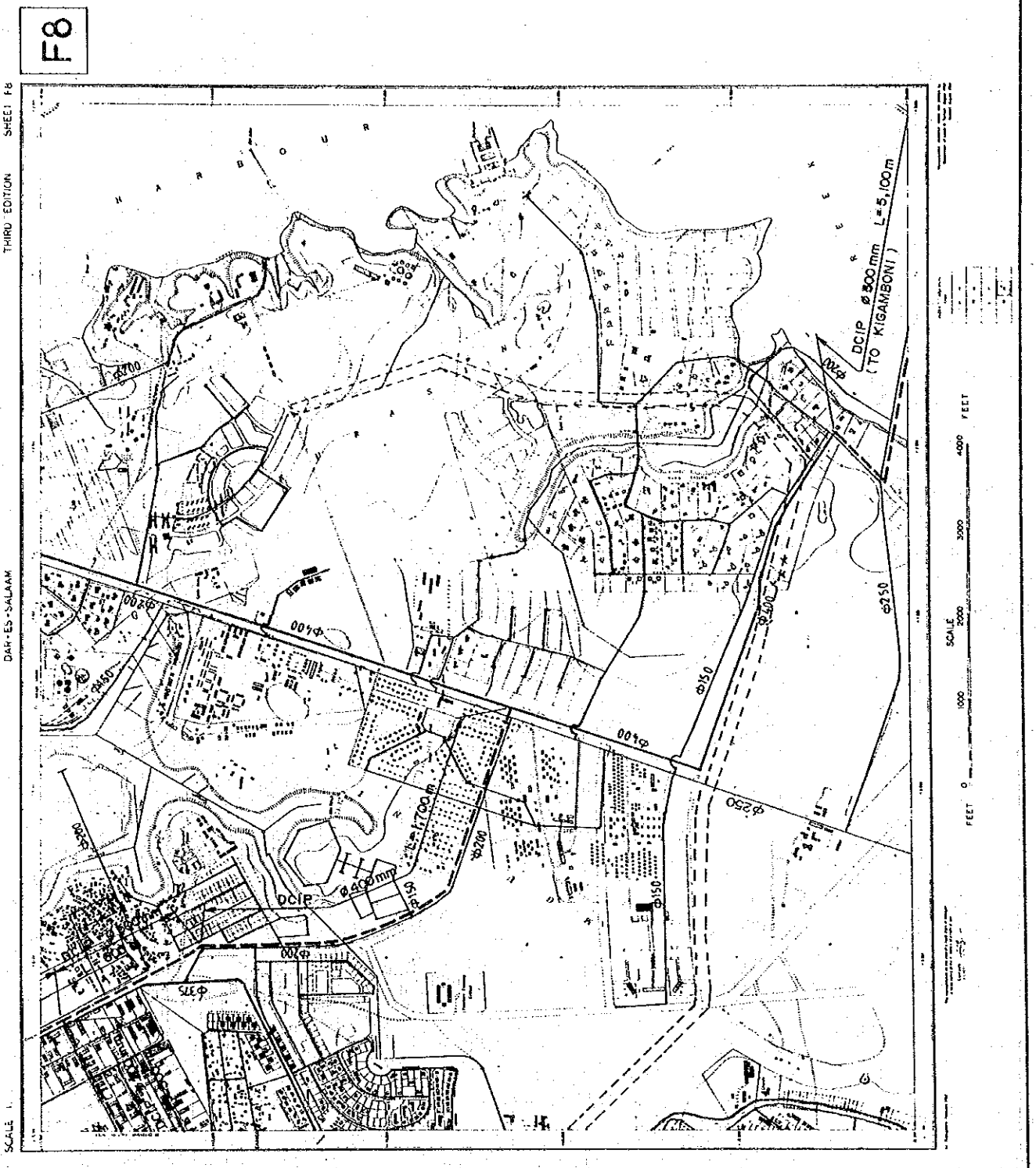



FIG. C.4.17 DISTRIBUTION PIPE DRAWING (5/18)

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

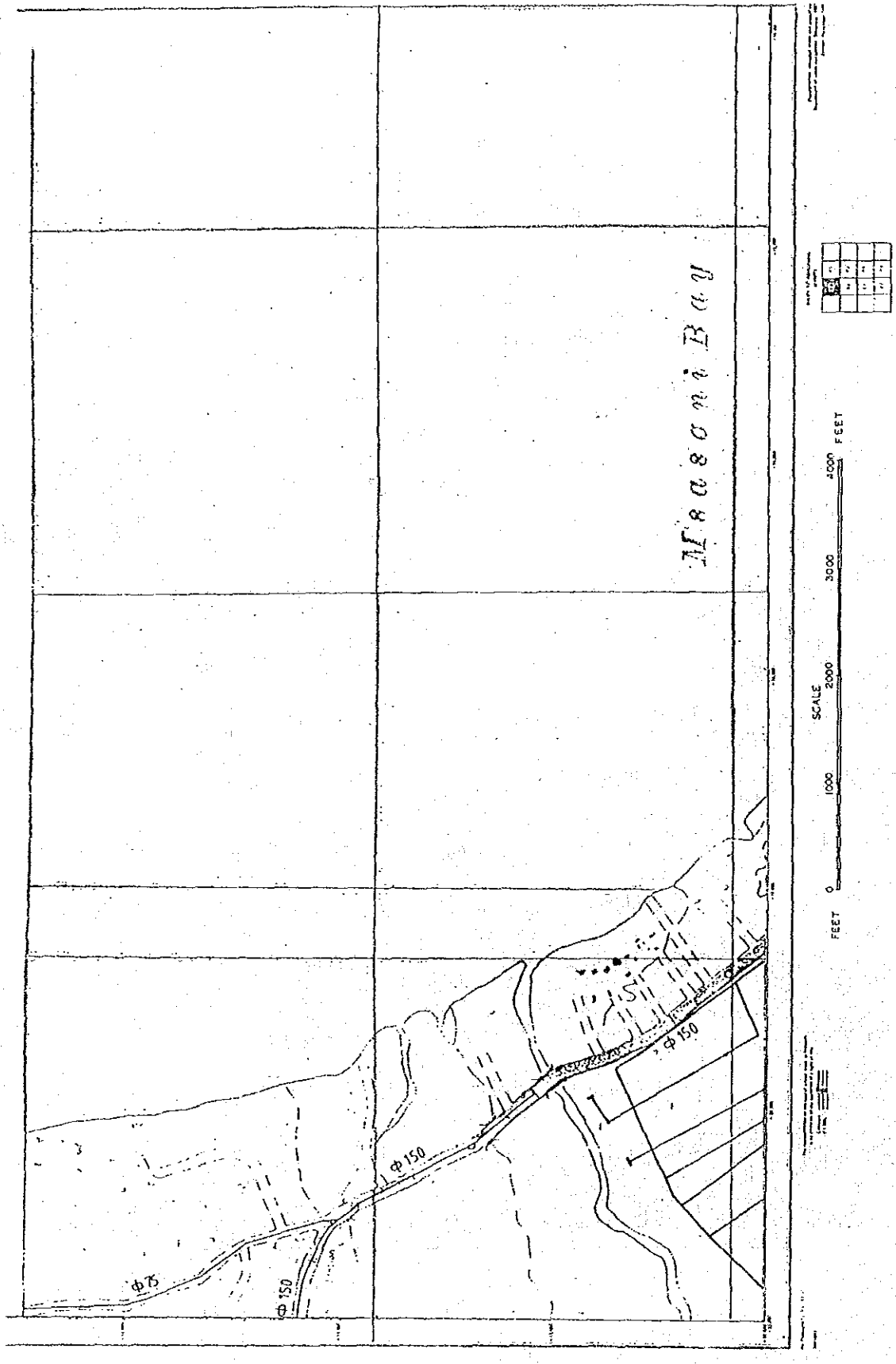
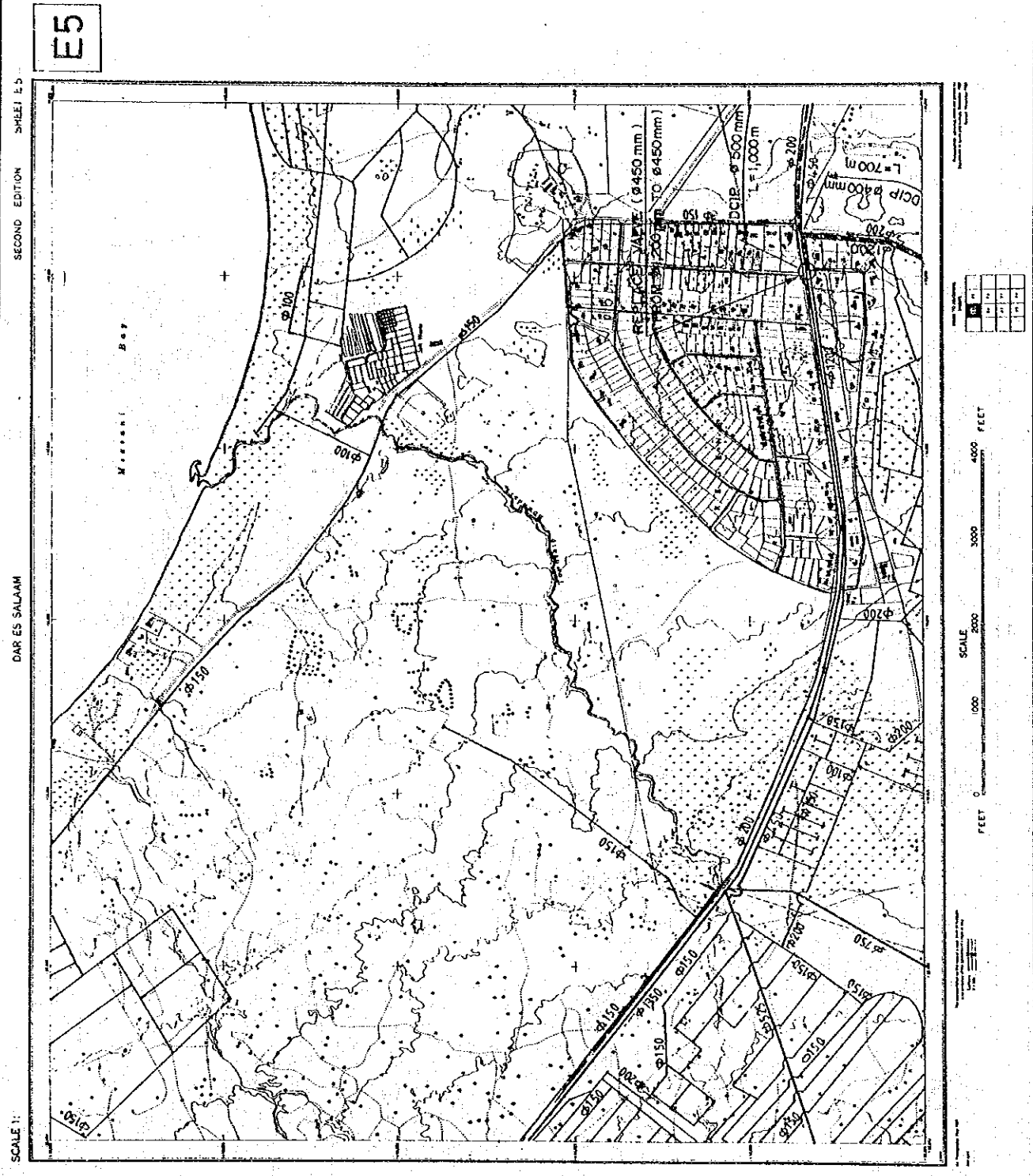



FIG. C.4.17 DISTRIBUTION PIPE DRAWING (6/18)

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY




| FIG. C.4.17 | DISTRIBUTION PIPE DRAWING (7/18) |
|---|---|

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

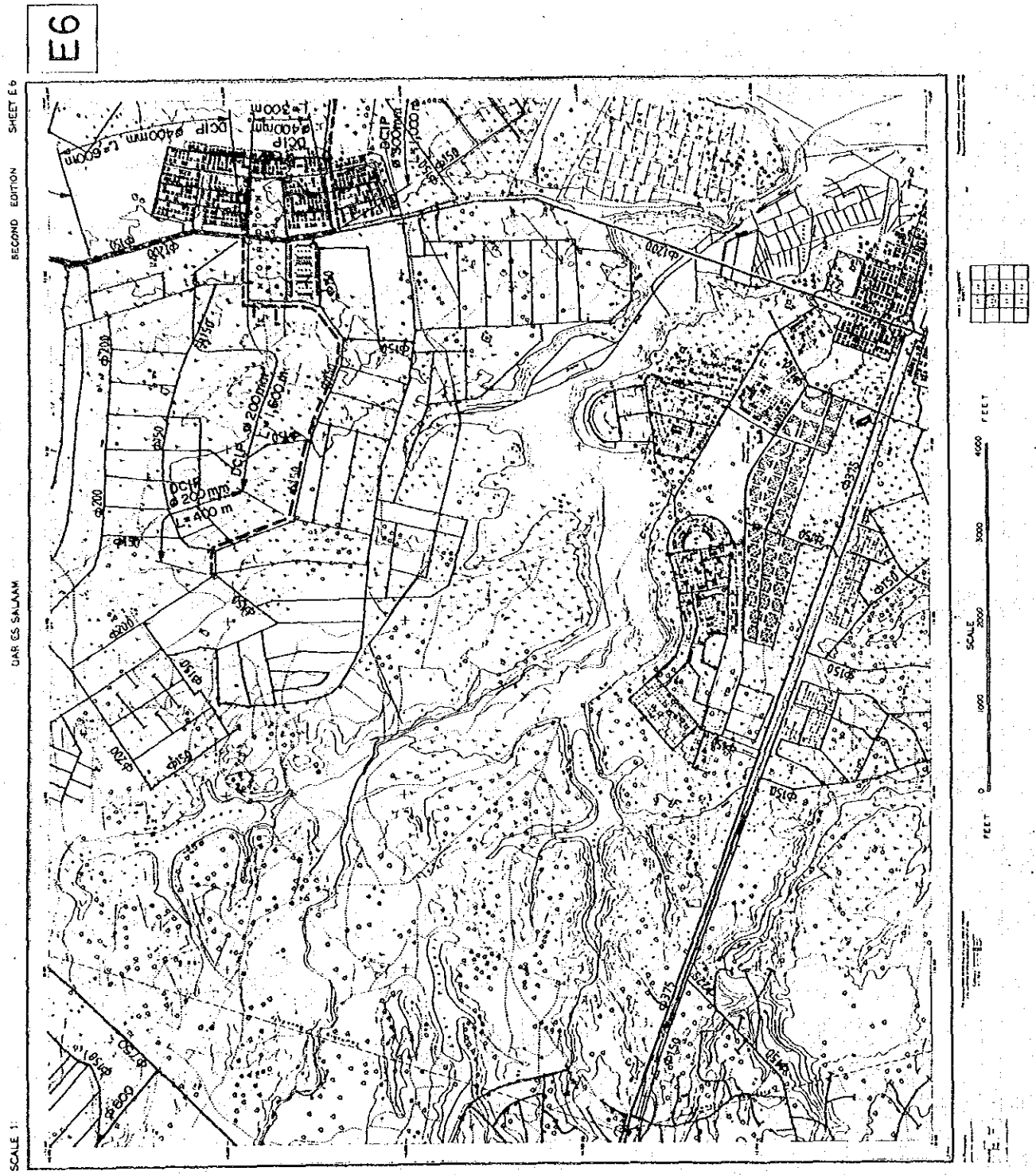



FIG. C.4.17 DISTRIBUTION PIPE DRAWING (8/18)

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

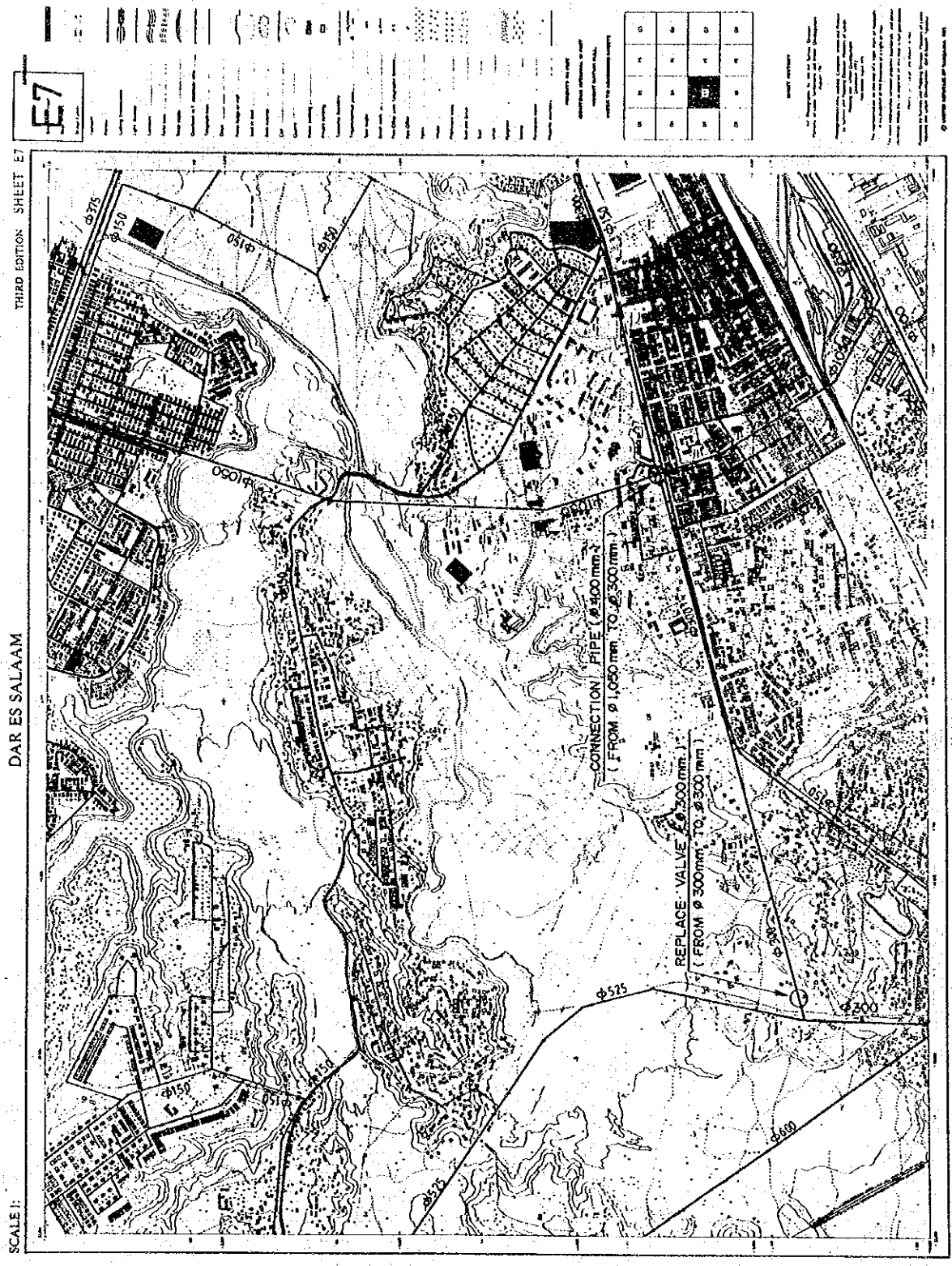



FIG. C.4.17 DISTRIBUTION PIPE DRAWING (9/18)

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

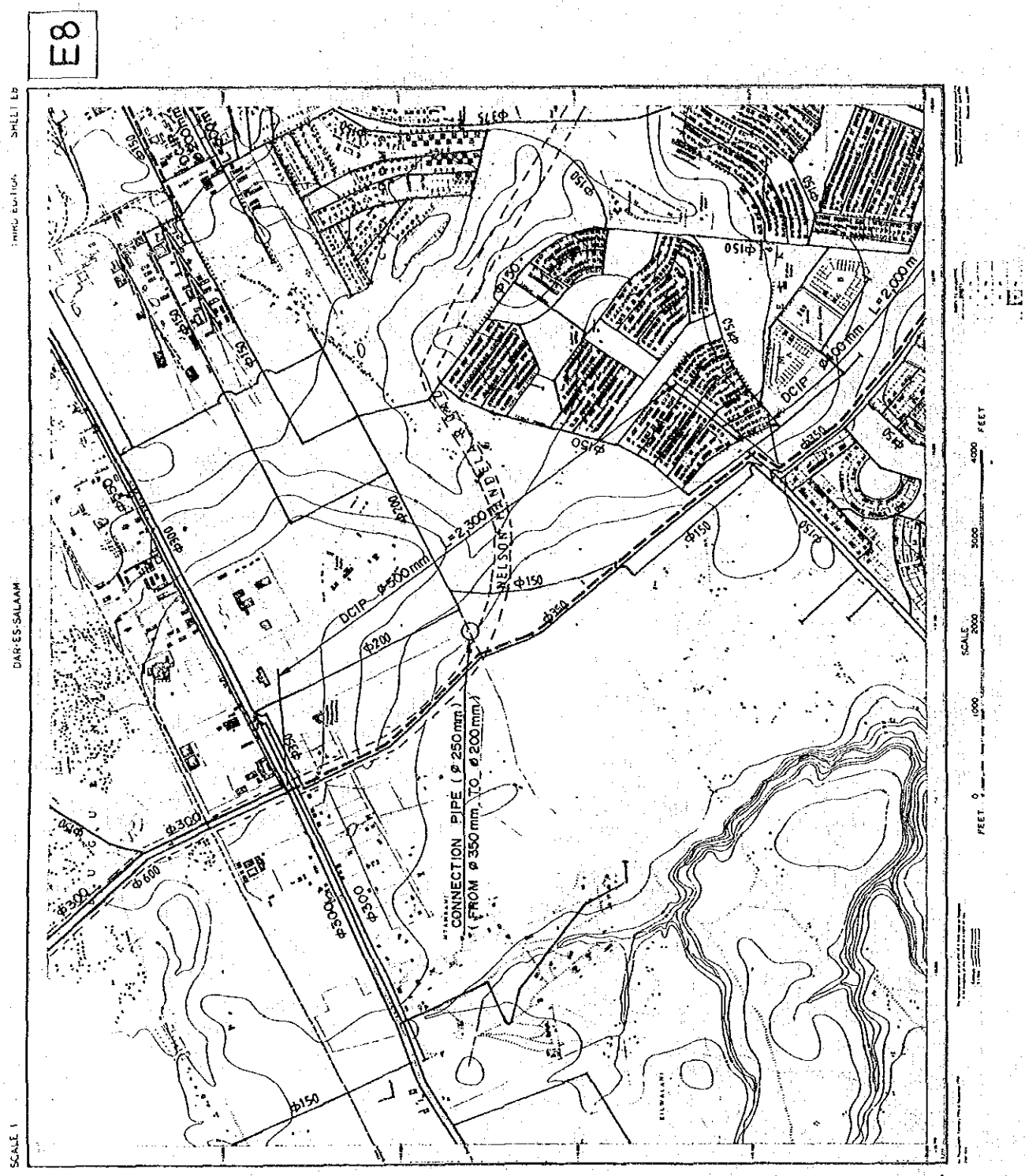



FIG. C.4.17 DISTRIBUTION PIPE DRAWING (10/18)

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

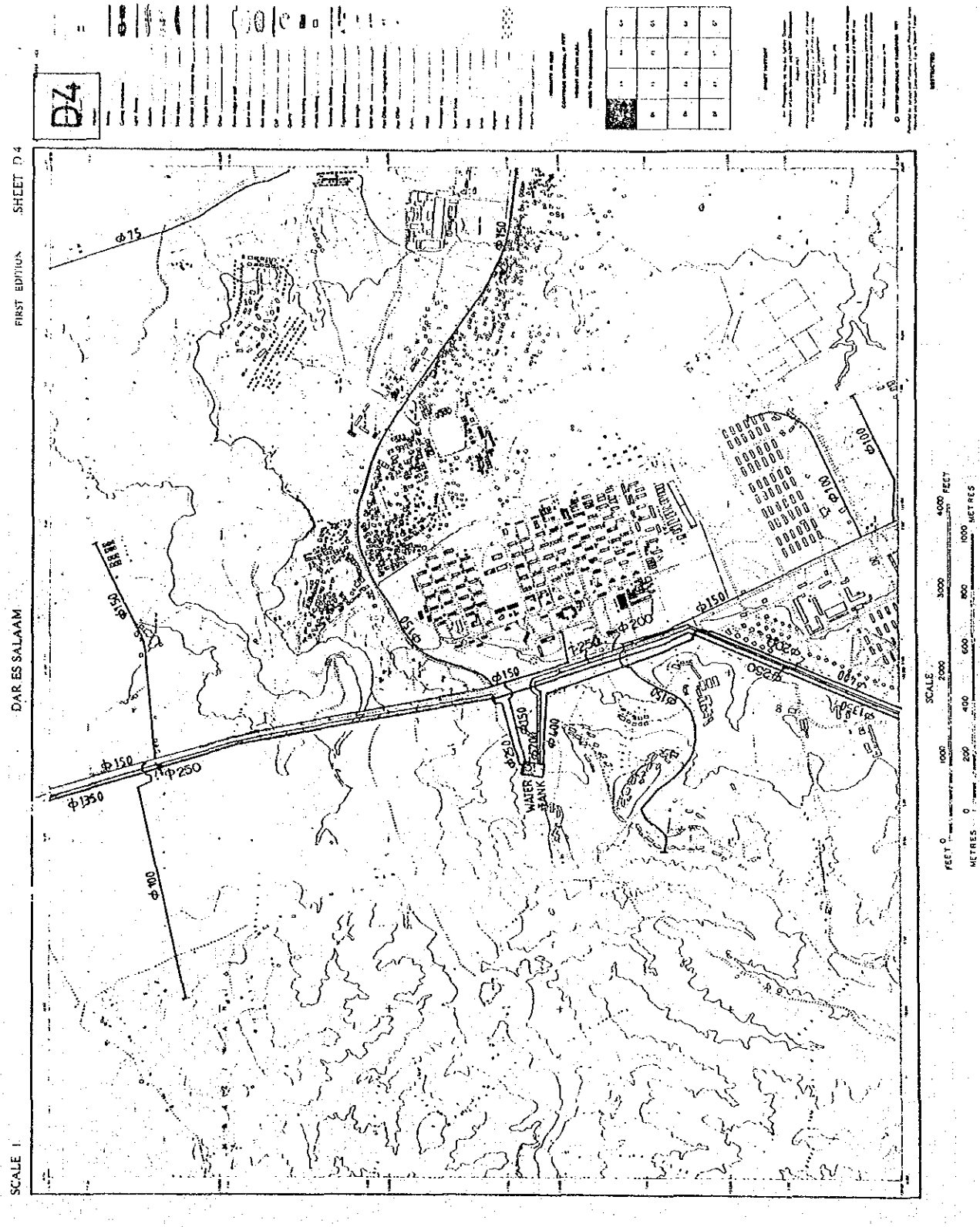



FIG. C.4.17 DISTRIBUTION PIPE DRAWING (11/18)

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

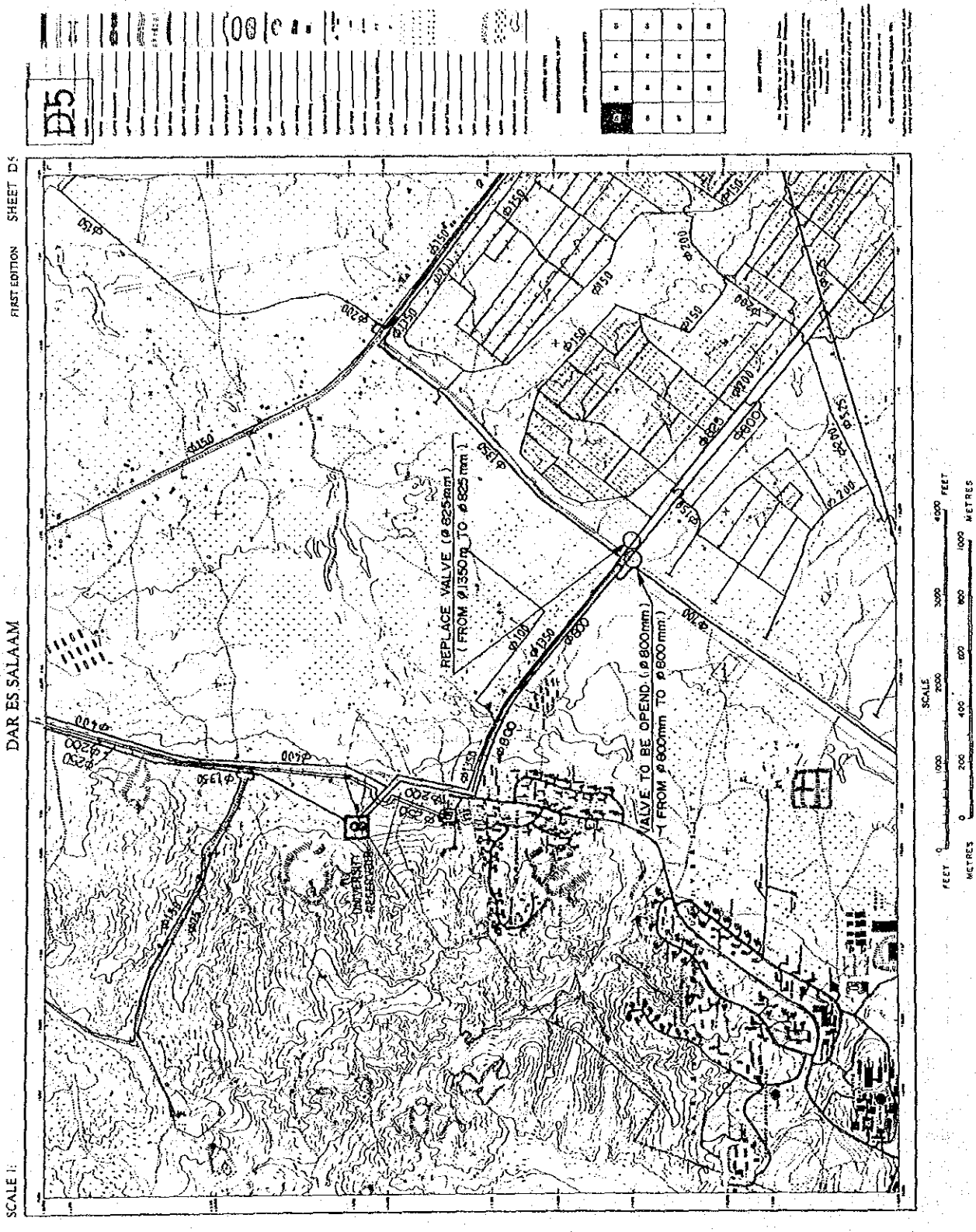



FIG. C.4.17 DISTRIBUTION PIPE DRAWING (12/18)

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

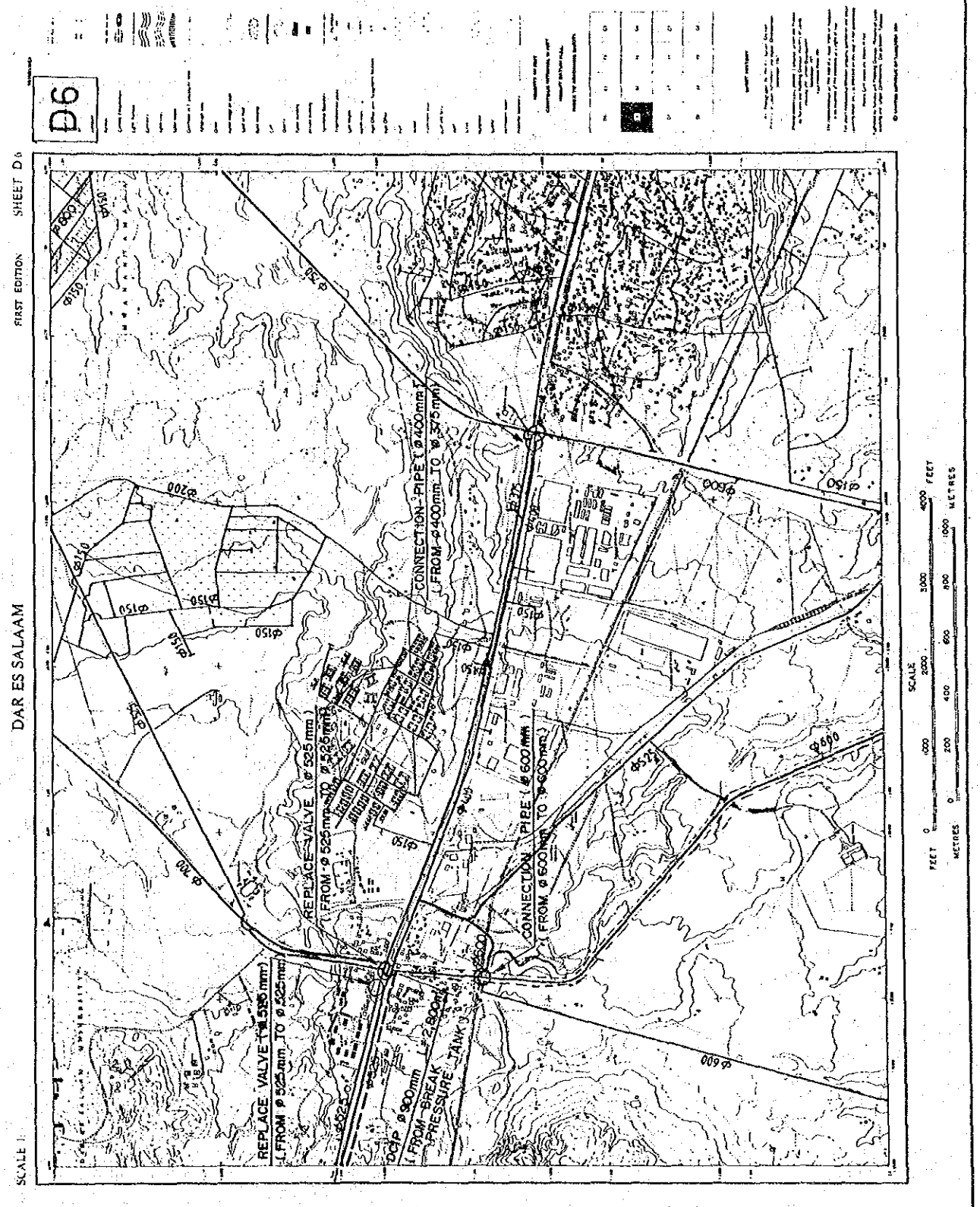



FIG. C.4.17 DISTRIBUTION PIPE DRAWING (13/18)

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

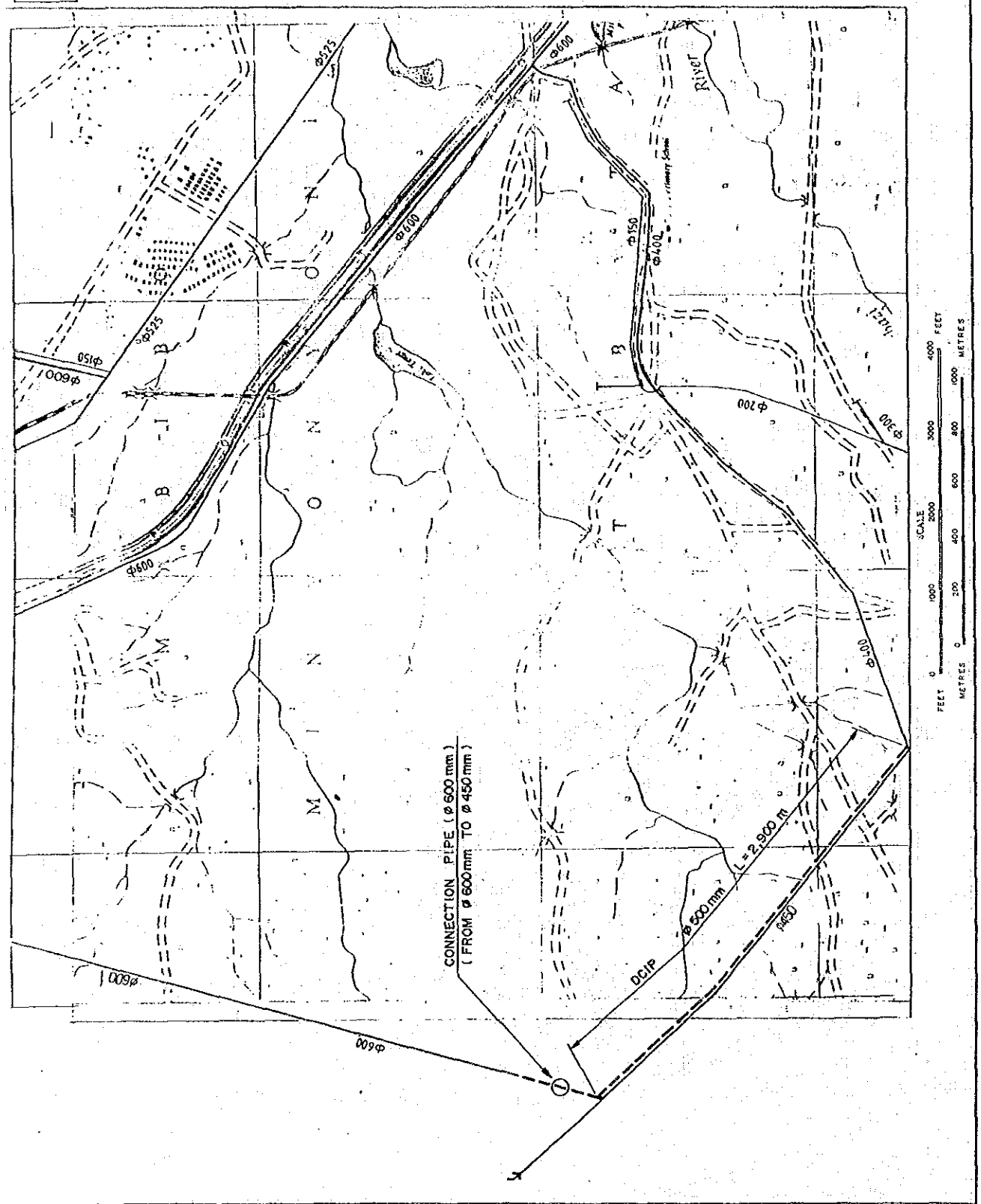



FIG. C.4.17 DISTRIBUTION PIPE DRAWING (14/18)

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

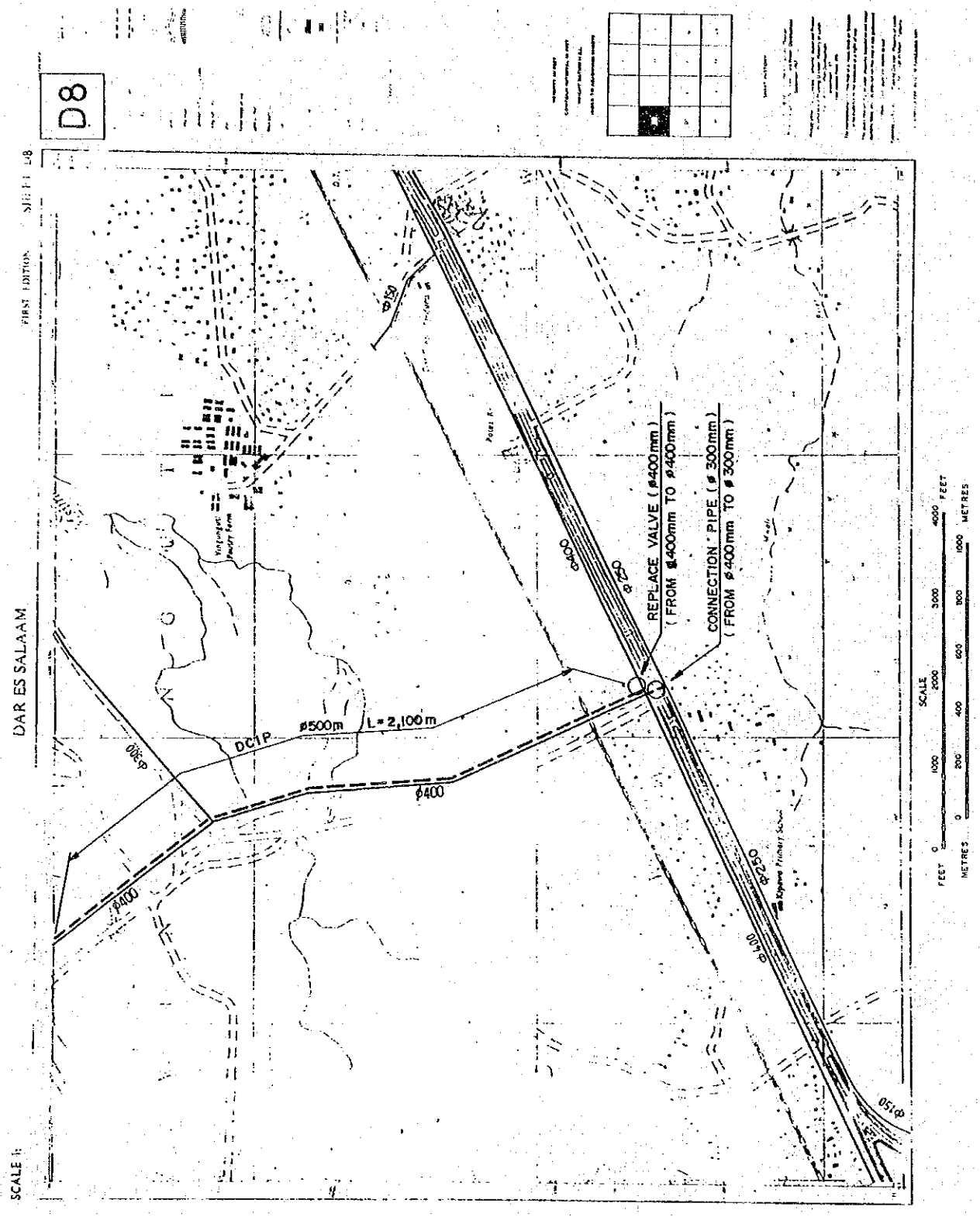



FIG. C.4.17 DISTRIBUTION PIPE DRAWING (15/18)

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

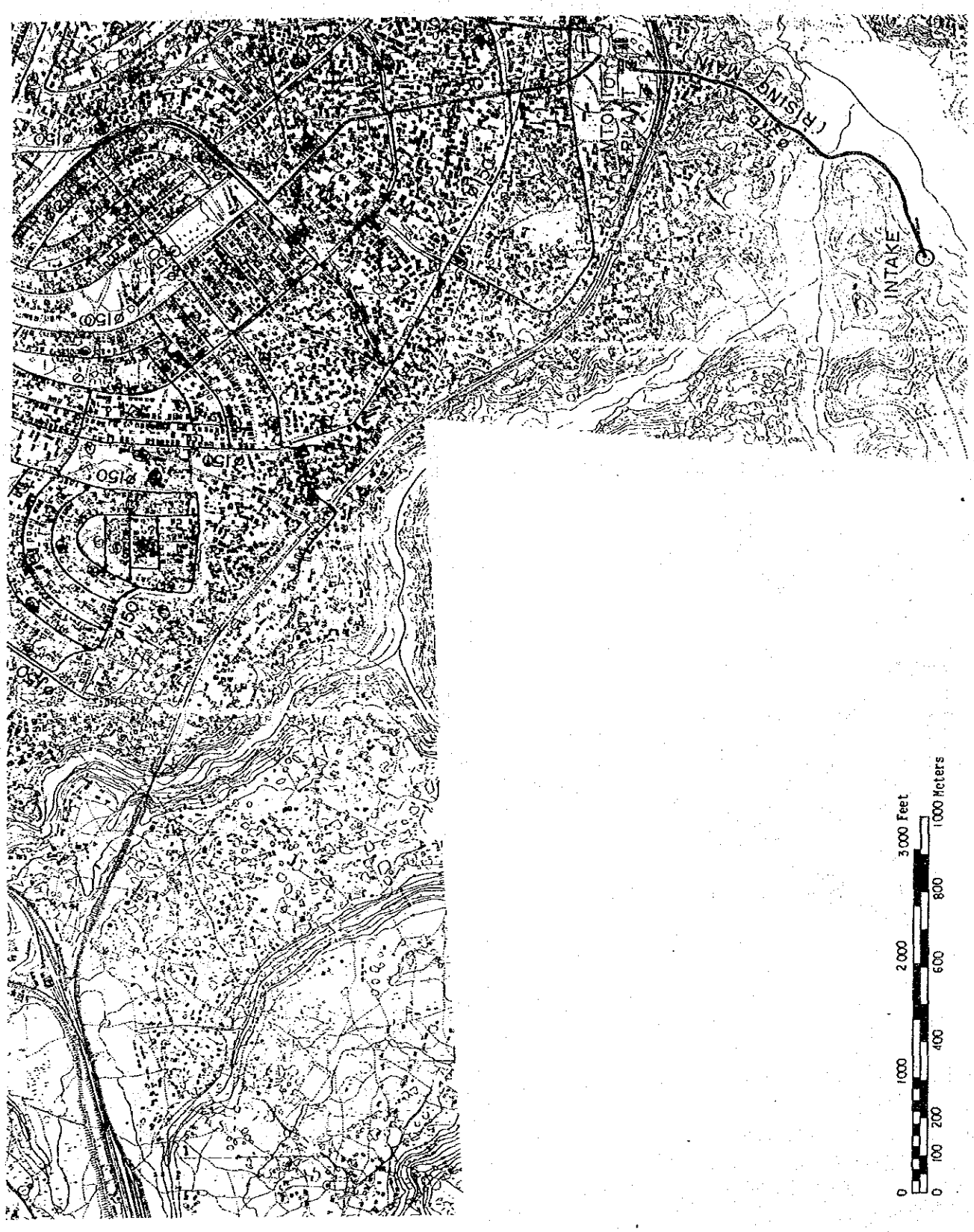



FIG. C.4.17 DISTRIBUTION PIPE DRAWING (16/18)

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

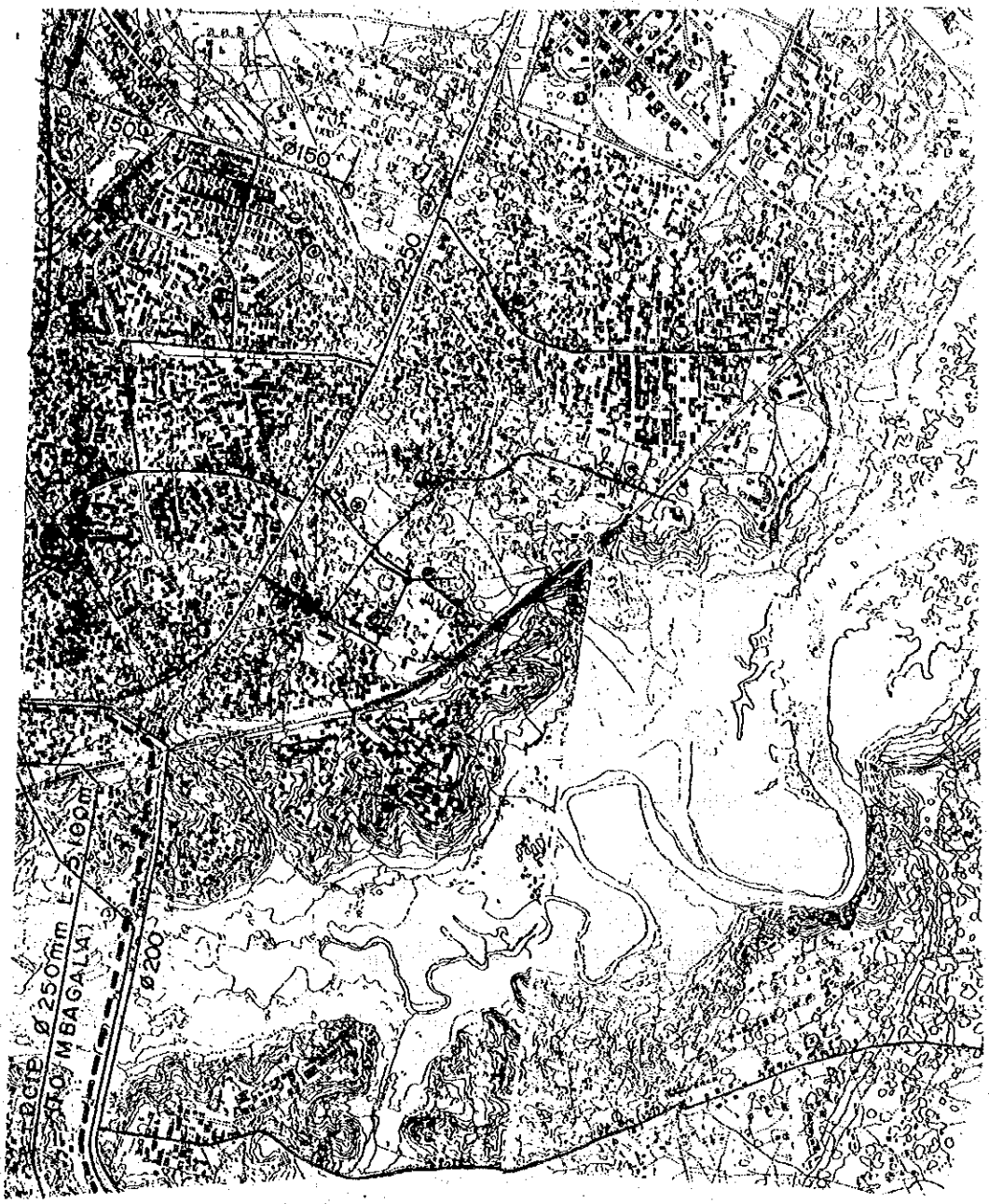
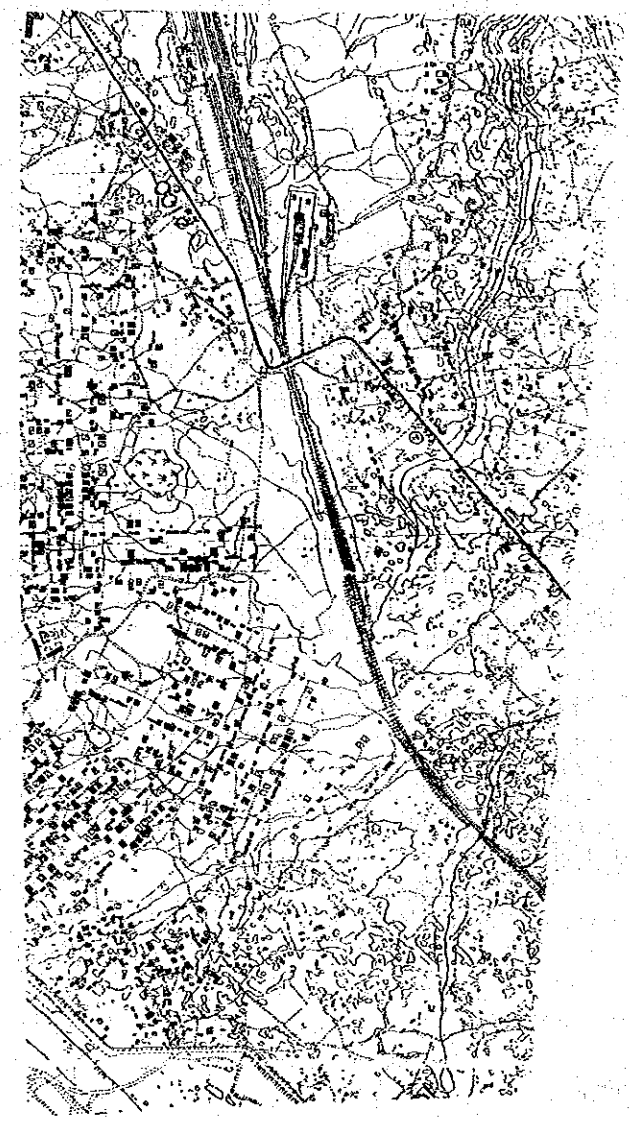
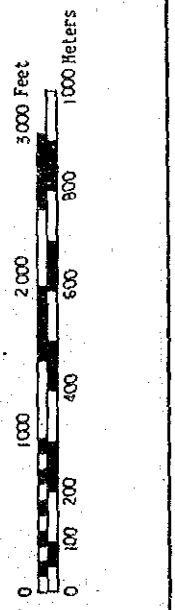



FIG. C.4.17 DISTRIBUTION PIPE DRAWING (17/18)

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY






| FIG. C.4.17 | DISTRIBUTION PIPE DRAWING (18/18) |
|---|---|

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

## 4.7 FLOW MEASUREMENT *

Flow measurements were conducted at all intake pumping stations, treatment plants and reservoirs in order to estimate the demand and the leakage along the transmission pipelines and the net supply to the City. The points, where measurements were made, and the time period when measurement was done, are shown in Table C.4.14. The results are given in Figures C.4.18 to C.4.24 and summarized in Table C.4.15.

**TABLE C.4.14 POINTS AND PERIOD OF FLOW MEASUREMENT**

| | Raw Water Pump Outflow | Treatment Plant Inflow | Treatment Plant Outflow | Reservoir Inflow | Reservoir Outflow |
|---|---|---|---|---|---|
| Upper Ruvu<br>-points<br>-period | Low lift main<br>4/1/90 to 6/1/90 | Low lift main<br>4/1/90 to 6/1/90 | High lift main<br>31/12/89, 2/1/90 to 3/1/90<br>and 16/3/90 17/3/90 | High lift main | Distribution main<br>21/12/89 to 23/12/89 and 25/12/89 to 27/12/89 |
| Lower Ruvu<br>-points<br>-period | ------<br>------ | ------<br>------<br>11/1/90) | High lift main<br>(9/1/90 to11/1/90) | High lift main<br>13/1/90 to 15/1/90 | Distribution main<br>8/1/90, 9/1/90 |
| Mtoni<br>-points<br>-period | Low lift main<br>11/1/90 | Low lift main<br>11/1/90<br>16/1/90 to 17/1/90 | High lift main<br>12/1/90 to 14/1/90 | ----- | ----- |

**TABLE C.4.15 FLOW IN TREATMENT PLANT AND RESERVOIR**

(unit: $m^3$/day)

| | From Intake | To Plant | From Plant | To Reservoir | From Reservoir |
|---|---|---|---|---|---|
| Upper Ruvu system<br>Maximum<br>Average | 67,000 (100%)<br>59,000 (100%) | 58,000 (87%)<br>51,000 (86%) | 55,000 (82%)<br>45,000 (76%) | .....<br>22,000 (38%) *1<br>10,000 (17%) *2 | .....<br>.....<br>intermittent |
| Lower Ruvu system<br>Maximum<br>Average | .....<br>..... | .....<br>..... | 207,000 (100%)<br>207,000 (100%) | 192,000 (93%)<br>172,000 (83%) | 187,000 (90%)<br>153,000 (74%) |
| Mtoni system<br>Maximum<br>Average | .....<br>11,500 (100%) | .....<br>10,500 (91%) | 18,000<br>5,000 (44%) | .....<br>..... | .....<br>..... |

*1 during night *2 during daytime

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* The contents of this section is used in section 2.5 "supply to the city", Main Report.

FIGURE C.4.18 FLOW FROM INTAKE TO PLANT, UPPER RUVU SYSTEM

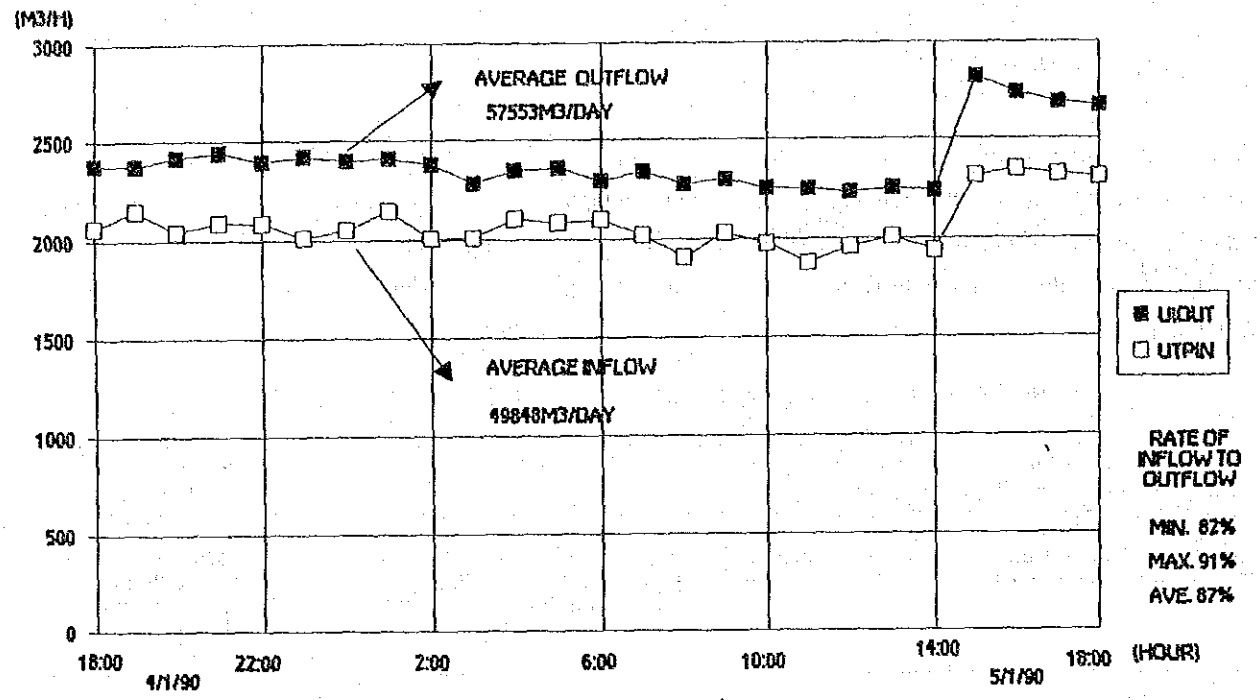



FIGURE C.4.18 FLOW FROM INTAKE TO PLANT, UPPER RUVU SYSTEM

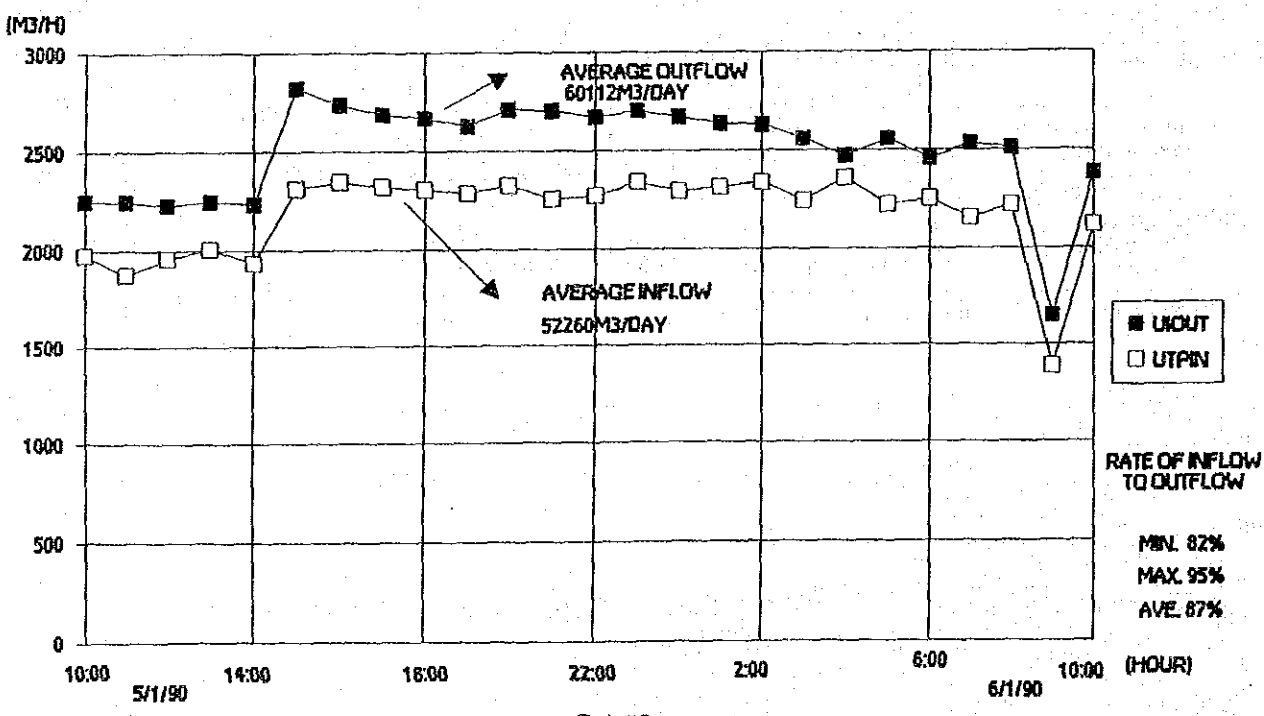


FIGURE C.4.19 FLOW FROM UPPER RUVU PLANT TO KIMARA RESERVOIR

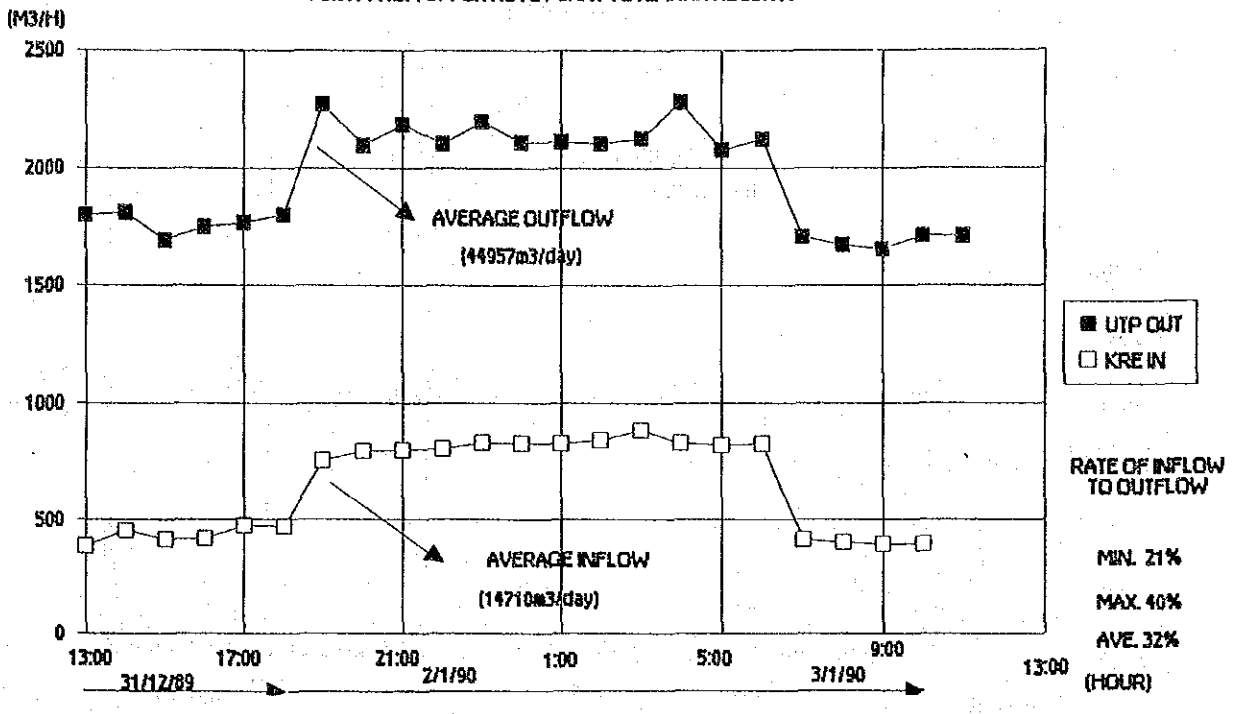



FIGURE C.4.19 FLOW FROM UPPER RUVU PLANT TO KIMARA RESERVOIR

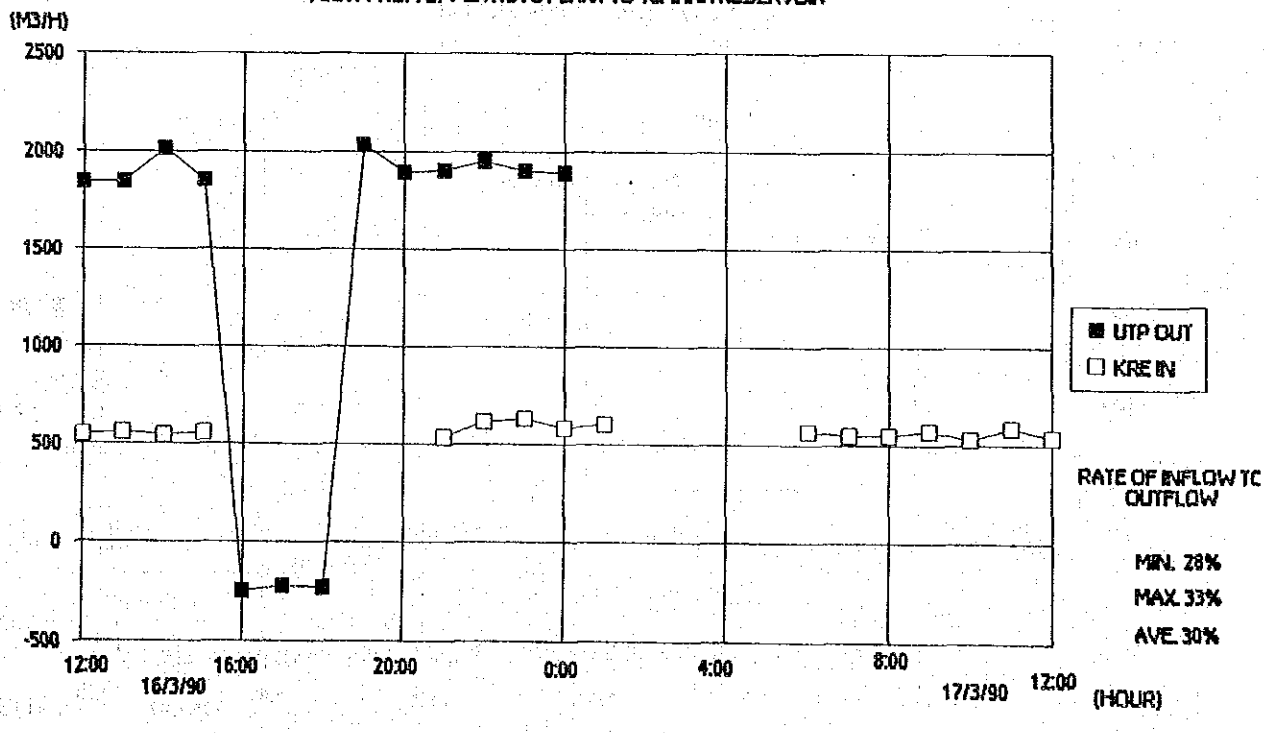


FIGURE C.4.20(1) FLOW FROM KIMARA RESERVOIR

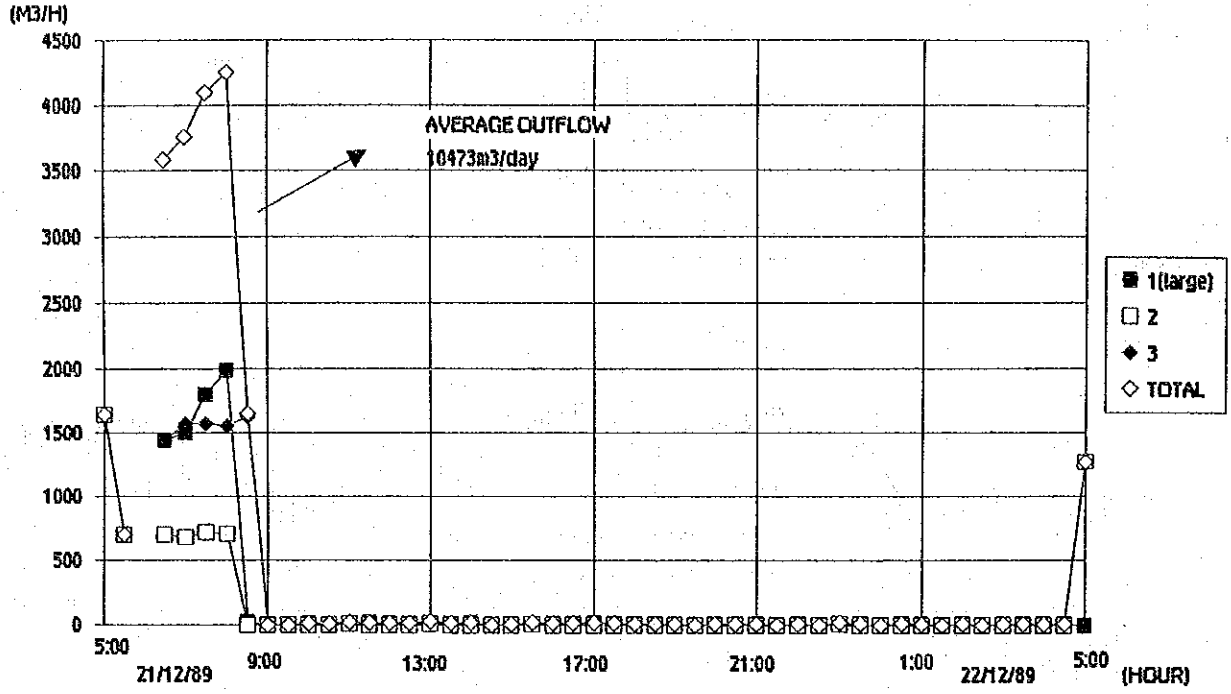



FIGURE C.4.20(1) FLOW FROM KIMARA RESERVOIR

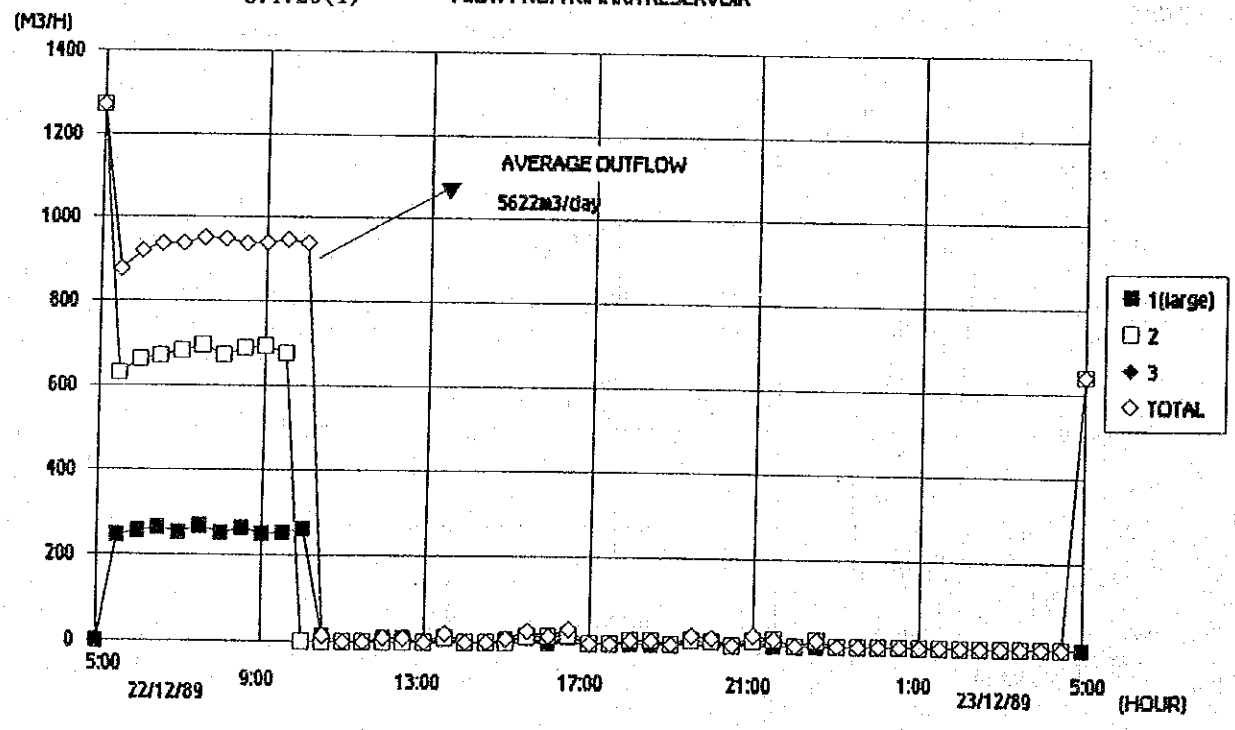


FIGURE C.4.20(2) FLOW FROM KIMARA RESERVOIR

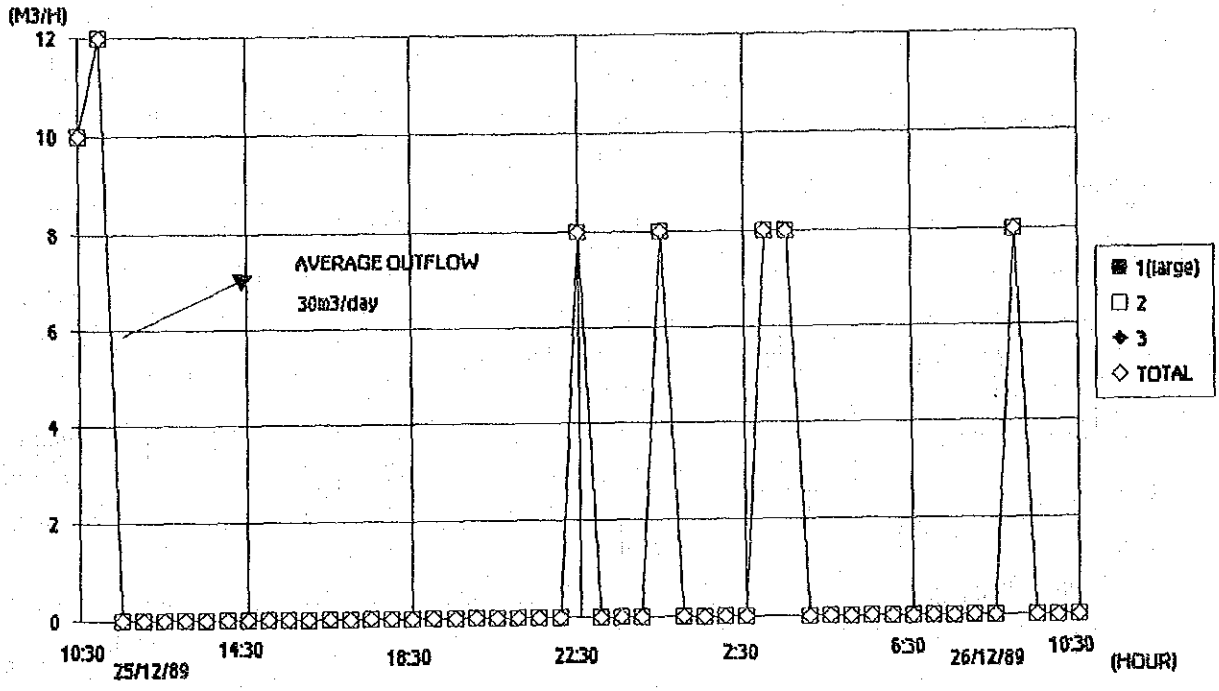



FIGURE C.4.20(2) FLOW FROM KIMARA RESERVOIR

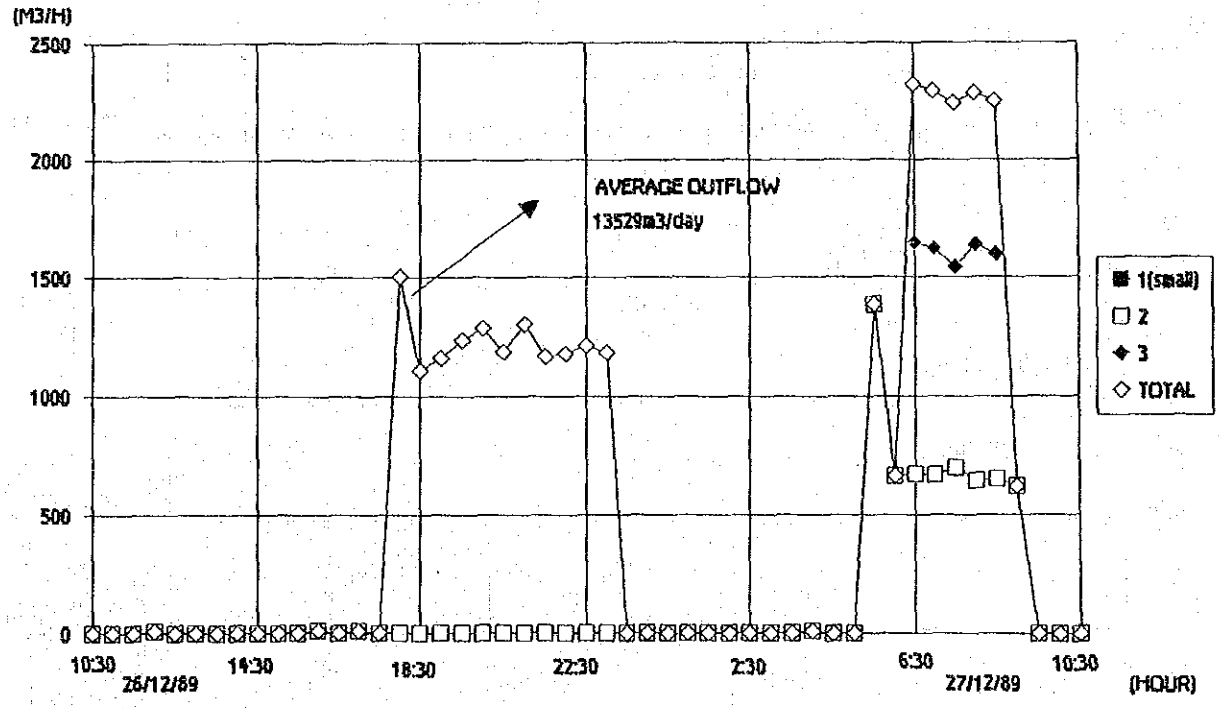


FIGURE C.4.21(1) FLOW FROM LOWER RUVU PLANT TO UNIV.RESERVOIR

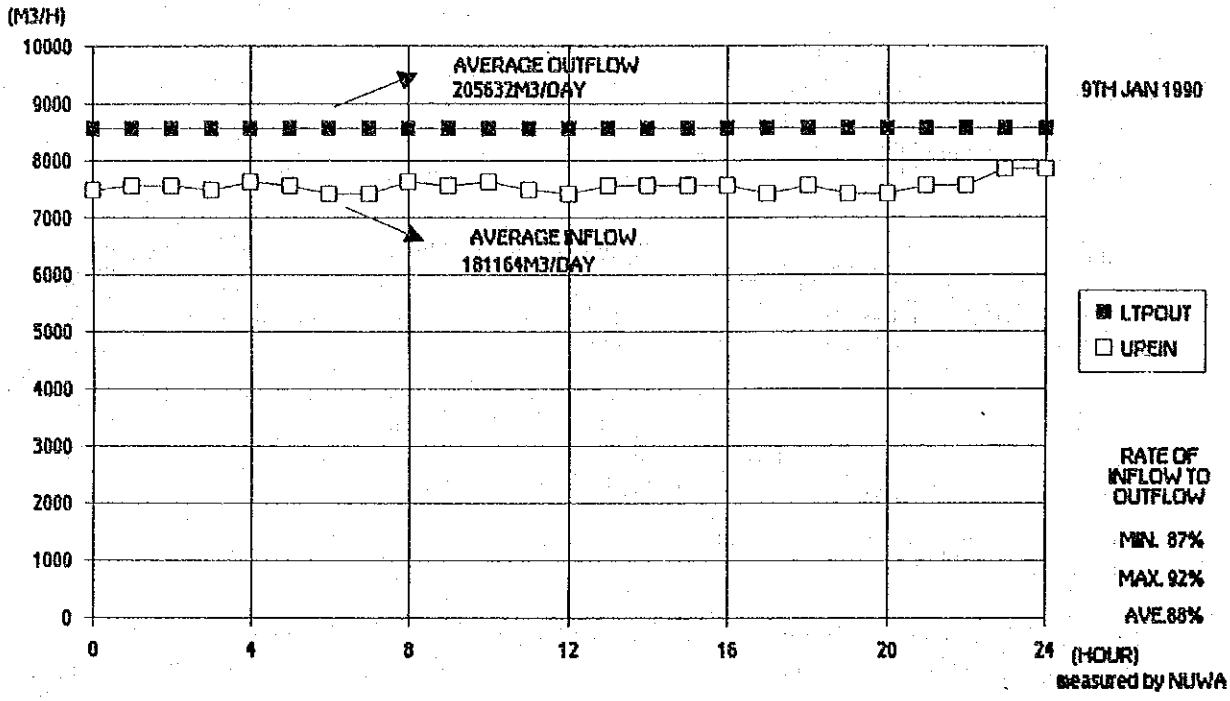



FIGURE C.4.21(1) FLOW FROM LOWER RUVU PLANT TO UNIV. RESERVOIR

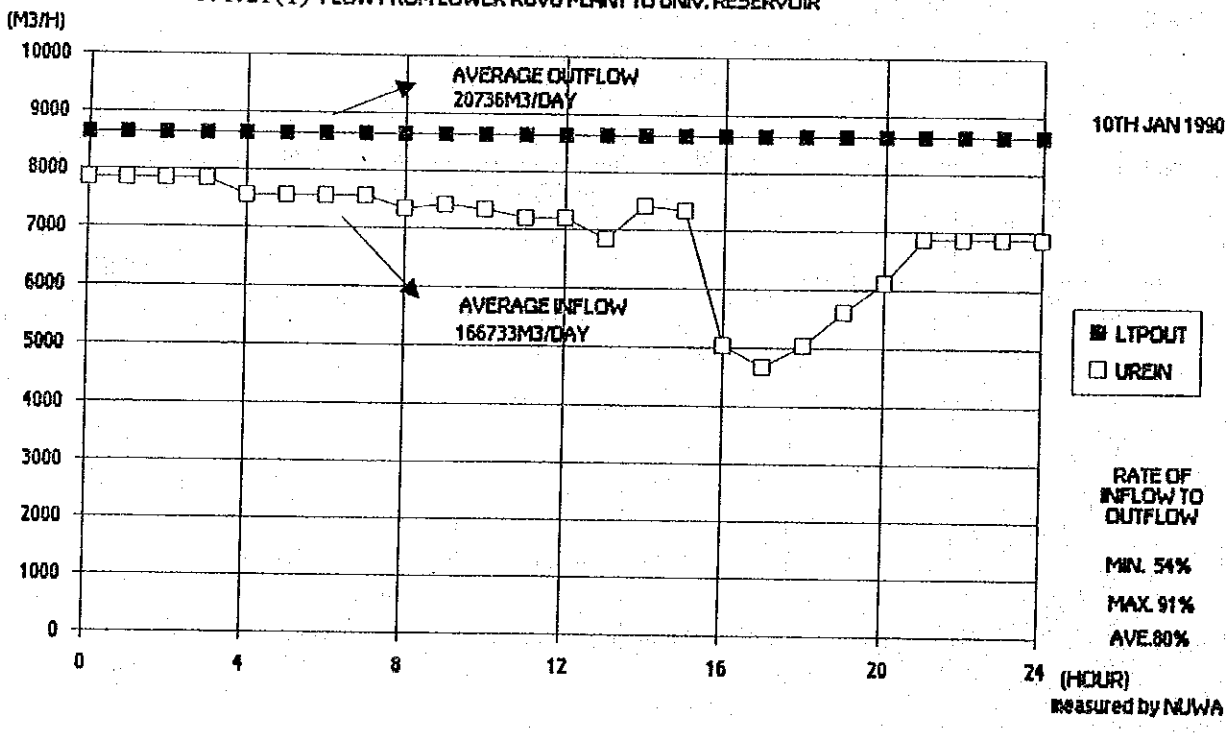
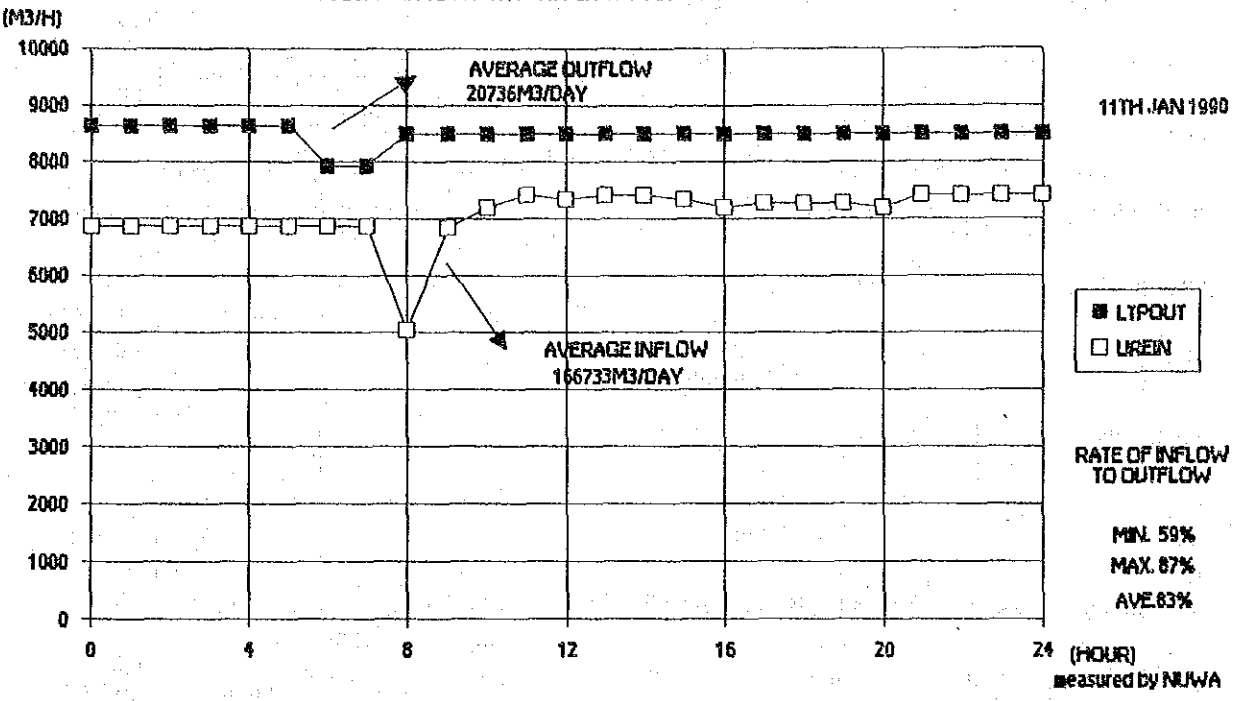
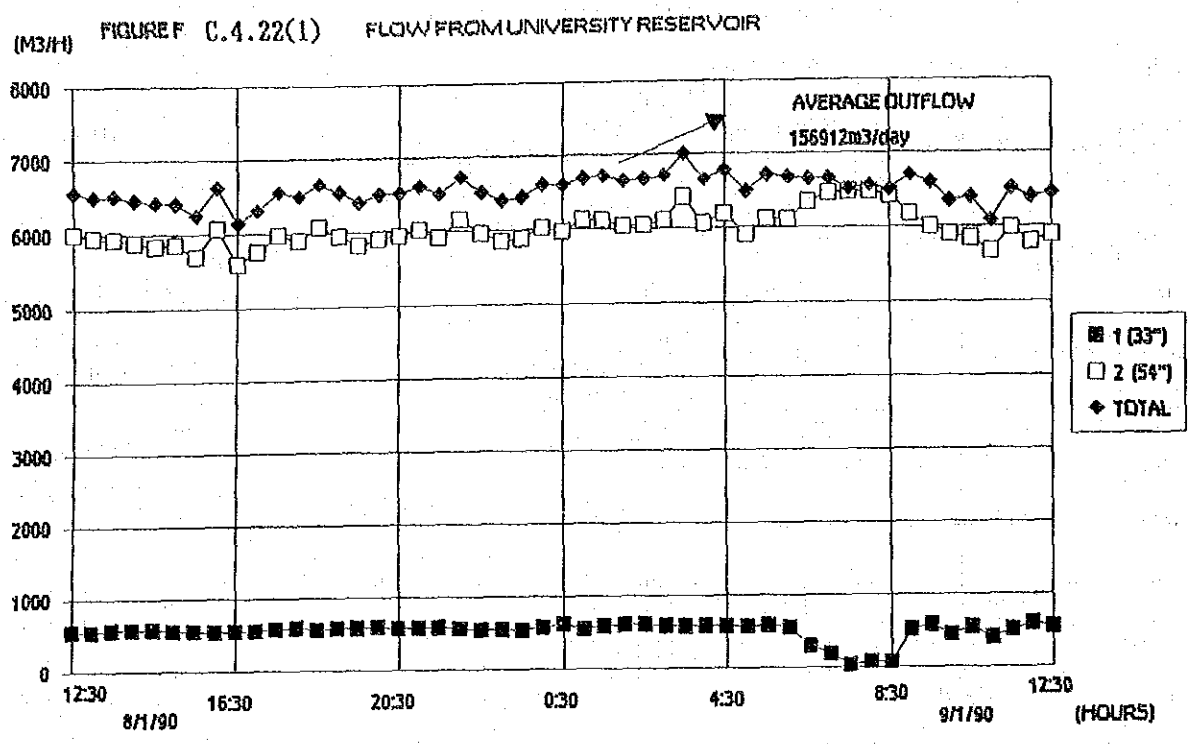
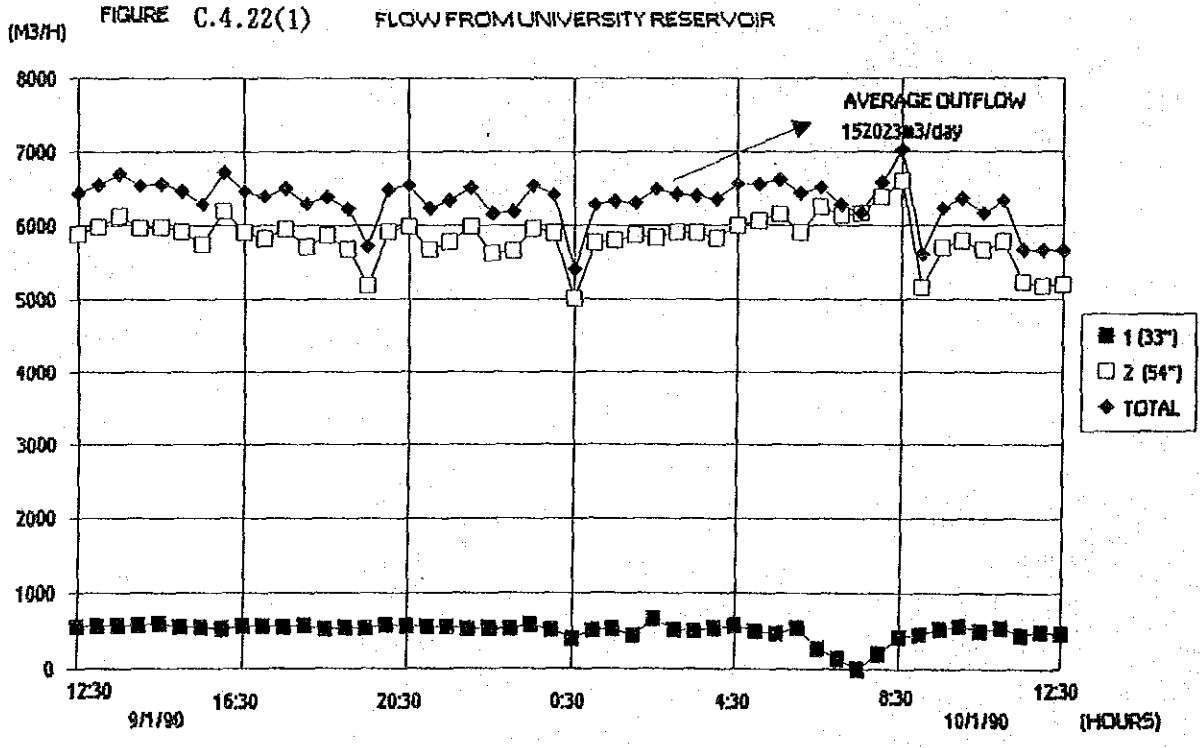
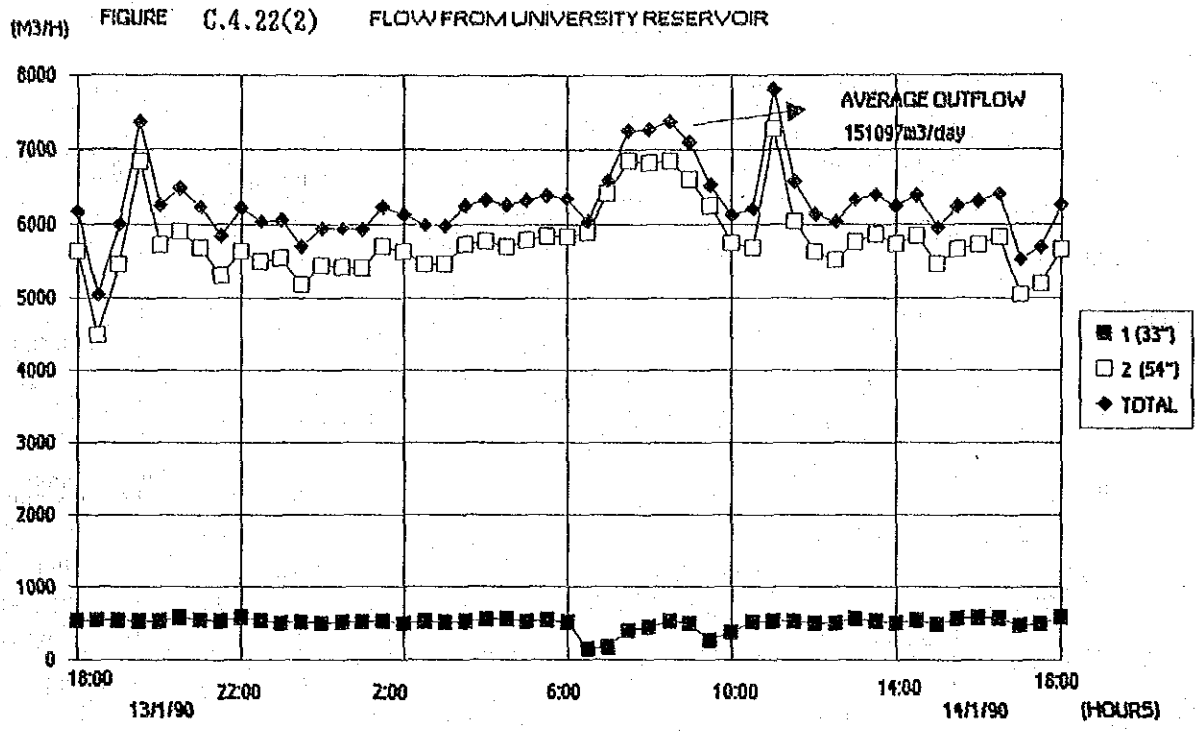


FIGURE C.4.21(2) FLOW FROM LOWER RUVU PLANT TO UNIV. RESERVOIR




(M3/H)
FIGURE F C.4.22(1) FLOW FROM UNIVERSITY RESERVOIR
8000
7000
6000
5000
4000
3000
2000
1000
0
AVERAGE OUTFLOW
156912m3/day
1 (33")
2 (54")
TOTAL
12:30
8/1/90
16:30
20:30
0:30
4:30
8:30
12:30
9/1/90
(HOURS)


(M3/H)
FIGURE C.4.22(1) FLOW FROM UNIVERSITY RESERVOIR
8000
7000
6000
5000
4000
3000
2000
1000
0
AVERAGE OUTFLOW
152023m3/day
1 (33")
2 (54")
TOTAL
12:30
9/1/90
16:30
20:30
0:30
4:30
8:30
12:30
10/1/90
(HOURS)


(M3/H)
FIGURE C.4.22(2) FLOW FROM UNIVERSITY RESERVOIR
8000
7000
6000
5000
4000
3000
2000
1000
0
AVERAGE OUTFLOW
151097m3/day
1 (33")
2 (54")
TOTAL
16:00
13/1/90
22:00
2:00
6:00
10:00
14:00
16:00
14/1/90
(HOURS)

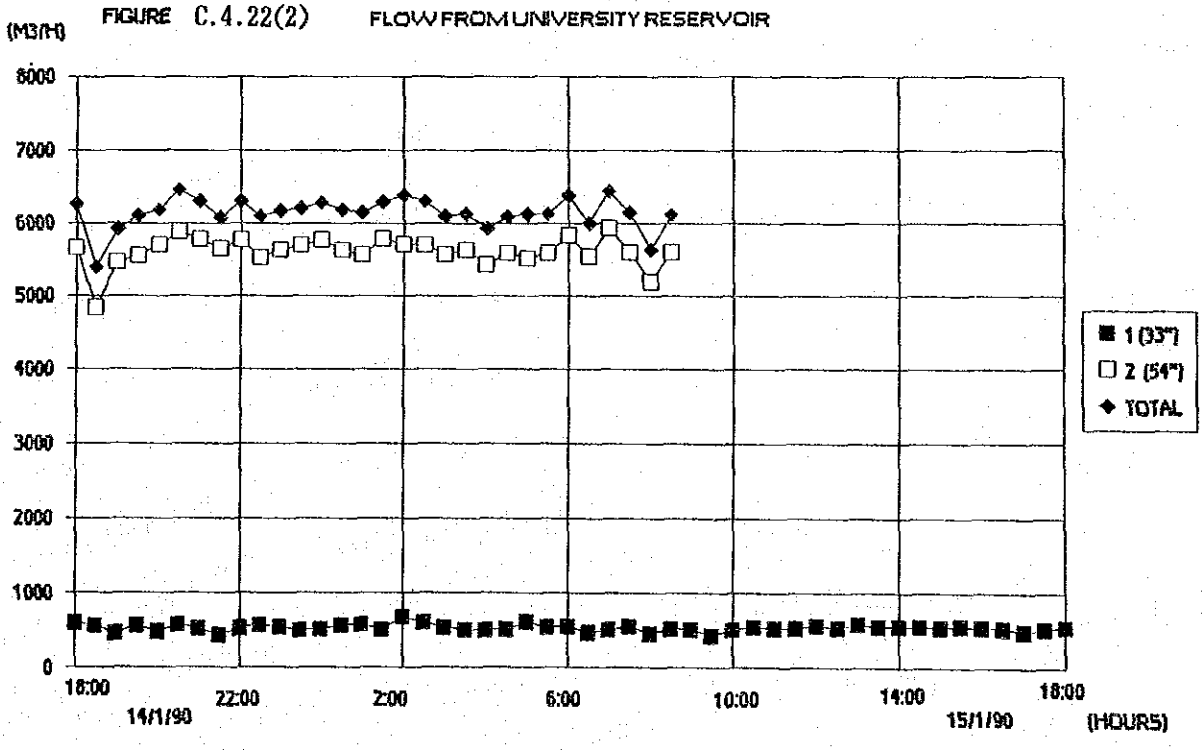

(M3/H)
FIGURE C.4.22(2) FLOW FROM UNIVERSITY RESERVOIR
8000
7000
6000
5000
4000
3000
2000
1000
0
1 (33")
2 (54")
TOTAL
16:00
14/1/90
22:00
2:00
6:00
10:00
14:00
16:00
15/1/90
(HOURS)

FIGURE C.4.23 FLOW FROM MTONI INTAKE TO MTONI PLANT

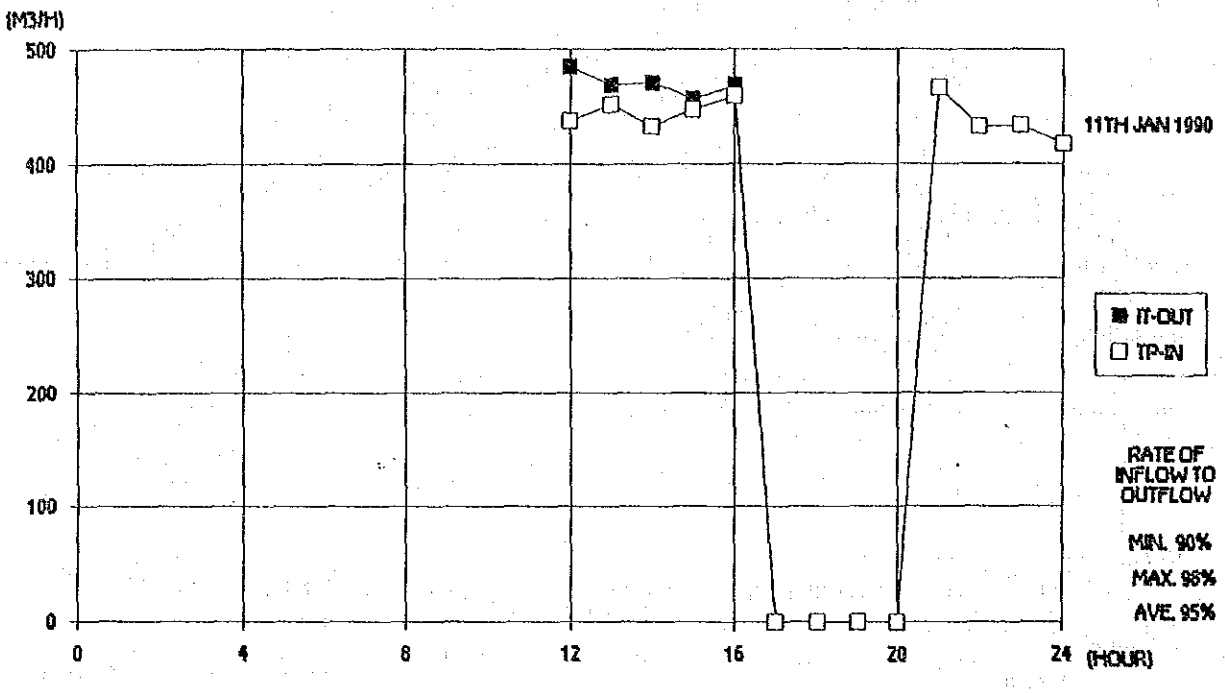


FIGURE C.4.24(1) FLOW FROM MTONI RESERVOIR

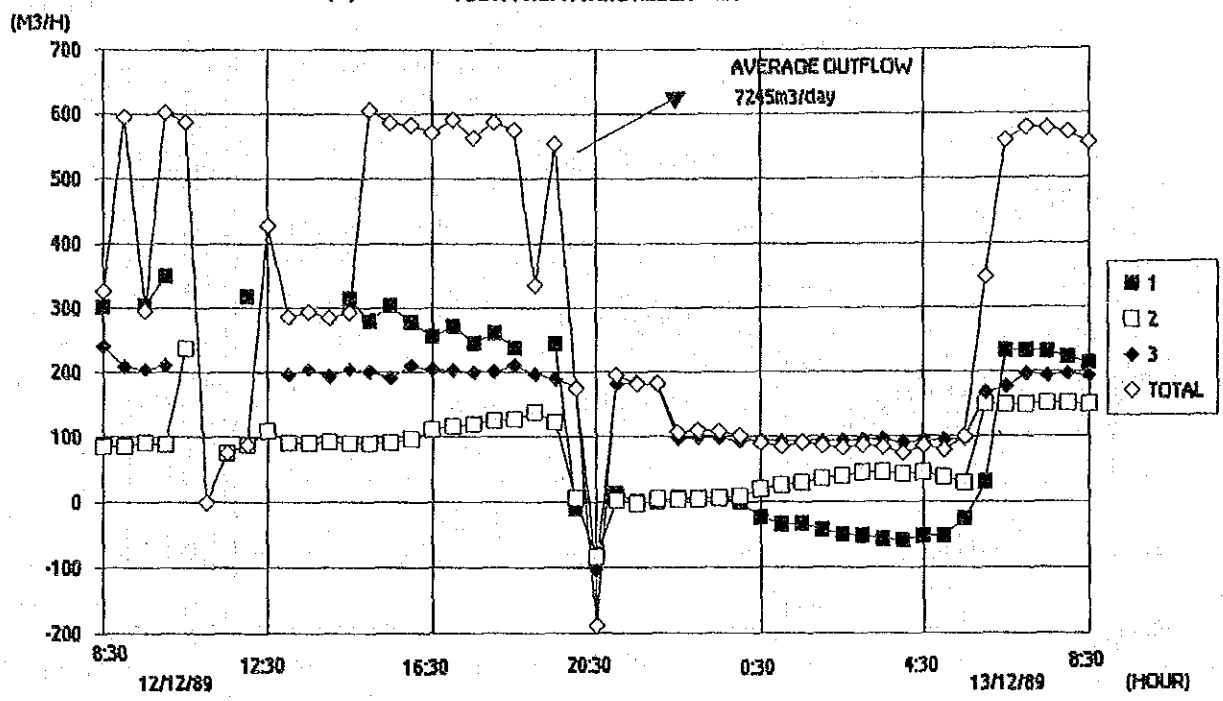



FIGURE C.4.24(1) FLOW FROM MTONI RESERVOIR

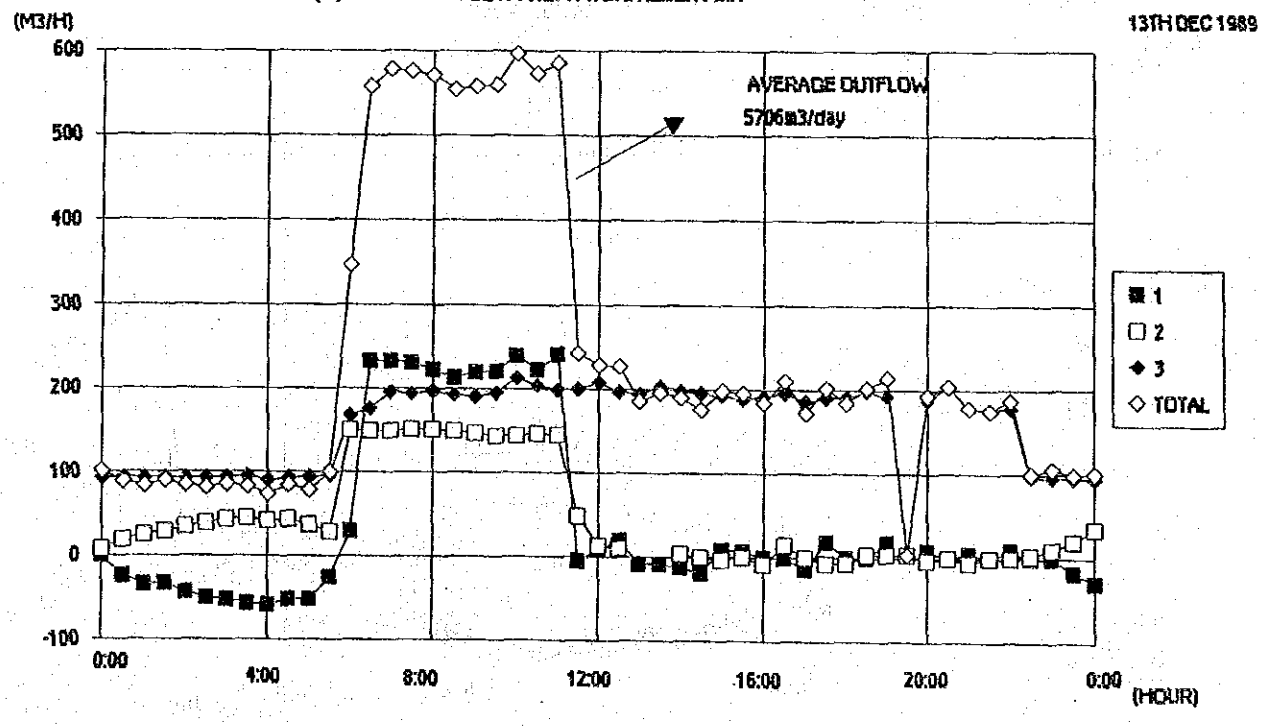


FIGURE C.4.24(2) FLOW FROM MTONI RESERVOIR

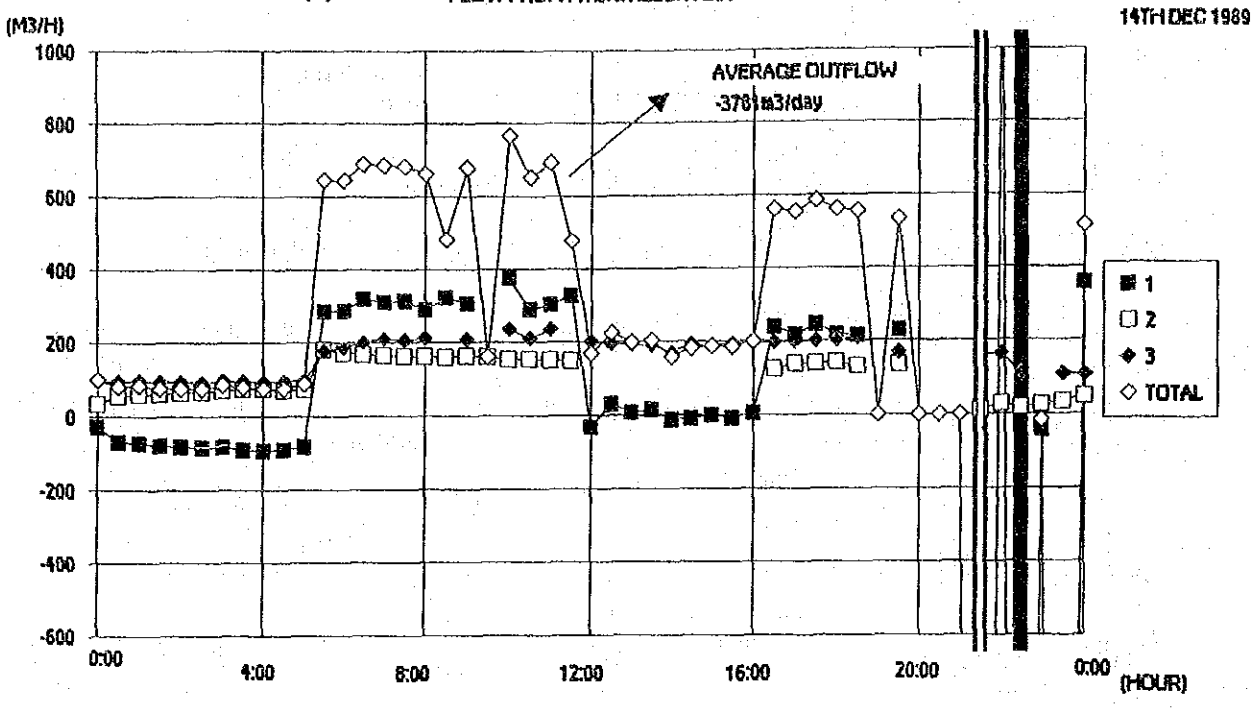
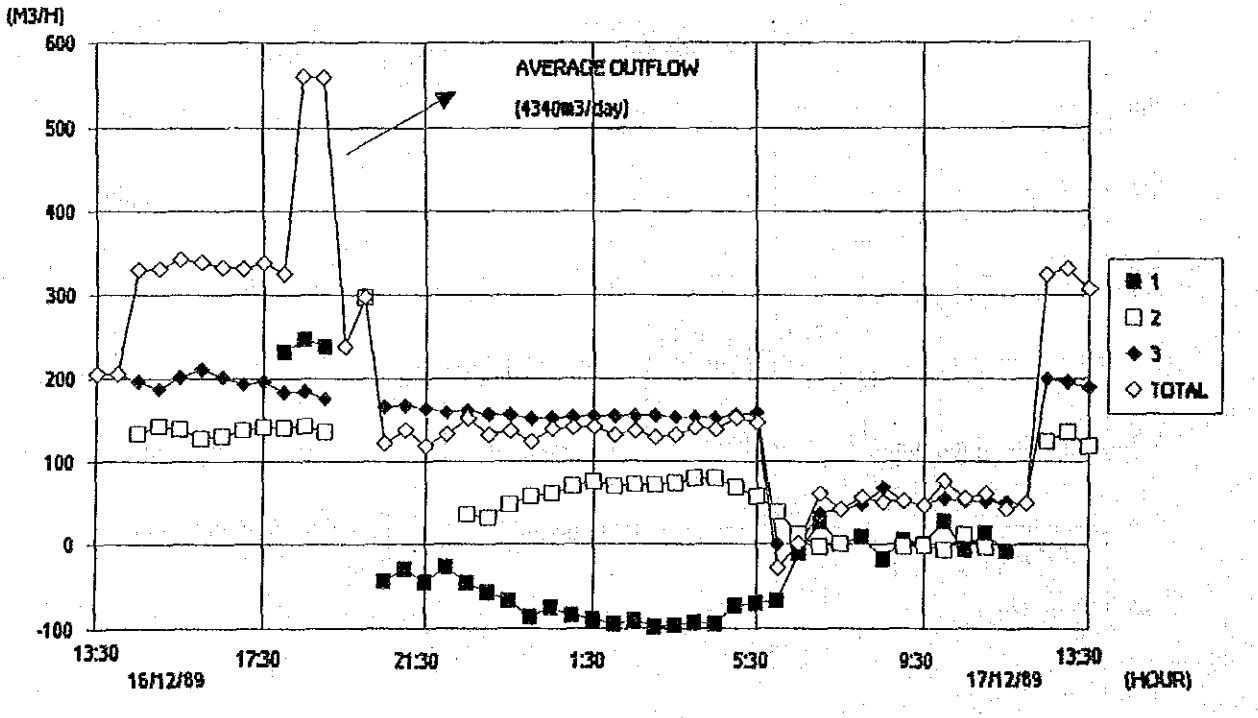



FIGURE C.4.24(2) FLOW FROM MTONI RESERVOIR



## 4.8 LEAKAGE MEASUREMENT IN TRANSMISSION PIPE *

### 4.8.1 PURPOSE

The purpose of this study was to estimate leakage along the Lower Ruvu transmission pipe.

### 4.8.2 PROCEDURE

1) Collect information on registered connections along the line.
2) Interview NUWA personnel on illegal connections and also estimate possible illegal connections based on; locations of settlements (demand-side approach) and, locations of air valves, washouts etc. which could easily have become tapping points (supply-side approach).
3) Investigate the line to estimate the number of legal and illegal tapping points.
4) Select points where consumption is to be measured.
5) Estimate total consumption based on measured consumption.
6) Estimate leakage, by subtracting all consumption from total amount lost from the transmission main (which was measured to be approximately 50,000 $m^3$/day during the first on-site study. This is obtained by subtracting the amount reaching the University Reservoir from the amount pumped from the treatment plant).

### 4.8.3 EQUIPMENT USED

- electromagnetic flow meter
- "Portaflow" flow meter

### 4.8.4 RESULT

According to NUWA engineers, seventeen known offtake points exist (refer to Figure C.4.25). There appear to be no additional unknown points because the transmission pipes are made of thick concrete making it difficult to drill through. Out of these, 10 off-takes are metered by NUWA. Data on withdrawal at offtakes between January 1989 and July 1989 was used. In addition, flow was measured at 4 off-takes, two of which are metered by NUWA.

Table C.4.16 shows that the total amount consumed along the transmission pipeline is 24,785 or 26,737

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* The contents of this section are summarized in section 4.3.3 "leakage and wastage in transmission line", Main Report.

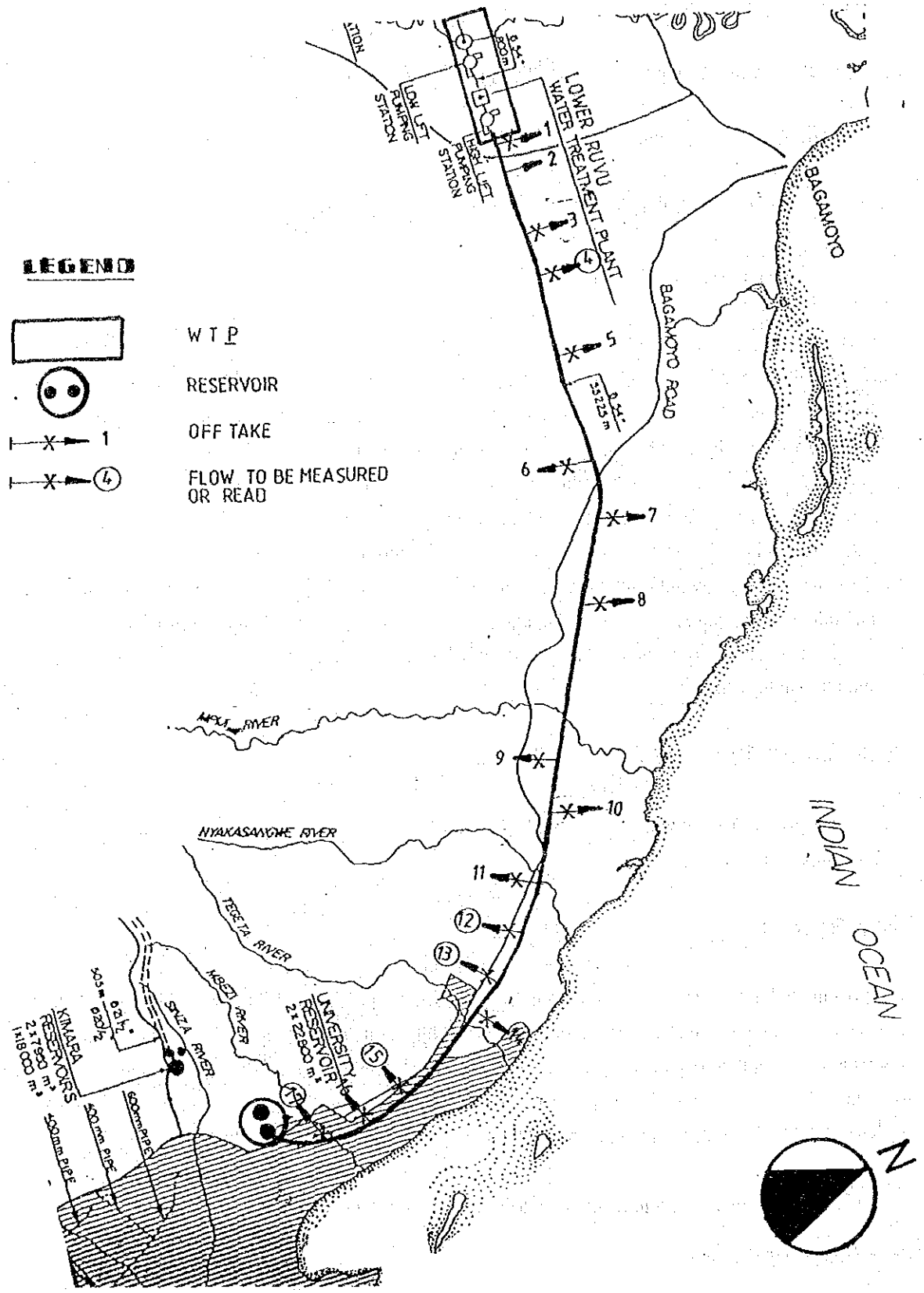



FIG. C.4.25 LOCATION OF OFF-TAKES IN LOWER RUVU SYSTEM

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

$m^3$/day. During the first on-site study, it was observed that approximately 206,000 $m^3$/day was delivered from the Lower Ruvu plant and that approximately 166,000 $m^3$/day reaches the University reservoir. The remaining 40,000 $m^3$/day is either consumed or lost by leakage along the transmission line. Hence leakage is 14,300 $m^3$/day.

**TABLE C.4.16 CONSUMPTION ALONG LOWER RUVU TRANSMISSION LINE**

| Off-take Points | Off-take Name | Distance (km) | Consumption ($m^3$/day) | Diameter of off-take pipe |
|---|---|---|---|---|
| 1 | NUWA staff house | 0.61 | 130M | 4" |
| 2 | BOMU | 1.74 | 900E | 6" |
| 3 | MATIMBWA to BAGAMOYO | 5.10 | 390M | 4" |
| 4 | CHAMBEZI to BAGAMOYO | 10.50 | 8,328* or 3,850M | 10" - 8" - 6" |
| 5 | ZINGA | 14.32 | 850M | 6" - 4" |
| 6 | | 17.74 | plugged | 6" |
| 7 | KEREGE A | 22.25 | 220M | 6" - 3" |
| 8 | KEREGE B | 24.41 | 380M | 6" |
| 9 | MAPINGA | 34.32 | 30M | 4" |
| 10 | BUNJU | 36.08 | 620E | 6" |
| 11 | BOKO A | 36.16 | 760E | 6" |
| 12 | BOKO B | 39.70 | 767* | 6" |
| 13 | WAZO CEMENT & MILITARY AREA | 42.48 | 1,490M | 8" - 8" & 3" |
| 14 | SISAL ESTATE | 45.40 | 1,990E | 6" |
| 15 | BAHARI BEACH HOTEL & others | 48.01 | 3,974* or 6,500M | 6" |
| 16 | MBEZI & GOBA | 51.26 | 1,970M | 6" |
| 17 | LUGALO | 52.48 | 3,938* | 8" - 6" |
| | TOTAL | | 26,737* to 24,785M | |

NOTE: *; measured for 24 hours in August,1990
M; averaged from monthly readings of NUWA between January, 1989 and July,1989.
E; estimated

### 4.8.6 ANALYSIS

12 % (25,700 $m^3$/day) consumption and 7 % (14,300 $m^3$/day) leakage along the 50 kms long transmission line seems acceptable, particularly since it is under very high pressure - up to 110 meters and averaging about 60 meters. Only one pipe burst has been reported in this line.

#### (1) WASTAGE CONTROL

In the future, consumption will be reduced to half or even one-third the present level. According to the 1988 census, 173,918 inhabitants (136,059 in 1978 census) live in Bagamoyo district, where the pipeline passes. Out of this total, 40,190 persons, at the maximum, appear to benefit from the water taken from the transmission line. This number is the total of the four wards/branches; Magomeni (13,735

persons), Dunda (9,193), Zinga and Kerege (11,287) and Yombo (5,975) through which the pipeline passes. The amount of water consumed in Bagamoyo district (off-take points 1 to 9 in Table C.4.16) is 11,228 $m^3$/day (metered value) or 6,759 $m^3$/day (measured value). This represents a very high consumption of 279 or 168 liter per capita per day (lpcd).

Assuming that the water service is by yard connections, the per capita consumption should be around 85 liters per day (derived from the per capita consumption study explained earlier). Based on this lpcd value, the amount consumed should only be 3,400 $m^3$ per day. One possible reason for this high consumption is that water is used for irrigation also. Further, high pressure and the resultant high leakage also contributes to high consumption.

### (2) PRESSURE CONTROL AND BULK METER INSTALLATION

Reduction in pressure generally reduces leakage. Theoretically, flow through an orifice is proportional to the square root of the pressure. However, a series of experiments has shown that this relationship does not hold for the effect of pressure on leakage from water supply systems. The results of these experiments are shown in Figure C.4.26. Because leakage does not depend solely upon pressure, the vertical scale represents the index of leakage (strictly net night flow) rather than leakage alone.

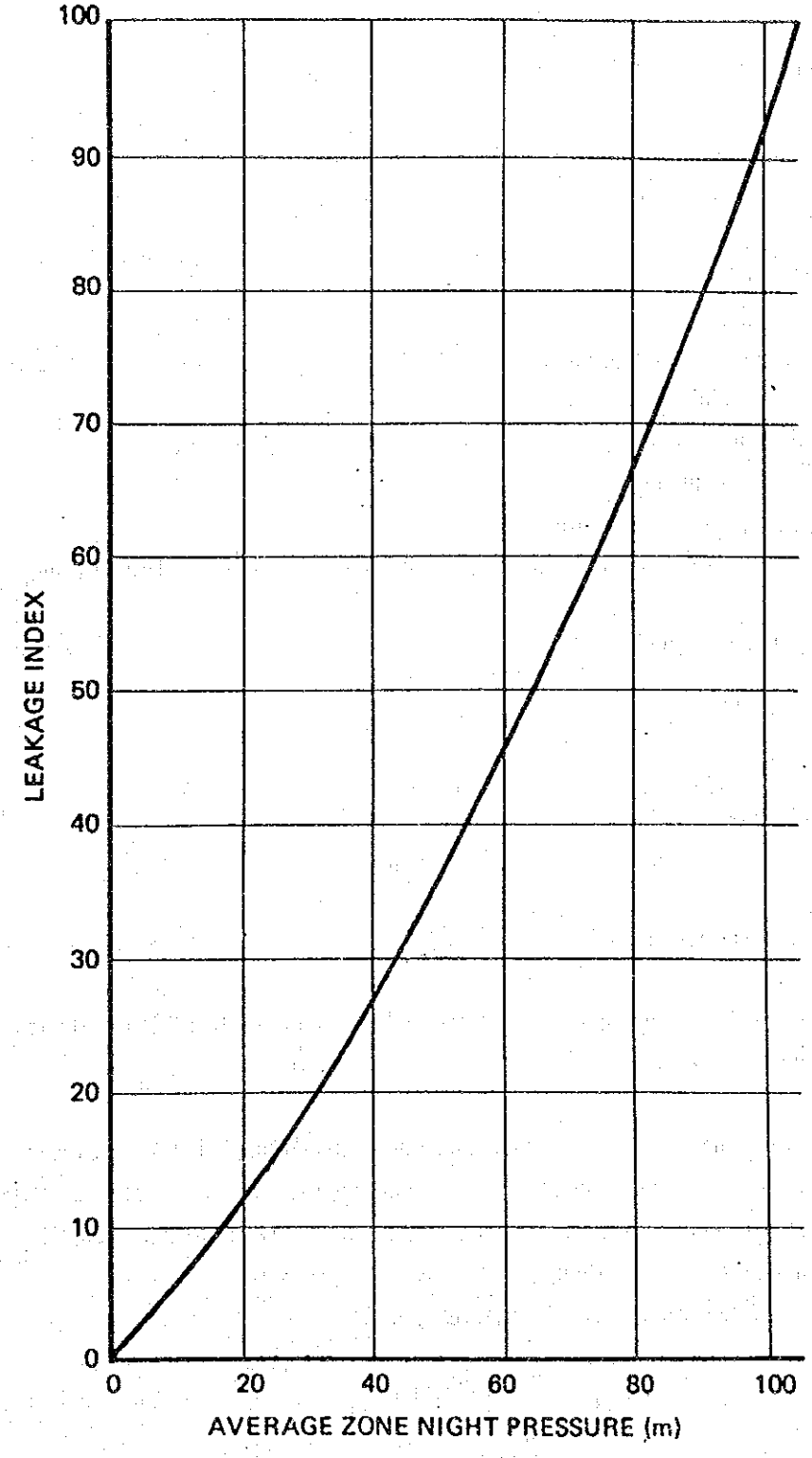
Since the present pressure in the off-takes from the feeder main is high, ranging from 60 to 100 metres, leakage must be high. At every off-takes, pressure reducing valves and bulk meters have been installed. However, they are not functioning. They need replacement to curb leakage and wastage.

Assuming that 50 metres is the maximum night pressures at present, the leakage index can be read off Figure C.4.26 as 36. This index value is equivalent to a leakage level of 14,300 $m^3$. When pressures are reduced to between 25 and 30 metres, the leakage index goes down to between 17 and 19.

Reduction of water leakage can be calculated as follows:-

* Original leakage index ---------- 36
* Proposed water pressure ---------- 25 to 30 metres
* Proposed leakage index ---------- 17 to 19
* Estimated leakage factor = Proposed leakage index / Original leakage index
  = (17 to 19) / 36 = 47 to 53 percent
* Expected leakage = 14,300 $m^3$ * (0.47 to 0.53) = 6,700 to 7,600 $m^3$/day
  = 7,150 $m^3$/day (Average)
* Saved leakage = 14,300 - 7,150 = 7,150 $m^3$/day

The amount of water saved will be sufficient for approximately 70,000 persons.




| | |
|---|---|
| FIG. C.4.26 | LEAKAGE INDEX |

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

## 4.9 FLOW MEASUREMENT IN DISTRIBUTION PIPES

### 4.9.1 PURPOSE

The purpose of this study is to determine the flow in the main distribution pipes, as well as the amount of inflow into some zones.

### 4.9.2 PROCEDURE

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) Find pipe location at each point with the help of a NUWA technician and pipe locator.
3) Excavation of the located point.
4) Measurement of flow with flow meter.
5) Measurement of effective sectional area with scale checker to adjust indicated flow.

### 4.9.3 EQUIPMENT USED

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

### 4.9.4 RESULT AND ANALYSIS

Selected points are shown in Figure C.4.27. The results obtained from this study are shown in Table C.4.17 and in Figure C.4.28.

Of the 17 pipes examined, the velocity in all pipes was between 0.1 - 1.0 m/sec. Pipes 1, 2 and 3 are in Msasani and the flow velocity is very high. Consequently, the load on the pipes is very high. Pipes 6, 9, 10, 11 and 16 are seen to have flow reversed at certain times in the day. Therefore, it appears that the distribution system is very complex. The reason for flow reversal in some pipes is because the reservoirs are connected through the distribution network.

## TABLE C.4.17 DISTRIBUTION PIPE FLOW

| NO. | Date | Diameter (mm) | Flow($m^3$/day) Average | Max | Min | Velocity(m/s) Average | Max |
|---|---|---|---|---|---|---|---|
| 1 | 7.Aug,90 | 250 | 4,256 | 4,608 | 3,888 | 0.915 | 0.990 |
| 2 | 7.Aug,90 | 200 | 2,981 | 3,168 | 2,880 | 0.942 | 1.001 |
| 3 | 8.Aug,90 | 200 | 1,989 | 2,160 | 1,872 | 0.647 | 0.703 |
| 4 | 8.Aug,90 | 250 | 379 | 576 | 288 | 0.081 | 0.124 |
| 5 | 9.Aug,90 | 400 | 4,082 | 4,320 | 3,888 | 0.380 | 0.402 |
| 6 | 27.Aug,90 | 300 | 1,038 | 2,736 | -432 | 0.151 | 0.399 |
| 7 | 9.Aug,90 | 400 | 6,228 | 6,912 | 5,472 | 0.641 | 0.711 |
| 8 | 10.Aug,90 | 375 | 7,738 | 9,648 | 6,336 | 0.768 | 0.958 |
| 9 | 7.Aug,90 | 375 | 76 | 501 | -254 | 0.008 | 0.051 |
| 10 | 10.Aug,90 | 350 | 2,619 | 6,480 | -1,008 | 0.299 | 0.739 |
| 11 | 11.Aug,90 | 250 | 1,231 | 2,448 | -720 | 0.268 | 0.533 |
| 12 | 12.Aug,90 | 450 | 1,784 | 2,304 | 1,152 | 0.130 | 0.168 |
| 13 | 16.Aug,90 | 525 | 1,082 | 7,056 | 0 | 0.058 | 0.376 |
| 14 | 15.Aug,90 | 525 | 1,327 | 28,655 | 0 | 0.071 | 1.526 |
| 15 | 13.Aug,90 | 525 | 5,124 | 6,048 | 4,032 | 0.257 | 0.303 |
| 16 | 16.Aug,90 | 700 | 10,157 | 13,247 | -3,888 | 0.307 | 0.400 |
| 17 | 13.Aug,90 | 1,350 | 122,074 | 149,034 | 112,028 | 0.985 | 1.203 |

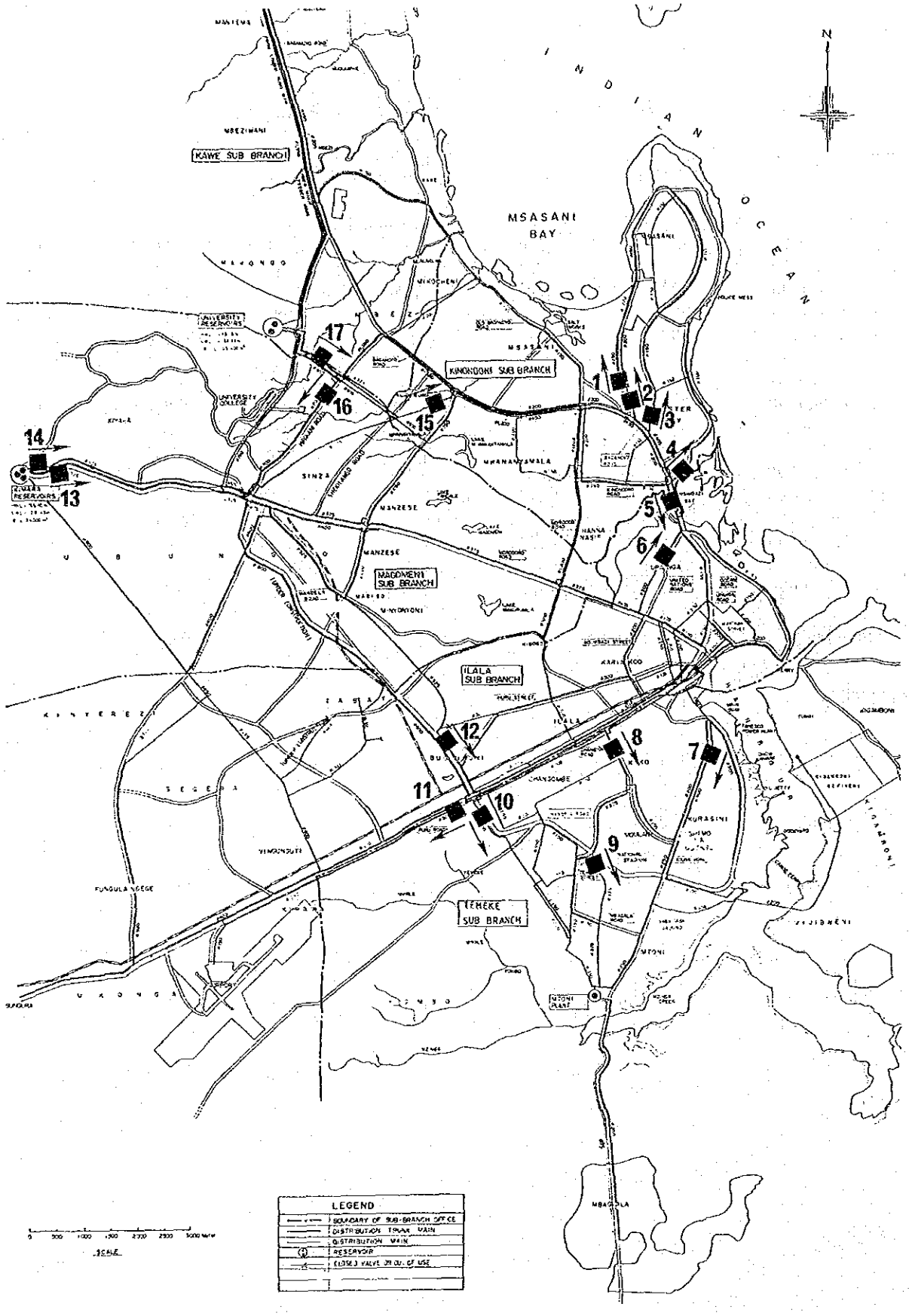



FIG. C.4.27 FLOW MEASUREMENT FOR DISTRIBUTION PIPES

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

FIG. C.4.28(1) Distribution Pipe Network Flowrate

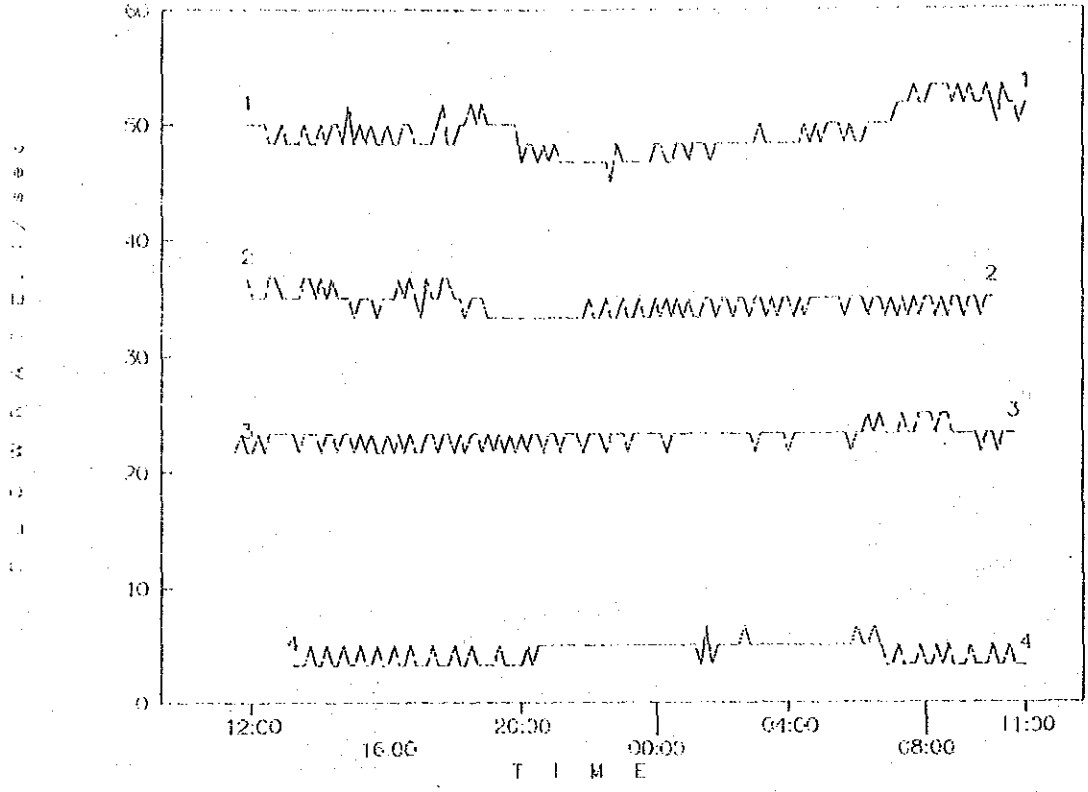



FIG. C.4.28(2) Distribution Pipe Network Flowrate

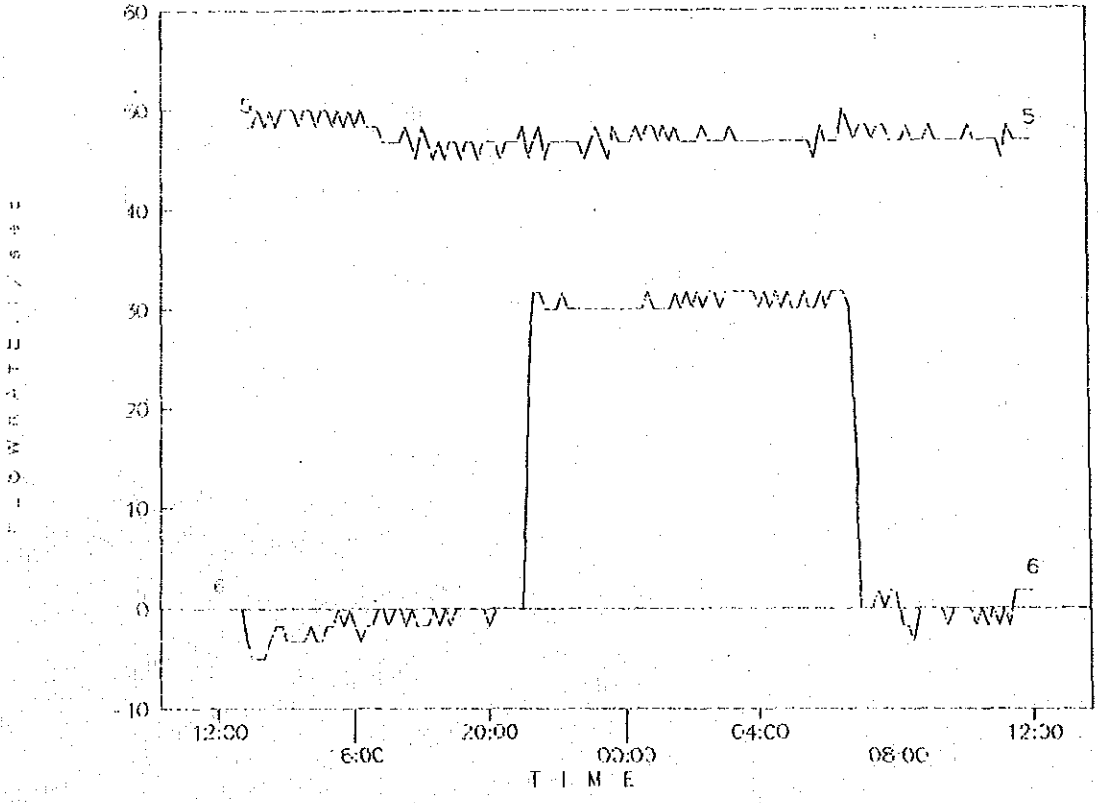


FIG. C.4.28(3) Distribution Pipe Network Flowrate

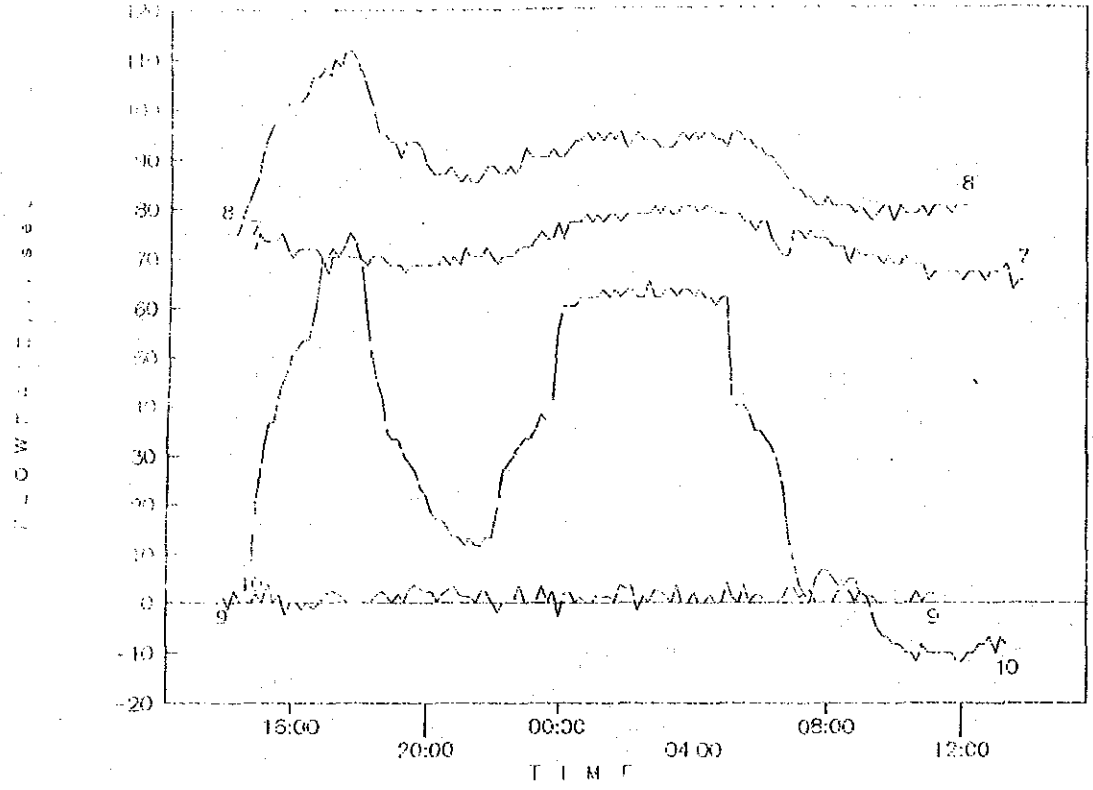



FIG. C.4.28(4) Distribution Pipe Network Flowrate

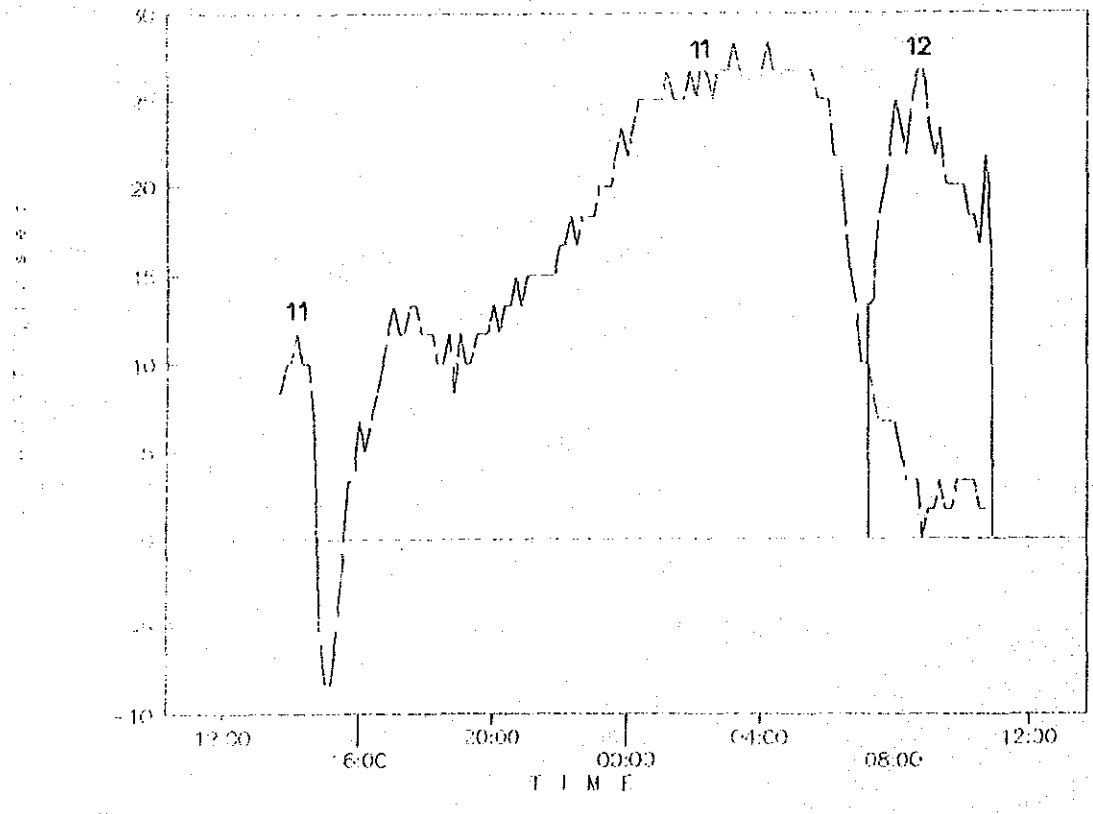


FIG. C.4.28(5) **Distribution Pipe Network Flowrate**

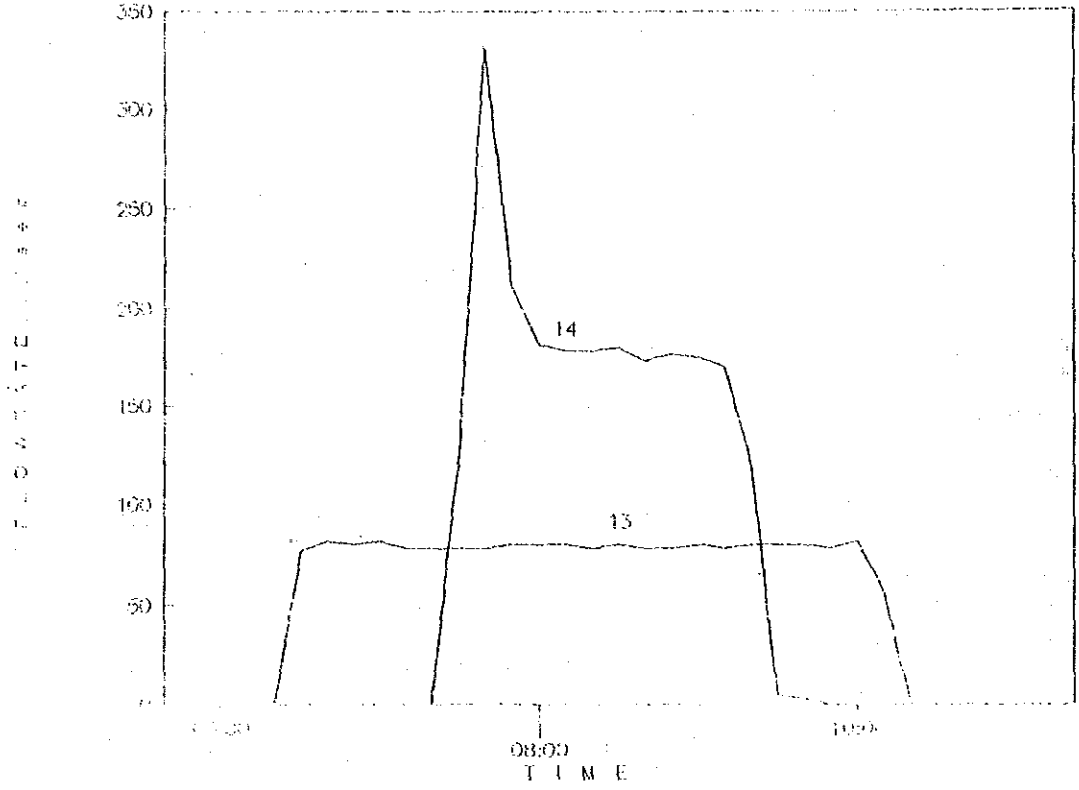



FIG. C.4.28(6) **Distribution Pipe Network Flowrate**

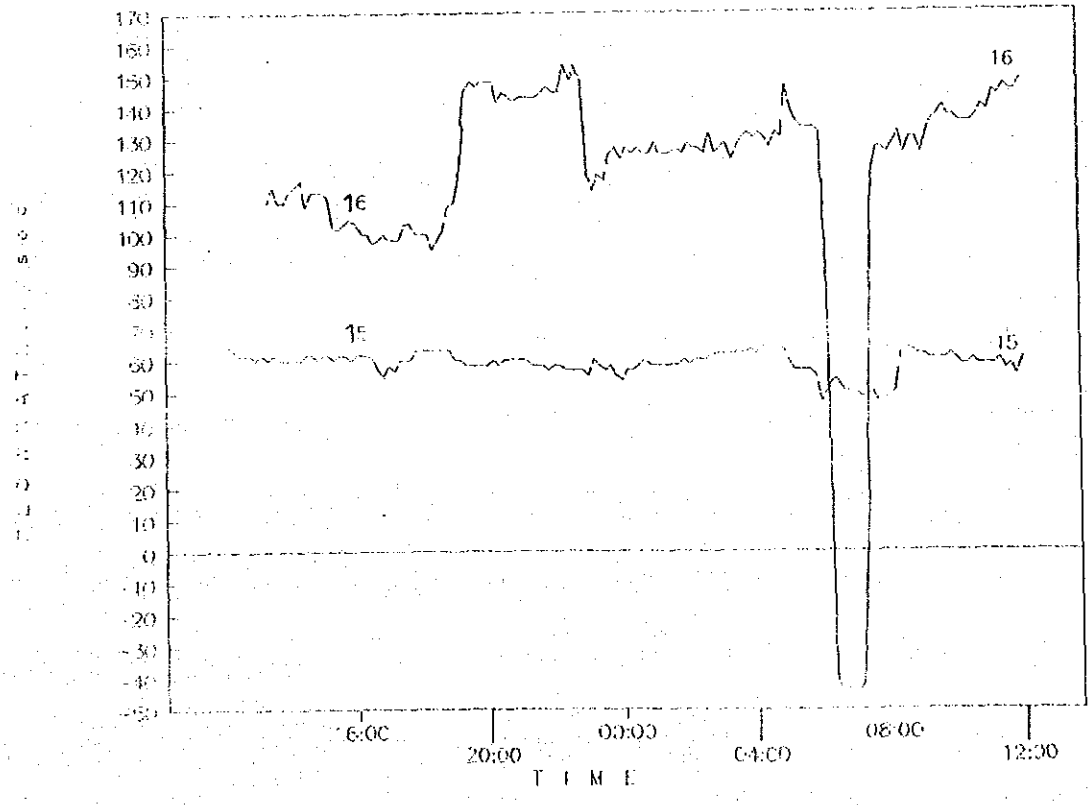
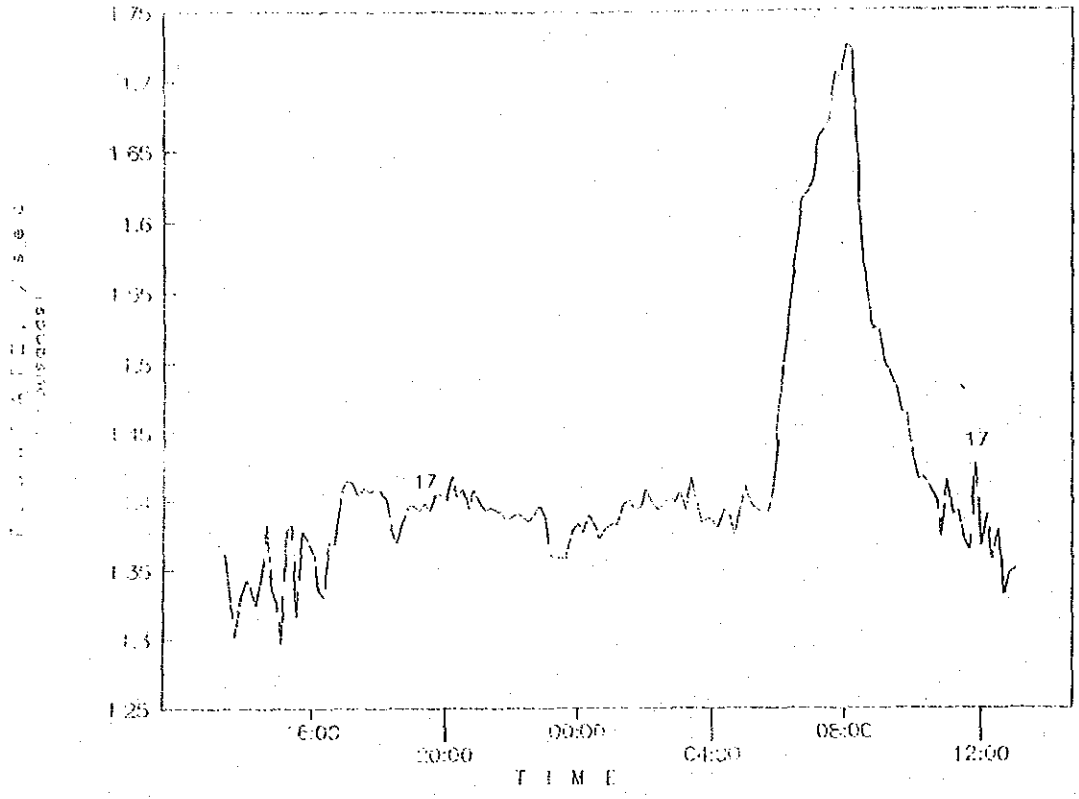


FIG. C.4.28(7) **Distribution Pipe Network Flowrate**



## 4.10 DETERMINATION OF ROUGHNESS COEFFICIENT ("C" VALUE) *

### 4.10.1 PURPOSE

The purpose was to determine the roughness coefficient so as to correlate it with the pipe age, pipe material, etc.

### 4.10.2 SECTIONS INVESTIGATED

Sections selected for roughness coefficient estimation were chosen on the basis that the sections should be as long as possible and there should be no offtake from the section. Six sections, which satisfied this criteria, were selected for investigation.

### 4.10.3 PROCEDURE

The following procedure was used to determine the roughness coefficient.

1) The section was investigated to ensure that there were actually no offtakes. This was done by studying maps and actual field surveys.
2) On the chosen section, a pressure gauge was installed on either end of the section.
3) A flow meter was installed at either end of the section.
4) The pressure and flow were measured at intervals of one minute for a period 30 minutes, during the peak hours.
5) The ground level elevation of the pressure gauges were obtained by surveying.

### 4.10.4 EQUIPMENT USED

- pipe locator, - scale checker, - pipe thickness meter, - "Portaflow" flow meter, - pressure gauges

### 4.10.5 RESULT

The pipe sections selected for investigation are shown in Figure C.4.29. Results of the investigation are given in Table C.4.18.

---

* The determined C-value is used in section 5.3.1, Appendix.

### 4.10.6 ANALYSIS

It can be seen from Table C.4.18 that, of the six sections, only three sections yielded meaningful results. This is because unless there is sufficient head drop between the two ends of the section, good estimates of the "C" values cannot be made. The meaningful results are given below :

| Diameter | Pipe Age | "C"-value |
|---|---|---|
| 375 | 27 | 80 |
| 200 | 37 | 70 |
| 150 | 37 | 60 |

In Japanese waterworks practice, as given in "Design Guidelines for Waterworks Facilities", cast iron pipes that are 30 years old have a "C" value of 80-90, while those that are about 40 years old have a "C" value of 70-80. It can be seen that the results of the three sections investigated fit in well with these guideline values.

Normally, for the same pipe age, with increase in diameter, the decrease in the roughness coefficients for larger pipes is lesser than for smaller pipes. In the sections investigated, it can be seen that there are two sections which are 37 years old. The pipe with the larger diameter has a greater "C" value, i.e. lesser decrease in "C" value.

**TABLE C.4.18 DETERMINATION OF C-VALUE**

| No. material | Age | Diameter (mm) | Distance (m) | time (min) | Difference energy (m) | Gradient (0/00) | Flow (l/s) | Velocity (m/s) | C-value |
|---|---|---|---|---|---|---|---|---|---|
| 1 cast iron | 37 | 150 | 200 | 1-10 | 6.59 | 32.95 | 16.9 | 1.0866 | |
| | | | | 11-20 | 6.55 | 32.75 | 16.9 | 1.0867 | |
| | | | | 21-30 | 6.67 | 33.35 | 17.2 | 1.1067 | |
| | | | | Average | 6.60 | 33.02 | 17.0 | 1.0967 | |
| 2 cast iron | 27 | 375 | 357 | 1-10 | 2.16 | 6.06 | 108.8 | 1.0285 | |
| | | | | 11-20 | 2.24 | 6.28 | 111.7 | 1.0586 | |
| | | | | 21-30 | 2.16 | 6.06 | 115.3 | 1.0890 | |
| | | | | Average | 2.19 | 6.13 | 111.9 | 1.0587 | |
| 3 cast iron | 37 | 200 | 137 | 1-10 | 1.22 | 8.91 | 22.4 | 0.7880 | |
| | | | | 11-20 | 1.31 | 9.57 | 22.3 | 0.7877 | |
| | | | | 21-30 | 1.28 | 9.35 | 22.1 | 0.7777 | |
| | | | | Average | 1.27 | 9.28 | 22.3 | 0.7878 | |

The C-values in the above table were against reduced effective areas. If C-values are expressed as against nominal pipe areas, C-values can be regarded as follows;

Pipe section No.1 (ND 150 mm, pipe age = 37): from 67 to 57

Pipe section No.2 (ND 375 mm, pipe age = 27): from 87 to 83

Pipe section No.3 (ND 200 mm, pipe age = 37): from 78 to 69

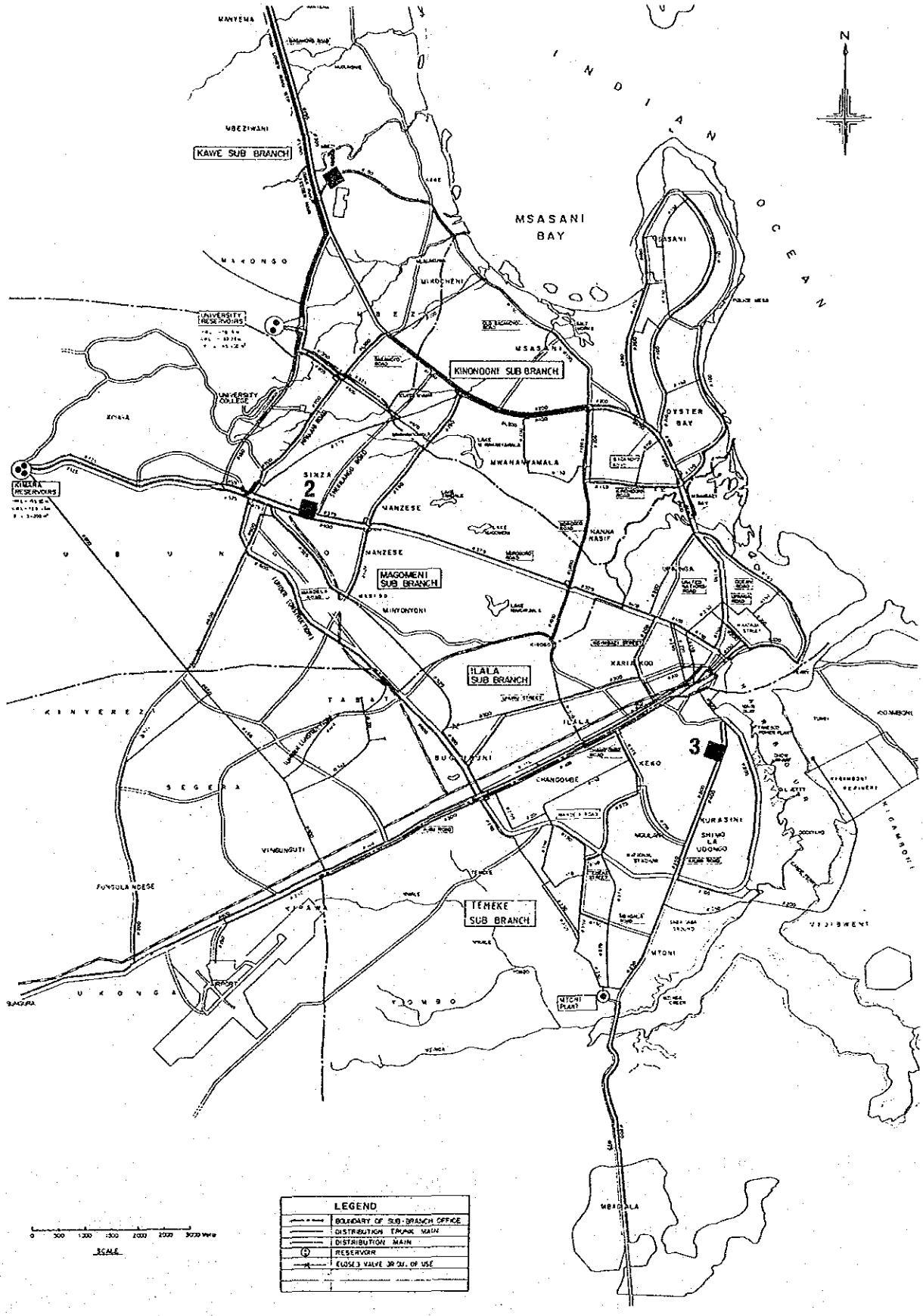



FIG. C.4.29 LOCATION OF INVESTIGATION OF COEFFICIENT FOR FLOW LATE

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

## 5. NETWORK ANALYSIS

In order to formulate an effective rehabilitation programme for the city's potable water infrastructure, the hydraulic analysis of the primary distribution system was made. The network analysis was carried out in the following three key stages;

(i) Data Collection
(ii) Model Construction and Calibration
(iii) Hydraulic Analysis of Existing, Rehabilitated and Future Systems.

### 5.1 DATA COLLECTION *

A data collection programme was undertaken in order to formulate the hydraulic network, based on the existing primary distribution system. The general plan of the water distribution system is given in Figure C.5.1. In addition to existing NUWA records and drawings, data was obtained from previous study reports (JICA,1984 and UNDERWOOD McLELLAN, 1977). Information regarding the distribution system and the current operating conditions was obtained by interviewing NUWA project engineers, sub-branch managers, technicians and keymen (valve operators). The interviews with NUWA staff of all grades were particularly useful, since the record drawings, when available, were often tender drawings. Some of these drawings were unreliable since, due to difficulties in procuring the specified pipes, the type and diameter of some principal mains were different from those shown on the drawings.

All the major components of the primary distribution system, given in Figure C.5.1, were extensively verified by NUWA during July and August 1990 under the supervision of JICA Study Team. The field verification was carried out at various key locations by digging trial pits and recording pipe and pipe-junction details. The status of key valves at the major pipe junctions were also verified.

The data collected was categorized into three sections comprising Node Data, Pipe Data and Source Data for the network model. Figure C.5.2 represents the network model formulated from the general plan.

#### 5.1.1 NODE DATA

The Node Data comprised of a Node Number, Sub Branch, Location and Ground Level. The complete list of Node Data for the primary distribution system is given in Table C.5.1.

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* refer to section 4.6 "inventory of distribution pipe", Appendix A.

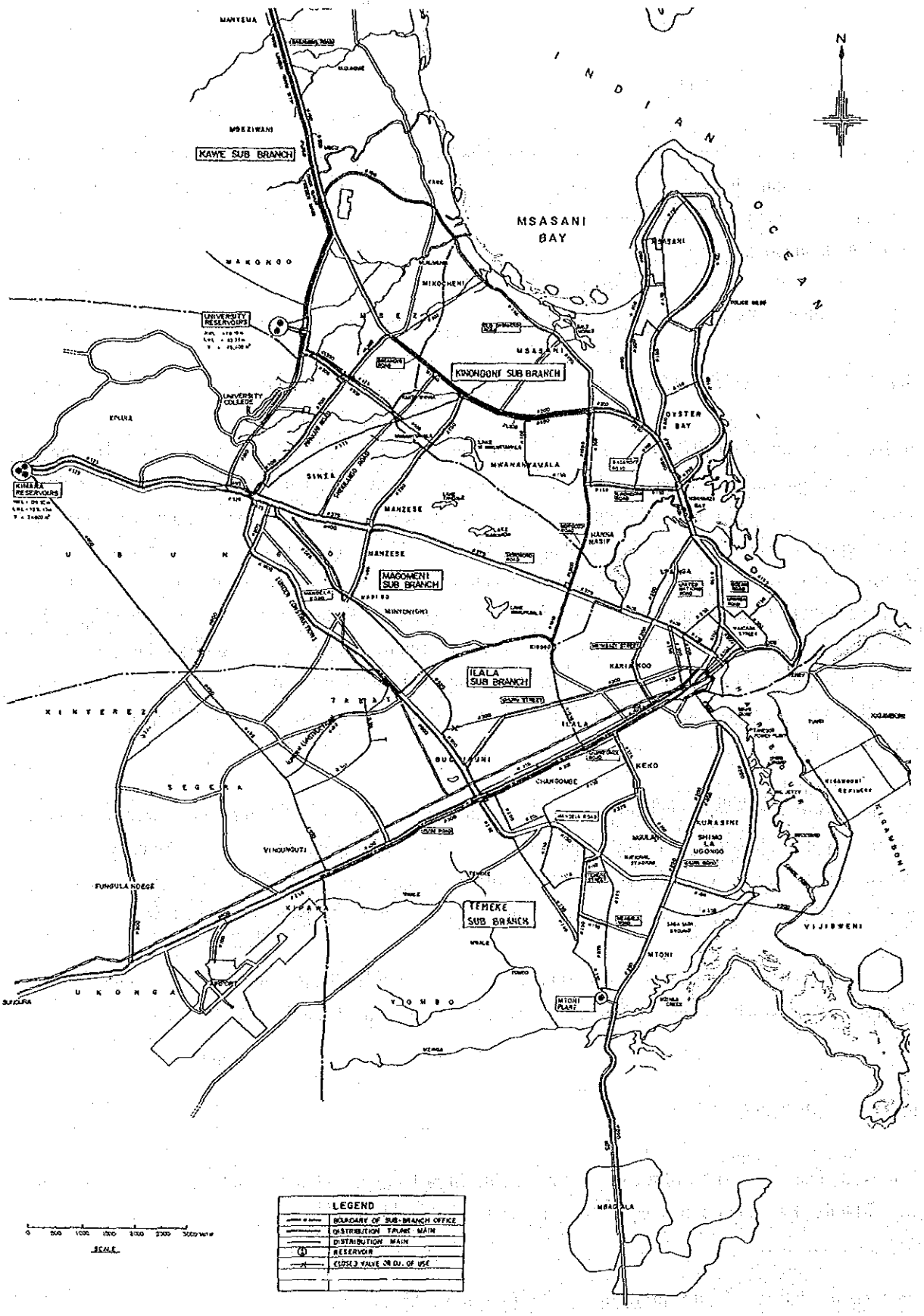


FIG. C.5.1 GENERAL PLAN FOR WATER SUPPLY SYSTEM

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

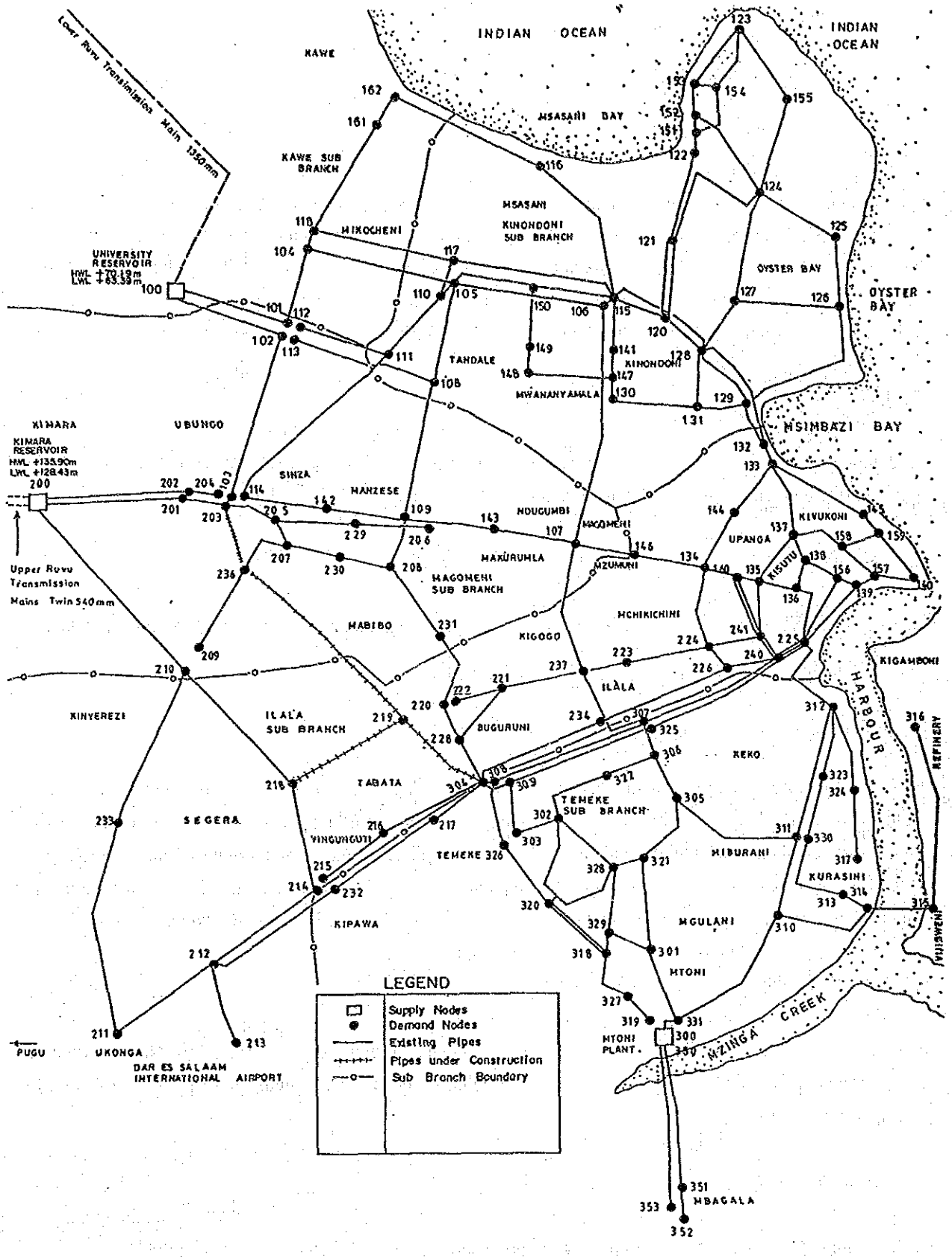


FIG. C.5.2 NETWORK MODEL FOR HYDRAULICK ANALYSIS

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

(1) Node Number

A unique number was assigned to each node in order to identify the node for hydraulic analysis. For convenience, the 100 series of node numbers were allocated to those nodes served by the University reservoir. Similarly the nodes served by Kimara reservoir were allocated the 200 series and Mtoni source nodes by the 300 series. The series were based on regional location of the nodes, since system hydraulics were not clarified at this stage. A total of 135 nodes are required in order to adequately represent the network model for the primary water distribution system of Dar-es-Salaam.

(2) Sub Branch

This information identifies the location of a node within one of the five NUWA sub branches namely Ilala, Kawe, Kinondoni, Magomeni or Temeke.

(3) Location

The location is the area within which the node is sited, based on ward and location names of Dar-es-Salaam.

(4) Level

The ground level at each node, in metres above mean sea level (m msl) was obtained from 1:2500 scale maps, marked with 2 metre interval contours, covering the entire Dar-es-Salaam area. The maps were prepared from aerial photographs of the Topographical Survey of Dar-es-Salaam, which was carried out in August 1981. Where available, pipe section drawings were also used. The ground levels ranged from 3 metres in the coastal node locations to 126.5 metres at Kimara reservoir.

5.1.2 PIPE DATA

The basic pipe data obtained for each pipe section comprised the length, diameter, date laid and pipe or lining material. The pipe data, given in Table C.5.2, consists of the following data for each of the 186 pipe sections defined.

(1) From Node

Node number identifying the origin node of a pipe section.

**(2) To Node**

Node number identifying the destination node of a pipe section.

**(3) Length**

Length of the pipe section (metres) is obtained from 1:20000 scale maps of Dar-es-Salaam. Where available, pipe section drawings giving the appropriate chainages were used. Some section lengths were verified using the 1:2500 scale maps of the Topographical Survey. The total length of the primary distribution system mains is 237 km.

**(4) Diameter**

Pipe diameters (millimeters) were obtained from available record drawings and verified by trial diggings and interviews with NUWA staff. The pipe diameters of the primary distribution system range from sections of 75 mm galvanized steel pipe to 1350 mm sections of pre-stressed concrete and steel pipes.

**(5) Date Laid**

The approximate date of commissioning of the pipe sections were based on information obtained from record drawings, previous reports and interviews with NUWA staff. These dates range from new, 1990, trunk mains to the original, 1953, pipe distribution system.

**(6) Age 1990**

The age of the pipe, as of 1990, was used to enable an assessment of the hydraulic condition of the pipe to be made. This includes estimates for the pipe roughness coefficients (Hazen-Williams C-value) of all pipes. The age of pipes in the system ranges from 0 to 39 years.

**(7) Pipe/Lining Material**

The pipe material for unlined pipes or the lining material of pipes was obtained from record drawings, interviews with NUWA staff and pipe samples. This information, together with the age of the pipe, is used to obtain initial, uncalibrated, estimates of the pipe C-value. In general, the older mains of the primary distribution system are predominantly unlined cast iron pipes, while the newer mains are steel pipes with bitumen lining and ductile iron pipes with cement mortar lining. The larger, greater than 400 mm, diameter mains are mostly either pre-stressed concrete pipes or steel pipes with bitumen

lining.

### 5.1.3 SOURCE DATA

The three sources of potable water for Dar-es-Salaam comprise reservoirs located at the University and Kimara with a small contribution from the pumped source at Mtoni. The location, type, capacity and operating levels of the sources are given in Table C.5.3. The reservoirs at the University and Kimara represent the principal sources of water for the city. Water gravitates from the reservoirs into the city distribution system.

**(1) University Reservoir**

University reservoir, with a total storage capacity of 45,400 $m^3$ in two equal compartments, is supplied, on average, with about 176,000 $m^3$/day from the Lower Ruvu treatment plant.

**(2) Kimara Reservoir**

Kimara reservoir normally has a total working capacity of 34,000 $m^3$ made up of two 8,000 $m^3$ tanks and one 18,000 $m^3$ tank. Both the smaller tanks are currently being rehabilitated. Kimara is currently supplied with 10,000 $m^3$/day from the Upper Ruvu treatment plant. Following rehabilitation of the plant and the transmission mains, the inflow to Kimara is expected to increase to about 50,000 $m^3$/day.

**(3) Mtoni Source**

Mtoni water treatment plant currently produces 6,800 $m^3$/day which is pumped into the southern distribution system of the city and to Mbagala in the south. The supply from Mtoni is intermittent since the treatment plant has deteriorated in recent years.

## 5.2 DEMAND ALLOCATION *

Following the analysis of water demand, the ward totals for each consumer group were obtained separately. These ward totals were distributed to the relevant nodes based on the population density maps of each ward and the location of each node. Major industrial, institutional and commercial consumers, with an average daily consumption of more than 10 $m^3$, were separated and their allocation to nodes were based on their proximity to the nodes. Domestic consumption and industrial, institutional and

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* refer to section 1 "water demand", Appendix A.

commercial consumers with average daily totals of less than 10 $m^3$ were allocated to nodes based upon a ward percentage contribution for each node.

### 5.2.1 MAJOR CONSUMERS

The large consumers consumption is given in Table C.5.4, and the allocation of demand to nodes for large consumers is given in Table C.5.6. A total of 34 major consumers, served by the city distribution system, were identified and their consumption totals allocated to one or two nodes. The allocation was determined using a 1:20000 scale map of the city with all major consumers and the network model marked. The percentage contribution to one or more nodes was then obtained based on the proximity and service connection details of the major consumer from the nodes. Table C.5.4 lists the name of each major consumer, the type of consumer (Industrial, Institutional or Commercial) and the location based on ward number and the average daily consumption. The percentage of the total contributing to each node and the node total value are also given in Table C.5.6.

The total demand for major consumers is 3,249 $m^3$/day with 1,904 $m^3$/day required by industry, 825 $m^3$/day for institutions and 520 $m^3$/day for commercial consumers. These totals represent the major consumption for 1990 and do not include leakage.

### 5.2.2 DOMESTIC CONSUMPTION

Although all 39 wards listed in Table C.5.5 would normally be supplied by the city distribution system, Pugu (ward No. 102) and Yombo Vituka (ward No. 209) are not currently being supplied due to the lack of water, pressure and adequate secondary pipework to these wards. The remaining 37 wards are totally supplied from the distribution system.

The total domestic consumption for Dar-es-Salaam is 111,056 $m^3$/day. The figures given in Table C.5.5 represent the total unsuppressed domestic, industrial, institutional and commercial consumption for the current population of Dar-es-Salaam and does not include leakage.

The allocation of the ward totals to a group of nodes was based on 1:20000 scale enumeration maps of the wards which were supplied in August, 1990 by the Census Office in Dar-es-Salaam. Each enumeration cell in a ward represents a population of about 400. These cell locations and node contribution boundaries were used to apportion the percentage contribution of wards to individual nodes. The ward percentage and total for each node is given by columns A and E of Table C.5.6. The ward contributions for each node, column F of Table C.5.6, were then summed to obtain the node total, column G of Table C.5.6, of domestic consumption for each node.