THE STUDY ON WATER SUPPLY FOR SEVEN TOWNS IN EASTER PROVINCE IN THE REPUBLIC OF KENYA

APPENDIX N

ANALYSIS OF PRIORITIZED SUPPLY AREA

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1. GENERAL

The study area for each town covers a wide area, particularly in Meru and Tigania, while supply areas of the existing water supply systems are limited to the town center. In planning distribution pipe network in these towns, it is necessary to select priority areas for future expansion. This prioritization shall be based on an evaluation of social and hygiene aspects of the area. Technical evaluation will follow thereafter. The study area may be divided into several zones, so that the treated water can be supplied to the people in an efficient and cost effective manner. Each distribution zone will have a sufficient capacity of one or more storage reservoirs. It is, however, difficult to look into the social and hygiene aspects particularly when the relevant data are not available for smaller units of administrative boundary, for instance, by sublocation. The Public Awareness Survey on Water Use and Sanitary Education carried out under the current study provides various data of households on water sources, water use practice and sanitary conditions as detailed in Supporting Report - I of the Interim Report. Utilizing these data by survey blocks (500 m x 500 m, 4 - 5 households surveyed for each survey block), prioritization of the area is carried out to maximize social benefits and achieve cost effectiveness of the water supply system.

2. DEFINITION

It is apparent that a cost effective solution is not necessarily optimal when all aspects considered. Social needs or urgency of the project shall be first assessed. The word "urgency" implies a degree of the urgency for the piped water supply to be provided. For computation purpose, we assumed that the urgency is expressed as functions of the water supply conditions whether served or not by piped water supplies, water scarcity particularly in dry seasons, sanitary conditions, and public opinion of the current water supply services.

To select priority areas for future expansion (Phase 1, 2000-2005), we further evaluate the planned distribution pipe network (for the target year 2010) from the view points of 1) construction cost, 2) unit cost and 3) reliability.

3. GENERAL APPROACH AND METHODOLOGY

3.1 Data Utilized for Analysis

Various data on households' generals, water sources, water use practice, health and hygienic aspects and income level are available from the Public Awareness Survey. The Survey was carried out at each survey block (500m x 500m for all towns except Nkubu where 250m x 250m block is applied) which contains 4 or 5 households interviewed. To identify social aspects and hygiene conditions of the area, these data by survey block were considered most useful. For analysis purpose, they are averaged by block to reduce effects of abnormalities and extreme figures of the households.

3.2 Factors Considered

Four key factors are considered relevant to the urgency or needs of piped water supply. They are 1) percentage of population to the total, who are not supplied by Ministry Water Supplies and Community Water Supply Schemes (or unserved ratio to the total population), 2) water scarcity during dry season (or severity of water shortage affecting population), 3) health conditions and 4) public view on water supply services which are explained below;

(1) Unserved Ratio to the Total Population

The Government of Kenya has a policy to supply potable water to whole nationals by the year 2000. Although many community water supply schemes have been extensively developed throughout the country, nearly a half of the population in the study area still cannot have any access to the piped water.

The target, although seemingly hard to attain under the current circumstances, aims to save people from hard tasks to collect water from the river. These unserved population shall be minimized as early as possible.

(2) Severity of Water Shortage in Dry Season

During dry season, water shortage becomes worse. Many population, even customers of the Ministry water supply and community water supply schemes cannot get water easily from their pipes due to a significant decrease in water production. People who are depending on river water are most miserable. As detailed in Supporting Report I, they normally collect water 4 times a day from their sources, far enough 2-4 km from their residences. These tasks are being undertaken by women and children. They spend many hours merely for water collection. Early provision of safe and clear water through pipe networks may save these people from their heavy burden, creating much time to be spent for other beneficial activities and enhancing social welfare.

(3) Health Conditions

A provision of safe and clean water will significantly benefit on improvement of living environment and accordingly public health as seen in many developing countries. The Public Awareness Survey indicated that almost all households in the area, despite poor and rich, are suffering from water related diseases. This situation shall be immediately overcome by providing safe water to those people who are heavily affected by such diseases.

(4) Public View on Water Supply

Many customers of Ministry W/S and Community W/S schemes in the study area are not necessarily satisfactory to the water supply services, due to frequent water rationing, low pressure, poor quality of water and slightly delayed customer services. To supply water continuously to the area where the majority of the households are unsatisfactory will benefit on obtaining public understanding and support.

3.3 Evaluation from Water Supply Efficiency

It is often the case that the area, despite urgency of the piped water supply, is located far from the major project facilities. In that case, a huge amount of costs is required to construct distribution facilities. They are no longer cost effective in terms of unit cost (/m3). Further, location and number of storage reservoirs are decisive factors in supplying water on continuous basis. In case of serious water shortage, water production is inevitably decreased to a certain critical level which may not be sufficient to meet water requirement. Accordingly, customers who resided on the edge of the supply area cannot receive water as they want. From this technical point of view, it may be most proper to construct reliable and cost effective facilities throughout the service area.

3.4 Prioritization of Area

In the course of the selection process, all above shall be evaluated equally. To this end, the following steps are undertaken.

1) Quantification of social factors
2) Summation of social factors and ranking
3) Mapping of urgency areas
4) Supply planning for 2010 (project facilities and funds requirement)
5) Definition of supply efficiency factors
6) Quantification of supply efficiency factors
7) Evaluation and selection of priority areas

4. QUANTIFICATION

4.1 Social Aspects

Quantification of social factors is tentatively made assuming following conditions;

(1) Social factors can be expressed as a combination of 4 variables; (1) percentage of population who are not served by Ministry and community water supply schemes, (2) health conditions, (3) severity of water shortage during dry season and (4) public view on water supply.

$$Sf = f1 \times User^j + f2 \times Sev^j + f3 \times He^j + f4 \times Unsf^j$$

Whereas,

Sf^j: an integrated social factor at the survey block j

j: Survey block number

f1, f2, f3 and f4: coefficient

$User^j$: percentage of population who are not served by Ministry and Community W/S schemes to the total

Sev^j: severity of water shortage in dry season

He^j: health conditions of the people

$Unsf^j$: public view on water supply

(2) Data obtained from the Survey are representative values for each survey block. The survey blocks applied for the Public Awareness Survey (PAS) are valid for the present analysis.

(3) Unserved ratio are estimated in the following equation;

$$User^j = 1 - (a^j / b^j)$$

Whereas,

a: number of households who receive water from Ministry Water Supply and/or Community water supply schemes in the survey block j,

b: total number of households questioned in the PAS in the same block j.

(4) Severity of water shortage during dry season is calculated as follows;

$$Sev^j = Ave^j (D_k \times F_k \times T_k) / Max^i(Sev)$$

whereas,

Sev^j: Severity of water shortage

i: Town

k: a household surveyed,

D: Distance to collect water (minutes)

F: Frequency of water collection (times/day)

T: Times missing water (days/month)

Ave^j: Average in the block j,

Max^i: maximum in the town i

(5) Health conditions in the area are expressed as the following equation;

$$He^j = Ave^j (Ds_k \times Kn_k) / Max^i(He)$$

whereas,

He^j: Health condition factor in the block j,

Ds_k: number of water related diseases affecting the family k

Kn_k : knowledge of water related diseases of the household k, Yes: 2, No: 1

(6) Public view on water supply is supposed to be expressed as follows;

$$Unsf^j = Y^j / b^j$$

whereas,

$Unsf^j$: public view factor,

Y^j: number of households who replied unsatisfactory in survey block j,

b^j: total number of huoseholds inquired in the PAS in the same block j.

4.2 Water Supply Efficiency

Supply efficiency is supposed to be a function of cost, unit cost and reliability. In calculating the supply efficiency, followings are assumed for simplification;

(1) Population in any survey blocks are of similar size, therefore population density is also same among the survey blocks.

(2) Per capita consumption is similar among the survey blocks and water requirement at each survey block are also same.

(3) Reservoirs to be constructed in the planned distribution pipe network has a similar size and a storage capacity. In other word, areas and consumers served from the reservoir are same in size and number.

(4) Construction cost required for pipeline installation is proportional to pipe diameter which are expressed as function of square root of water demand. T he cost is further proportional to pipeline length required from the treatment works to the block considered.

Based on the above assumption, cost and cost effectiveness are computed in the following equation.

(1) Cost

$$C^j = c \times Dt^j \times Dm^{\wedge}(1/2)$$

whereas,
C^j : cost,
c:Coefficient to estimate construction cost, tentatively assumed as 1.0.
Dt^j: pipeline length required from the treatment plant to the block
Dm: Water demand, tentatively assumed as 1.0.

(2) Cost Efficiency

$$Uc^j = c \times Dt^j \times Dm^{(1/2)}/Dm$$

whereas,
Uc^j : unit cost per demand
c: coefficient to estimate construction cost, tentatively assumed as 1.0.
Dt^j: pipeline length required from the treatment plant to the block
Dm: Water demand, tentatively assumed as 1.0.

From the equations above, it is easily understood that the unit cost factor has a same value as the cost factor.

(3) Reliability

In case of water shortage, water production may decrease to a critical level. Storage reservoirs near the treatment plant may have no serious effect on water distribution because they usually receive abundant water more than the required. If the water production is decreased, they can easily adjust the flow rate by decreasing water transmission to the reservoirs located downflow. From this technical point of view, reservoirs on the edge of the supply area cannot receive sufficient water. Therefore, reliability of water supply was supposed to be expressed in the following equation;

$$Rl^j = Rs^j$$

whereas,
Rl^j : Reliability
Rs^j : Numbers of service reservoirs subordinate to the area

5. EVALUATION METHOD

5.1 Social Factor

In our analysis, all coefficients, f1, f2, f3 and f4 are supposed to be 1.0 for simplification. From the computed value of the factor, all blocks are grouped into 8 ranks as follows:

Rank	Value	Rank	Value
1	0.0-0.5	5	2.0-2.5
2	0.5-1.0	6	2.5-3.0
3	1.0-1.5	7	3.0-3.5
4	1.5-2.0	8	3.5-40

For mapping the degree of the social factors, two groups are identified. Ranks 5 - 8 are considered as highly urgent, while ranks 1-4 are rather low in urgency.

5.2 Supply Efficiency

To achieve cost effectiveness within the limited funds, the investment cost required for construction of distribution facilities and social factors estimated are first brought into focus. Blocks that require extremely high investment cost and unit costs are excluded from the proposed supply area. Priority areas selected are then cross-checked from a view point of reliability per unit cost. If the reliability is significantly low, such blocks are canceled. In these areas, a possibility of small scale water sources shall be further looked into as they are considered more cost effective and reliable.

6. RESULTS OF ANALYSIS

(1) Meru

Table N6-1 gives all results of analysis including the ranking of the areas in terms of social factors and supply efficiency. ***Figure N6-1*** shows the areas where the piped water supply is urgently needed. As seen in the figure, urgency of the project is serious at the outside boundary of the Ministry Water Supply. Severest areas are south-eastern division of Meru District. Within the boundary of the current Ministry Water Supply, a high level distribution zone, just north of the town center, is evaluated as urgent.

From ***Table N6-1***, it is understood that the proposed supply area for Phase I will cover such areas where the urgency of the piped water supply is identified and the cost required for construction of the distribution facilities is considered reasonable. Proposed supply area for phases 1 and 2 are given in ***Figure N6-2***.

(2) Tigania

The study area in Tigania extends to a vast area of 300 km2. Most of the southern part of the area is evaluated urgent as shown in ***Figure N6-3***. Although areas that receive water from the existing water supply system is relatively low in urgency, it is considered important to reinforce the existing water systems by the pipelines to be newly constructed under Phase 1. Proposed supply area for phases 1 and 2 are given in ***Figure N6-4***.

(3) Nkubu, Isiolo, Chuka, Chogoria and Maua

As shown in ***Figures N6-5*** to ***N6-9***, most of the study area are suffering from water shortage and evaluated highly urgent except the limited core areas of the present water supply. Due to relatively smaller areas than Meru and Tigania, all study areas are considered to be covered by Phase 1 project.

7. CONCLUSION AND RECOMMENDATION

The analysis for priority area was made from the view points of social and technical aspects. All results were further reviewed by DWEs for confirmation. From this review, it was found that the results are quite consistent with their views reflecting the actual conditions of the area.

In the course of the analysis, many assumptions were inevitably made for simplification. For an in-depth and thorough analysis to be made in the future, followings are considered important.

(1) Because of the limited number of the survey blocks in each town (20 - 25 blocks), it was difficult to map "urgency contours" in details. To this end, a sufficient number of blocks, preferably more than 50, is recommended to be surveyed in each town in the

Public Awareness Survey.

(2) It was assumed that the urgency factors can be expressed as a combination of (1) percentage of population who are not served by Ministry and Community W/S schemes to the total population, (2) Water scarcity in dry season, (3) Health condition and (4) Public view on water supply services. In view of the limited data currently available, it was further assumed that the equations given in the foregoing sections, although some are not necessarily appropriate, represent these factors. It is recommended that this kind of questionnaire survey to be carried out in the future shall be carefully designed with much attention to the analysis of the priority area.

(3) To estimate the urgency of the project in each area, it was assumed that the coefficients (or weight) of the above factors are equivalent to 1.0 without any thorough analysis. These weights, in principle, shall vary reflecting water supply conditions in the area and government's policy for water sector and public health. To look into this in further details, a Delphi method may be an effective means to obtain the most appropriate figures. This method, in a series of interviews with selected respondents, is to reach to consensus. At every interview other than the first, the respondents are informed the averaged weights obtained at the previous interview.

(4) Zonal water demand and demographic features of the area were not considered precisely in the analysis. If these data are available, re-computation might result in a slight variation in the priority areas. It is, therefore, recommended to make efforts to obtain relevant data by smaller administrative units.

TABLES

Table N6-1 Social Factor, Supply Efficiency and Evaluation, Meru

	Social Aspects						Supply Efficiency		Evaluation
Block No.	Unserved	Severity	Health	Unsatisfact.	Urgency	Rank	Cost Efficiency	Reliability/cost	
1	0.75	0.35	0.44	1.00	2.54	6	20.0	0.10	II
2	1	0.67	0.39	1.00	3.06	7	21.0	0.10	II
3	0	0.29	0.33	0.75	1.37	3	20.0	0.10	II
4	0.5	0.29	0.39	0.75	1.93	4	22.0	0.09	II
5	0	0.58	0.44	0.75	1.77	4	20.0	0.10	II
6	0.75	0.16	0.22	1.00	2.13	5	16.0	0.19	I
7	0.25	0.13	0.28	0.75	1.41	3	26.0	0.04	II
8	0.5	0.32	0.17	1.00	1.99	4	14.0	0.64	I
9	0	0.06	0.50	0.75	1.31	3	28.0	0.04	II
10	0.5	0.30	0.44	1.00	2.25	5	14.0	0.64	I
11	0.75	0.70	0.33	1.00	2.78	6	23.0	0.04	II
12	0.5	0.48	0.11	0.75	1.84	4	7.0	0.43	I
13	0.75	0.70	0.50	1.00	2.95	6	23.0	0.04	II
14	0.25	0.36	0.22	1.00	1.83	4	18.0	0.17	I
15	0.25	0.65	0.11	0.75	1.76	4	17.0	0.12	I
16	0.5	0.39	0.44	0.25	1.59	4	21.0	0.05	II
17	0	0.48	0.39	1.00	1.87	4	11.0	0.09	I
18	0.25	0.17	1.00	0.50	1.92	4	20.0	0.05	II
19	0.25	0.45	0.44	0.50	1.64	4	16.0	0.19	I
20	0.25	0.39	0.56	1.00	2.20	5	14.0	0.07	I
21	0	0.41	0.39	0.75	1.54	4	12.0	0.25	I
22	1	1.00	0.39	1.00	3.39	7	15.0	0.13	I
23	0.5	0.46	0.39	1.00	2.35	5	16.0	0.06	I
24	0.5	0.61	0.33	1.00	2.44	5	19.0	0.05	I
25	0	0.07	0.39	0.50	0.96	2	23.0	0.04	II

Note:

1) "Unserved" implies non-dependency of the population on Ministry WS and Community WS.
2) "Severity" implies degree of water shortage during dry season.
3) "Health" implies number of diseases households are suffering.
4) "Unsatisfaction" implies degree of unsatisfaction expressed by Households for the water supply services.
5) Evaluation was made as follows:
   - (i) If cost efficiency is more than 20, then it was considered costly, therefore excluded from Phase 1 supply area.
   - (ii) If the reliability factor is less than 0.5, then the blocks are excluded.
   - (iii) Then, a cross check of the priority area with the urgency area is made.

Table N6-2 Social Factor, Supply Efficiency and Evaluation, Nkubu

Block No.	Social Aspects						Supply Efficiency		Evaluation
	Unserved	Severity	Health	Unsatisfact.	Urgency	Rank	Cost Efficiency	Reliability/cost	
1	0	0.00	0.58	0.80	1.38	3	Not evaluated	Not evaluated	I
2	0	0.00	0.33	0.20	0.53	2	do	do	I
3	0	0.00	0.67	0.60	1.27	3	do	do	I
4	0	0.00	0.83	1.00	1.83	4	do	do	I
5	0.2	0.30	0.83	0.40	1.73	4	do	do	I
6	0	0.20	0.42	0.80	1.42	3	do	do	I
7	0	0.40	1.00	0.20	1.60	4	do	do	I
8	0	0.13	0.42	0.40	0.95	2	do	do	I
9	0	0.10	1.00	0.80	1.90	4	do	do	I
10	0	0.00	0.33	0.20	0.53	2	do	do	I
11	0.4	1.00	0.83	0.80	3.03	7	do	do	I
12	0.6	1.00	0.67	0.60	2.87	6	do	do	I
13	0.4	0.33	0.50	0.60	1.83	4	do	do	I
14	0	0.00	0.83	1.00	1.83	4	do	do	I
15	0	0.27	0.75	0.60	1.62	4	do	do	I
16	0.2	0.50	0.33	0.60	1.63	4	do	do	I
17	0.4	0.90	0.67	0.60	2.57	6	do	do	I
18	0.4	0.63	0.67	0.60	2.30	5	do	do	I
19	0	0.13	0.50	0.40	1.03	3	do	do	I
20	0	0.00	0.83	0.60	1.43	3	do	do	I

Note:

1) "Unserved" implies non-dependency of the population on Ministry WS and Community WS.

2) "Severity" implies degree of water shortage during dry season.

3) "Health" implies number of diseases households are suffering.

4) "Unsatisfaction" implies degree of unsatisfaction expressed by Households for the water supply services.

Table N6-3 Social Factor, Supply Efficiency and Evaluation, Isiolo

Block No.	Social Aspects						Supply Efficiency		Evaluation
	Unserved	Severity	Health	Unsatisfact.	Urgency	Rank	Cost Efficiency	Reliability/cost	
1	1	0.41	0.38	1.00	**2.80**	6	Not evaluated	Not evaluated	I
2	0.4	1.00	0.69	0.80	**2.89**	6	do	do	I
3	1	0.81	0.77	1.00	**3.58**	8	do	do	I
4	0	0.19	0.77	0.60	**1.56**	4	do	do	I
5	0	0.00	0.77	0.20	**0.97**	2	do	do	I
6	0	0.25	0.77	1.00	**2.02**	5	do	do	I
7	0	0.24	0.46	0.60	**1.30**	3	do	do	I
8	0.8	0.31	0.62	1.00	**2.72**	6	do	do	I
9	0	0.16	0.62	0.80	**1.58**	4	do	do	I
10	0	0.19	0.77	0.20	**1.16**	3	do	do	I
11	0	0.11	0.46	0.60	**1.17**	3	do	do	I
12	0	0.00	0.54	0.00	**0.54**	2	do	do	I
13	0	0.00	0.62	0.80	**1.42**	3	do	do	I
14	0.2	0.16	0.62	0.60	**1.58**	4	do	do	I
15	0	0.00	0.62	0.80	**1.42**	3	do	do	I
16	0	0.12	0.62	0.60	**1.33**	3	do	do	I
17	1	0.13	0.69	0.80	**2.62**	6	do	do	I
18	0.4	0.39	1.00	0.80	**2.59**	6	do	do	I
19	0.6	0.59	0.62	1.00	**2.80**	6	do	do	I
20	0	0.49	0.62	0.80	**1.91**	4	do	do	I

Note:

1) "Unserved" implies non-dependency of the population on Ministry WS and Community WS.

2) "Severity" implies degree of water shortage during dry season.

3) "Health" implies number of diseases households are suffering.

4) "Unsatisfaction" implies degree of unsatisfaction expressed by Households for the water supply services.

Table N6-4 Social Factor, Supply Efficiency and Evaluation, Chuka

Block No.	Social Aspects						Supply Efficiency		Evaluation
	Unserved	Severity	Health	Unsatisfact.	Urgency	Rank	Cost Efficiency	Reliability/cost	
1	0.4	0.25	0.20	1.00	1.85	4	2.0	1.00	I
2	0	0.17	0.80	0.80	1.77	4	4.0	0.50	I
3	0.2	0.40	0.65	1.00	2.25	5	6.0	0.17	I
4	0.2	0.38	0.45	0.40	1.43	3	5.0	0.20	I
5	0.8	0.44	0.50	1.00	2.74	6	5.0	0.20	I
6	0.4	0.58	0.30	1.00	2.28	5	6.0	0.17	I
7	0.6	0.56	0.60	0.60	2.36	5	7.0	0.14	I
8	0.8	0.38	0.45	1.00	2.63	6	8.0	0.13	I
9	0	0.08	0.30	0.80	1.18	3	7.0	0.14	I
10	0	0.42	0.60	1.00	2.02	5	9.0	0.11	I
11	1	0.50	0.20	1.00	2.70	6	8.0	0.13	I
12	0.4	0.40	0.45	1.00	2.25	5	11.0	0.09	II(I)
13	1	0.56	0.45	0.80	2.81	6	9.0	0.11	I
14	0.8	0.35	0.30	1.00	2.45	5	10.0	0.10	I
15	1	1.00	0.30	1.00	3.30	7	13.0	0.08	II(I)
16	1	0.98	0.50	1.00	3.48	7	12.0	0.08	II(I)
17	1	0.60	0.30	1.00	2.90	6	13.0	0.08	II(I)
18	1	0.75	0.40	0.80	2.95	6	15.0	0.07	II(I)
19	1	0.60	1.00	1.00	3.60	8	14.0	0.07	II(I)
20	1	0.58	0.50	0.60	2.68	6	14.0	0.07	II(I)

Note:

1) "Unserved" implies non-dependency of the population on Ministry WS and Community WS.

2) "Severity" implies degree of water shortage during dry season.

3) "Health" implies number of diseases households are suffering.

4) "Unsatisfaction" implies degree of unsatisfaction expressed by Households for the water supply services.

Table N6-5 Social Factor, Supply Efficiency and Evaluation, Chogoria

Block No.	Social Aspects						Supply Efficiency		Evaluation
	Unserved	Severity	Health	Unsatisfact.	Urgency	Rank	Cost Efficiency	Reliability/cost	
1	0	0.22	0.63	0.00	**0.85**	**2**	**2.0**	**3.00**	I
2	0	0.17	0.38	0.80	**1.35**	**3**	**5.0**	**1.20**	I
3	0	0.10	0.63	0.60	**1.33**	**3**	**1.0**	**3.00**	I
4	0.2	0.26	0.56	0.80	**1.82**	**4**	**9.0**	**0.67**	I
5	0	0.16	0.50	0.60	**1.26**	**3**	**7.0**	**0.86**	I
6	0.6	0.33	0.88	0.20	**2.00**	**5**	**4.0**	**0.75**	I
7	0	0.14	0.63	0.40	**1.16**	**3**	**10.0**	**0.20**	I
8	0	0.05	0.63	0.80	**1.48**	**3**	**14.0**	**0.14**	I
9	0.2	0.07	0.63	0.20	**1.09**	**3**	**12.0**	**0.17**	I
10	0	0.14	0.63	0.80	**1.56**	**4**	**15.0**	**0.13**	I
11	0.6	0.88	0.56	0.60	**2.64**	**6**	**18.0**	**0.06**	I
12	0.2	0.31	0.50	0.20	**1.21**	**3**	21.0	0.05	II
13	0.2	0.34	0.88	0.80	**2.22**	**5**	24.0	0.04	II
14	0.4	0.55	0.69	0.80	**2.44**	**5**	**17.0**	**0.18**	I
15	0.2	0.14	0.44	0.80	**1.58**	4	**18.0**	**0.17**	I
16	1	1.00	0.63	1.00	**3.63**	**8**	**17.0**	**0.12**	I
17	1	0.62	0.63	1.00	**3.25**	**7**	**19.0**	**0.11**	I
18	1	0.90	0.75	1.00	**3.65**	**8**	**18.0**	**0.11**	I
19	1	0.48	1.00	1.00	**3.48**	**7**	21.0	0.05	I
20	1	0.62	0.63	1.00	**3.25**	**7**	23.0	0.04	I

Note:

1) "Unserved" implies non-dependency of the population on Ministry WS and Community WS.

2) "Severity" implies degree of water shortage during dry season.

3) "Health" implies number of diseases households are suffering.

4) "Unsatisfaction" implies degree of unsatisfaction expressed by Households for the water supply services.

Table N6-6 Social Factor, Supply Efficiency and Evaluation, Maua

	Social Aspects						Supply Efficiency		Evaluation
Block No.	Unserved	Severity	Health	Unsatisfact.	Urgency	Rank	Cost Efficiency	Reliability/cost	
1	0	0.20	0.36	0.40	0.96	2	Not evaluated	Not evaluated	I
2	0.4	0.19	0.18	0.80	1.57	4	do	do	I
3	0.6	0.26	0.82	0.80	2.48	5	do	do	I
4	1	0.72	0.64	1.00	3.35	7	do	do	I
5	1	0.74	1.00	1.00	3.74	8	do	do	I
6	0	0.11	0.45	0.60	1.16	3	do	do	I
7	0.6	0.24	0.55	0.80	2.18	5	do	do	I
8	0.6	0.41	0.18	0.60	1.79	4	do	do	I
9	1	1.00	0.55	1.00	3.55	8	do	do	I
10	1	0.33	0.55	1.00	2.88	6	do	do	I
11	0	0.20	0.36	0.40	0.96	2	do	do	I
12	0.6	0.12	0.00	1.00	1.72	4	do	do	I
13	0	0.00	0.55	0.60	1.15	3	do	do	I
14	0	0.70	0.45	1.00	2.15	5	do	do	I
15	0.6	0.74	0.45	1.00	2.79	6	do	do	I
16	0	0.05	0.73	0.80	1.58	4	do	do	I
17	0	0.00	0.18	0.20	0.38	1	do	do	I
18	0.8	0.51	0.27	0.80	2.38	5	do	do	I
19	0.2	0.12	0.73	0.80	1.84	4	do	do	I
20	0.6	0.71	0.45	0.80	2.56	6	do	do	I

Note:

1) "Unserved" implies non-dependency of the population on Ministry WS and Community WS.

2) "Severity" implies degree of water shortage during dry season.

3) "Health" implies number of diseases households are suffering.

4) "Unsatisfaction" implies degree of unsatisfaction expressed by Households for the water supply services.

Table N6-7 Social Factor, Supply Efficiency and Evaluation, Tigania

Block No.	Social Aspects					Rank	Supply Efficiency		Evaluation
	Unserved	Severness	Health	Unsatisfact.	Urgency		Cost Efficiency	Reliability/cost	
1	0	0.08	0.40	1.00	1.48	3	Existing	Existing	I
2	0.25	0.26	0.80	0.75	2.06	5	do	do	I
3	1	0.34	0.60	1.00	2.94	6	do	do	I
4	0	0.18	0.80	1.00	1.98	4	do	do	I
5	0	0.17	1.00	1.00	2.17	5	do	do	I
6	0.5	0.12	0.40	1.00	2.02	5	10	0.50	I
7	0	0.31	0.60	1.00	1.91	4	Existing	Existing	I
8	0.5	0.14	0.40	0.75	1.79	4	do	do	I
9	1	0.47	0.70	1.00	3.17	7	11	0.45	I
10	0.75	0.45	0.50	1.00	2.70	6	9	0.56	I
11	0.75	0.29	0.50	1.00	2.54	6	16	0.19	I
12	1	0.13	0.80	1.00	2.93	6	22	0.14	I
13	0	0.17	0.80	0.50	1.47	3	11	0.09	I
14	1	0.39	0.80	1.00	3.19	7	21	0.14	I
15	1	0.39	0.60	1.00	2.99	6	17	0.18	I
16	0	0.16	0.60	0.50	1.26	3	11	0.09	I
17	1	0.22	0.80	1.00	3.02	7	OB	OB	OB
18	0	0.07	0.50	1.00	1.57	4	14	0.07	I
19	0.25	0.14	0.70	1.00	2.09	5	OB	OB	OB
20	0.5	0.47	0.80	1.00	2.77	6	14	0.07	I
21	0.75	0.50	0.90	0.75	2.90	6	OB	OB	OB
22	1	1.00	0.60	1.00	3.60	8	do	do	do
23	1	0.30	1.00	1.00	3.30	7	do	do	do
24	1	0.23	0.80	1.00	3.03	7	do	do	do
25	1	0.19	0.80	1.00	2.99	6	do	do	do

Note:

1) "Unserved" implies non-dependency of the population on Ministry WS and Community WS.

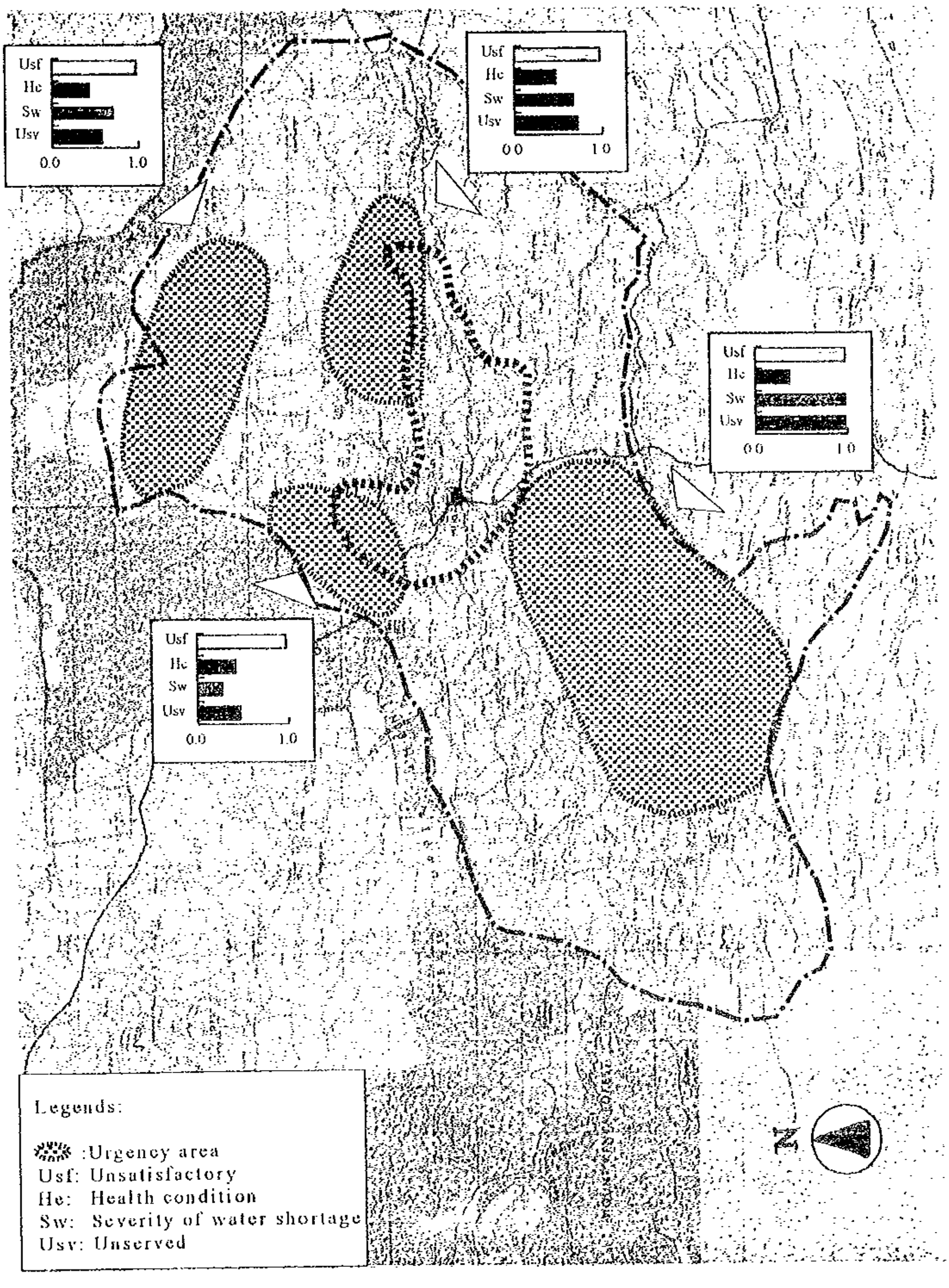
2) "Severity" implies degree of water shortage during dry season.

3) "Health" implies number of diseases households are suffering.

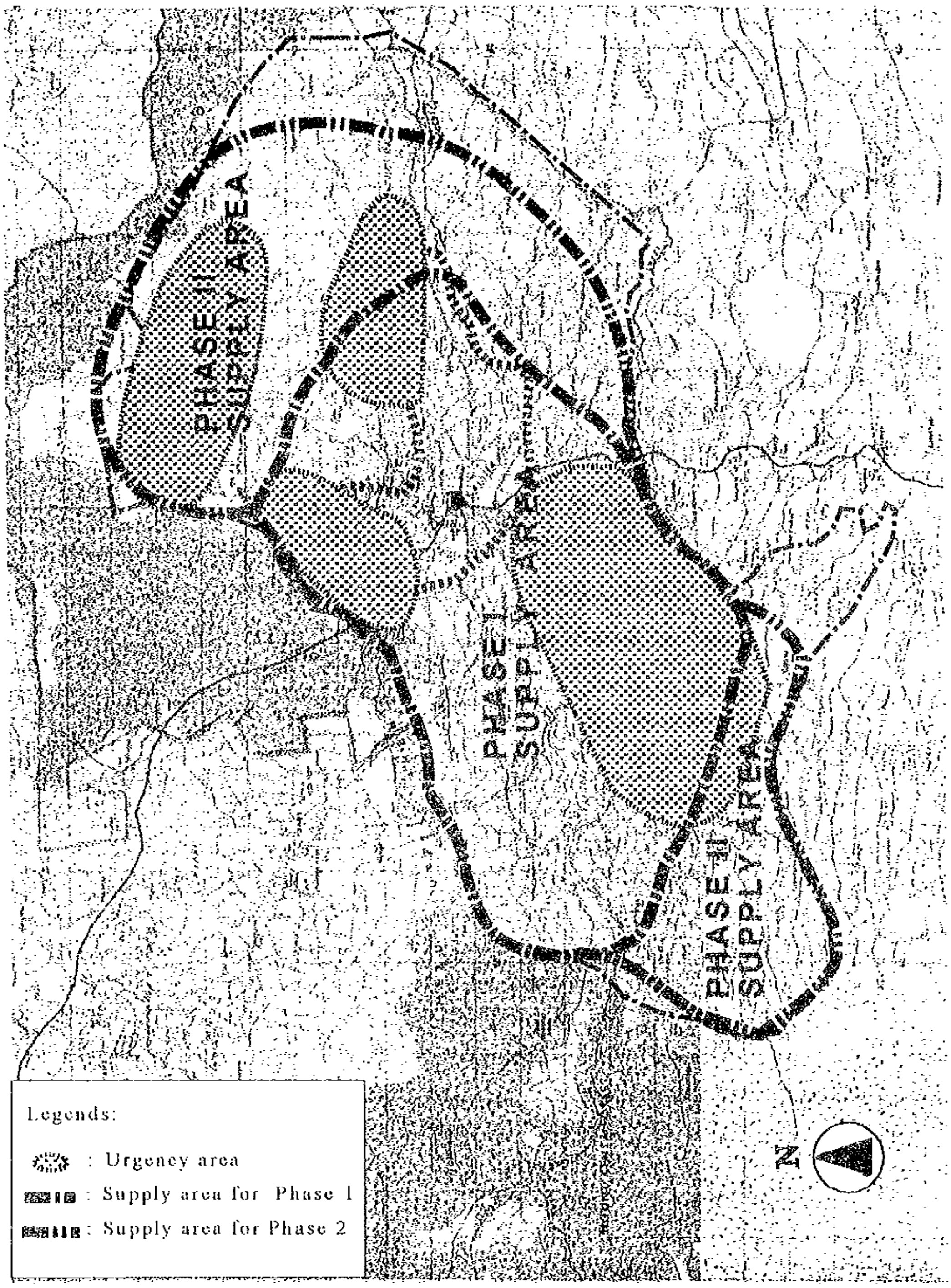
4) "Unsatisfaction" implies degree of unsatisfaction expressed by Households for the water supply services.

5) "OB" means out of supply boundary.

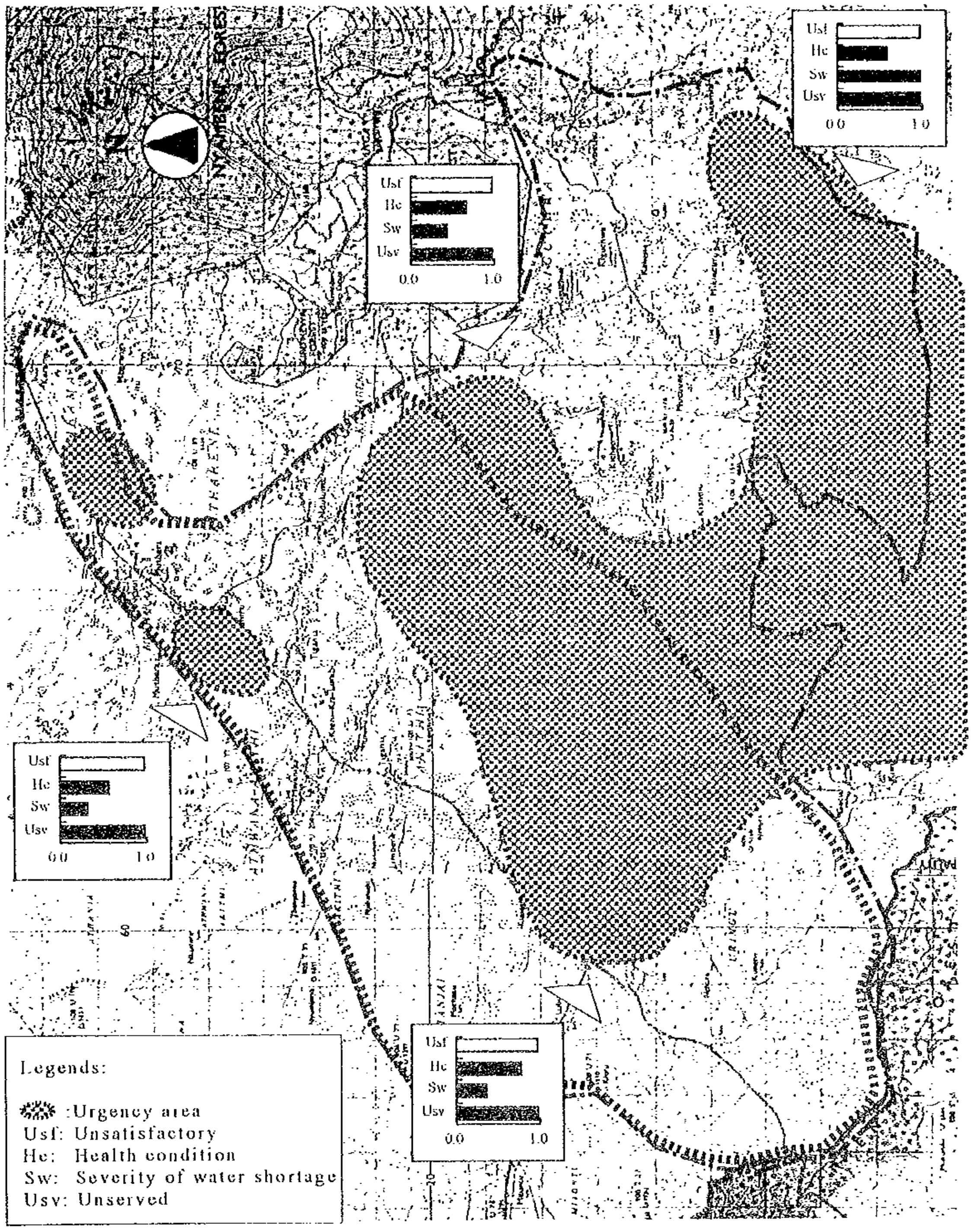
FIGURES



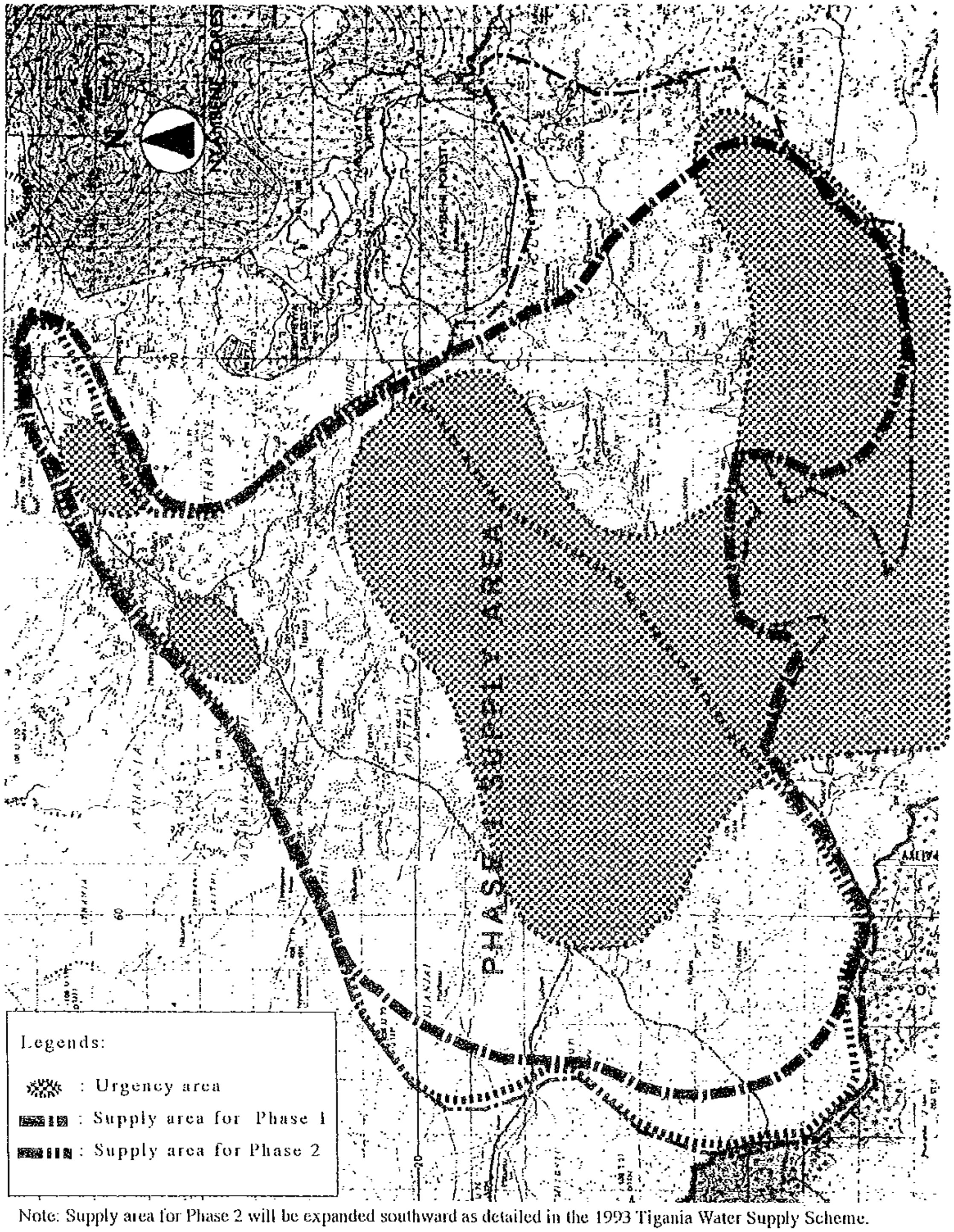
THE STUDY ON THE WATER SUPPLY FOR SEVEN TOWNS IN EASTERN PROVINCE IN THE REPUBLIC OF KENYA	Figure N6-1
JAPAN INTERNATIONAL COORERATION AGENCY	Urgency Area in Meru



THE STUDY ON THE WATER SUPPLY FOR SEVEN TOWNS IN EASTERN PROVINCE IN THE REPUBLIC OF KENYA	Figure N6-2
JAPAN INTERNATIONAL COORERATION AGENCY	**Supply Area In Meru**

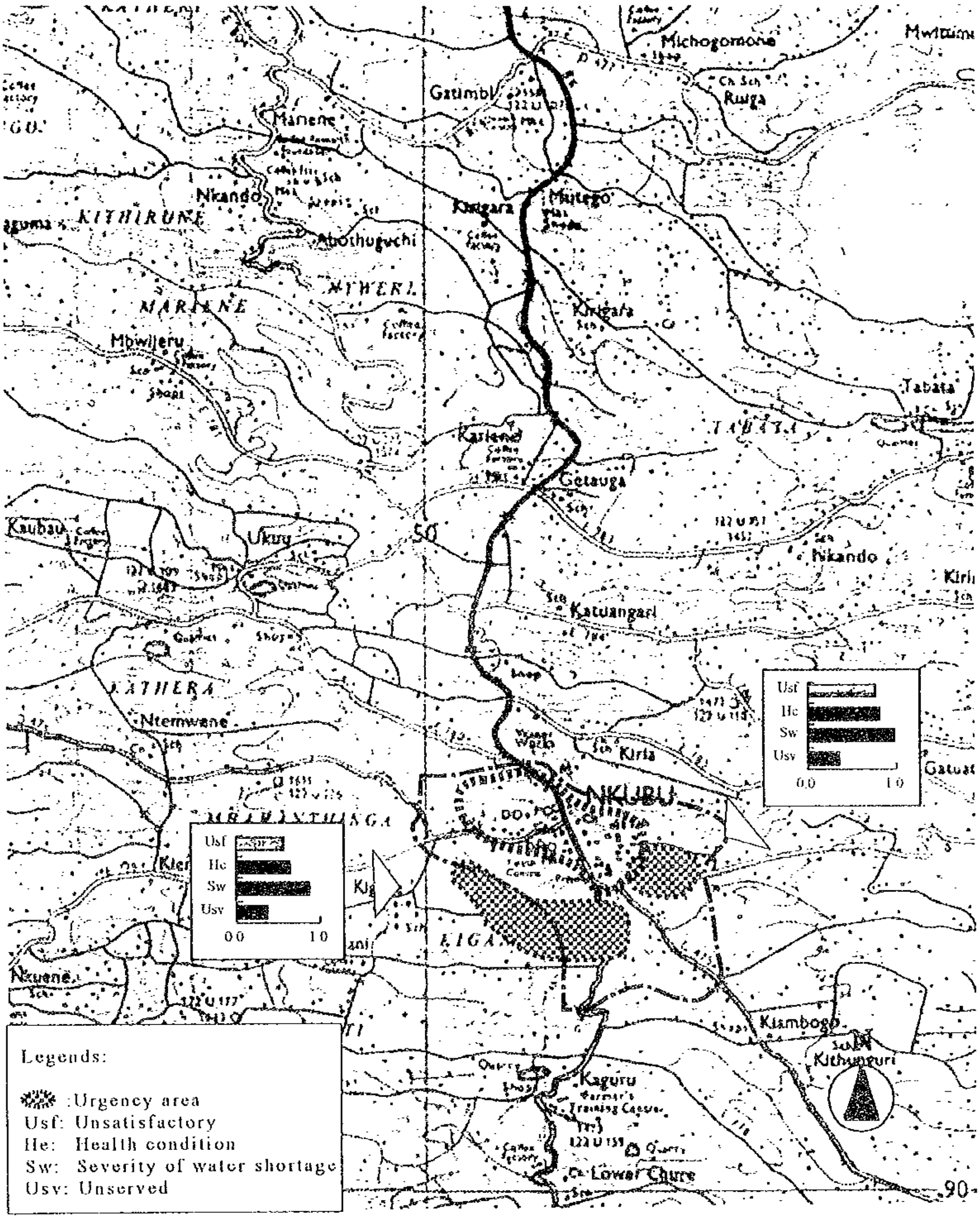


THE STUDY ON THE WATER SUPPLY FOR SEVEN TOWNS IN EASTERN PROVINCE IN THE REPUBLIC OF KENYA	Figure N6-3
JAPAN INTERNATIONAL COORERATION AGENCY	**Urgency Area in Tigania**

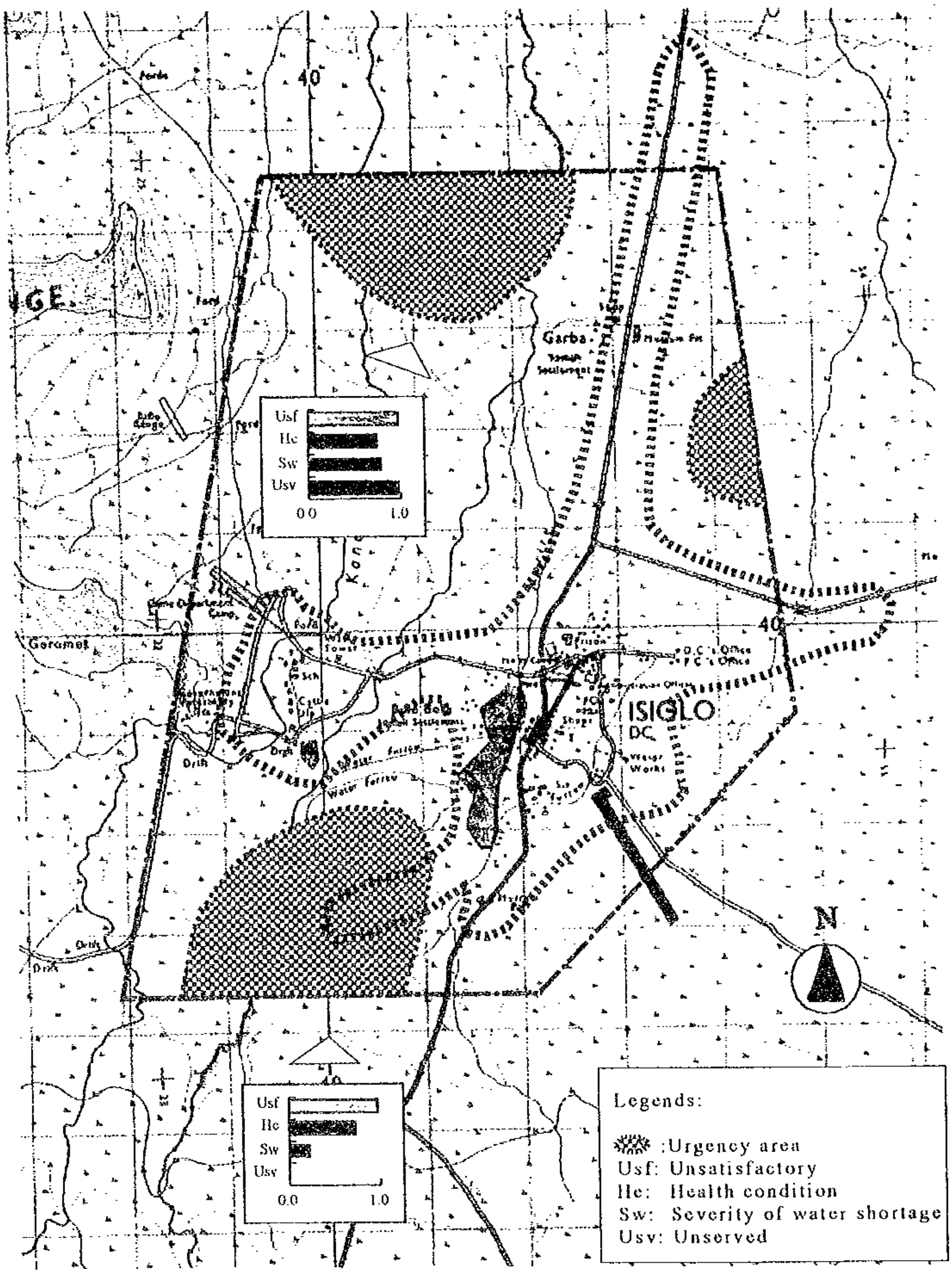


Note: Supply area for Phase 2 will be expanded southward as detailed in the 1993 Tigania Water Supply Scheme.

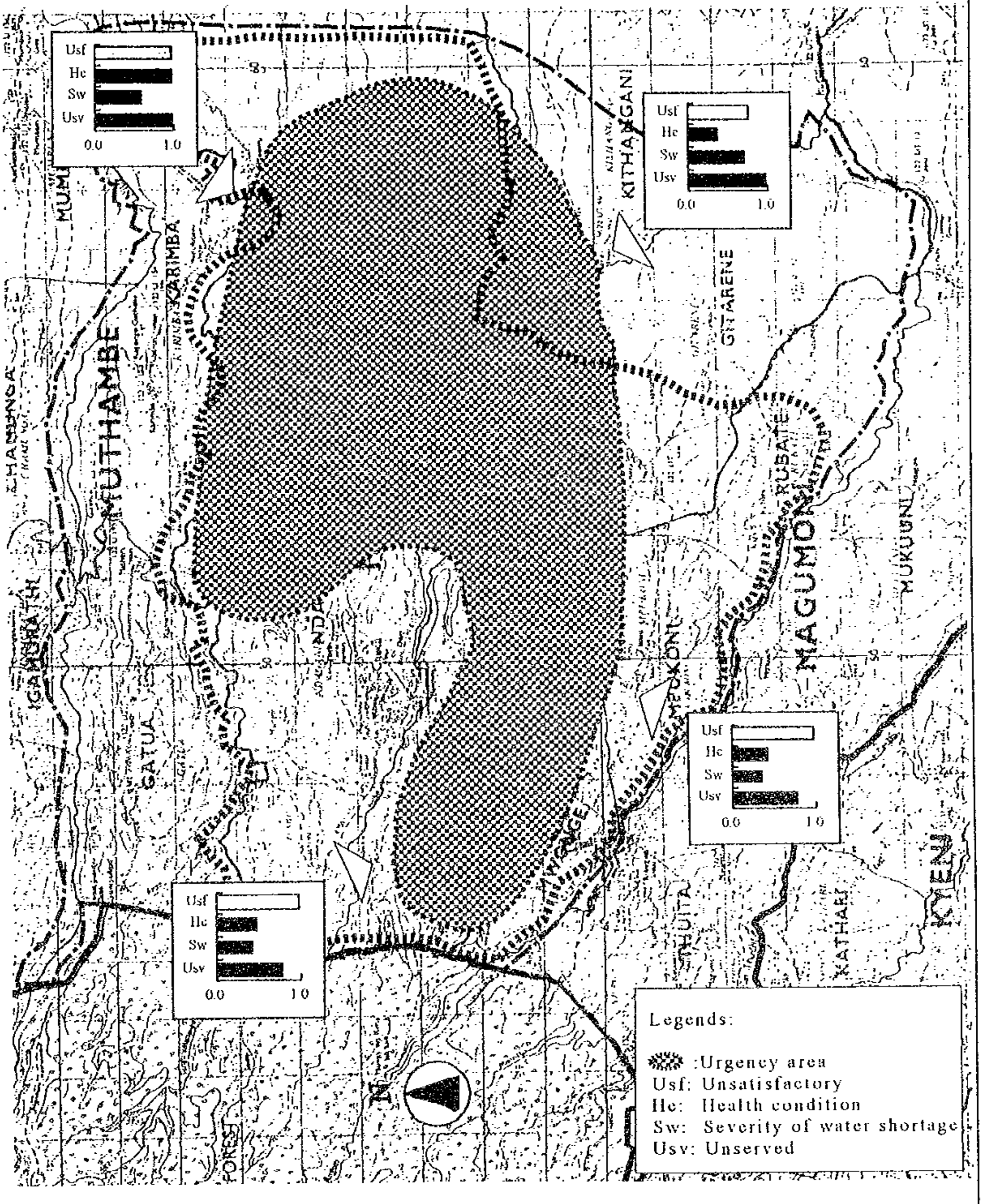
THE STUDY ON THE WATER SUPPLY FOR SEVEN TOWNS IN EASTERN PROVINCE IN THE REPUBLIC OF KENYA	Figure N6-4
JAPAN INTERNATIONAL COORERATION AGENCY	**Supply Area in Tigania**



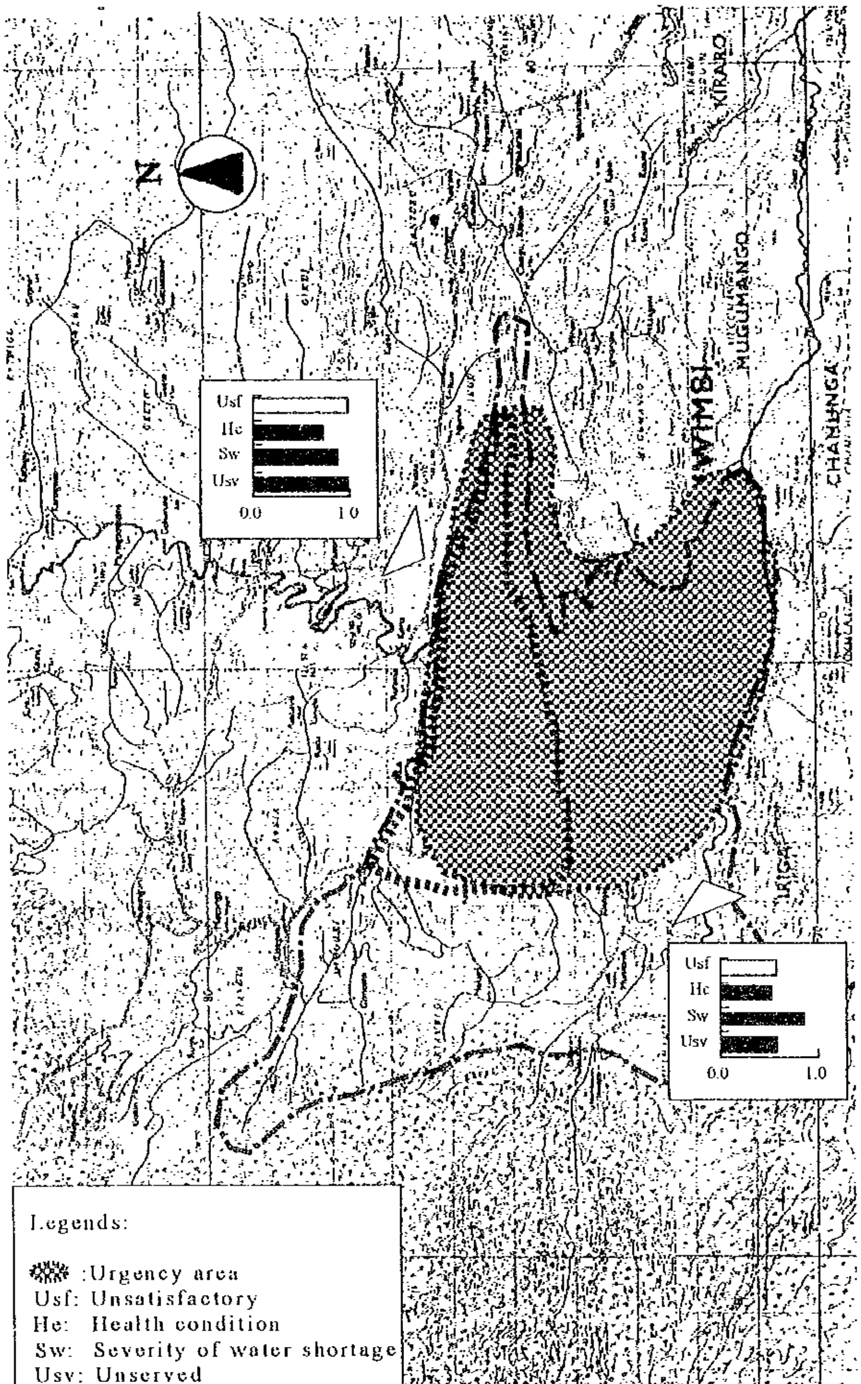
THE STUDY ON THE WATER SUPPLY FOR SEVEN TOWNS IN EASTERN PROVINCE IN THE REPUBLIC OF KENYA	Figure N6-5
JAPAN INTERNATIONAL COORERATION AGENCY	Urgency Area in Nkubu



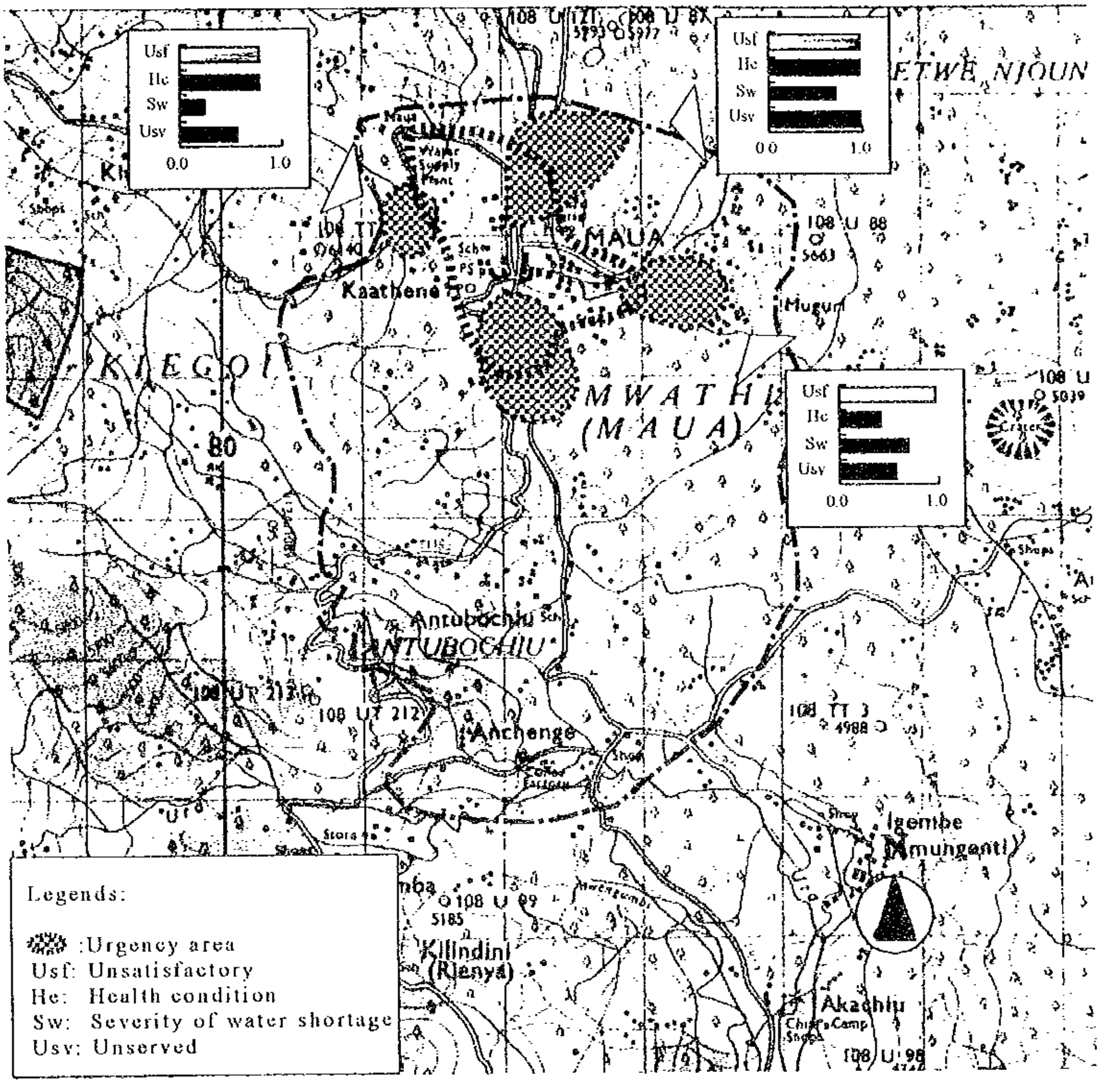
THE STUDY ON THE WATER SUPPLY FOR SEVEN TOWNS IN EASTERN PROVINCE IN THE REPUBLIC OF KENYA	Figure N6-6
JAPAN INTERNATIONAL COORERATION AGENCY	Urgency Area in Isiolo



THE STUDY ON THE WATER SUPPLY FOR SEVEN TOWNS IN EASTERN PROVINCE IN THE REPUBLIC OF KENYA	Figure N6-7 **Urgency Area in Chuka**
JAPAN INTERNATIONAL COORERATION AGENCY	



THE STUDY ON THE WATER SUPPLY FOR SEVEN TOWNS IN EASTERN PROVINCE IN THE REPUBLIC OF KENYA	Figure N6-8
JAPAN INTERNATIONAL COORERATION AGENCY	**Urgency Area in Chogoria**



THE STUDY ON THE WATER SUPPLY FOR SEVEN TOWNS IN EASTERN PROVINCE IN THE REPUBLIC OF KENYA	Figure N6-9
JAPAN INTERNATIONAL COORERATION AGENCY	Urgency Area in Maua

THE STUDY ON WATER SUPPLY FOR
SEVEN TOWNS IN EASTER PROVINCE
IN THE REPUBLIC OF KENYA

APPENDIX O

DESIGN CALCULATIONS

SYSTEM DESIGN OF TREATMENT PLANT

Flows		
Phase 1 design flow rate	10,000	m^3/d
Treatment plant design peak factor	1.1	
Plant design flow rate (10,000 x 1.1)	11,000	m^3/d
Works Inlet		
Design for future chemical mixing using a smple weir with a 300 mm fall to provide the mixing energy.		
Head over 1,000 mm wide weir	0.170	mm
Flocculation Basin		
Although not anticipated to be required, it is advisable to size the flocculation basin requirements in order to allow sufficient space at the treatment works for future construction in the event of raw water quality deterioration:		
Type of flocculation basin	Helical flow	
Velocity gradient can be manipulated by adjustment of penstocks to facilitate optimum mixing. Assume head loss of	500	mm
Choose retention period of:	30	min
Velocity gradient	45	Sec^{-1}
Corresponding GT value This is within the normally accepted range of between 20,000 and 150,000 for turbidity and colour removal (Smethurst, 1979).	81,000	
Assume depth of basin	3	m
Therefore surface area required (11,000/24/2/3)	76.4	m^2
Number of flocculation chambers	6	
Plan dimensions of chamber (l x b)	3.6 x 3.6	m

Sedimentation

Type of sedimentation basin	Horizontal flow	
Design parameters:		
Surface loading	<0.75	m/hr
Weir loading	<150	$m^3/m/d$
Inlet to be baffled to allow even flow distribution		
Minimum depth of tank at outlet	3	m
Floor of tank to slope towards inlet		
Sludge collection troughs to be provided at the inlet end of the basin		
Collecting trough	V notch weir trough	
Sludge removal	Manual flushing	
Number of basins	4	units
Minimum length/breadth ratio	3	
Required surface area (11,000/24/4/0.75)	152.8	m^2
Therefore Length $(A/3)^{.5}$	22	m
Width of basin (L/3)	6.9	m
Length of overflow weir/basin (11,000/4/150)	18	m
It is therefore necessary to use multiple weirs		
Retention above maximum sludge level (152.8 x 2.5/(11,000/4/24))	3.3	hrs

Sedimentation sludge

The low solid content of the raw water will result in long periods between cleaning and hence high solids concentration. The actual concentration is difficult to pre-judge, but can conservatively be estimated as:	2%	
Average raw water solids content	10	mg/l
Weight of sludge production per day (10,000x10/1,000/1,000)	0.1	t/d
Volume of sludge (0.1 x 100/2)	5	m^3/d
Available volume for accumulation of sludge (22 x 6.9 x 1) per tank	152	m^3
Sludge retention time (if sludge is not drawn off from the desludging valves) ((152 x 4)/5)	120	days

However hydrostatic desludging by operation of the sludge drawoff penstocks at the inlet end of the tank should be undertaken every two or three days. This will remove the majority of the sludge and extend the period for manual emptying and cleaning of the tank to a year, when annual maintenance works to the structure and its facilities can be also undertaken.

Filters

Similarly to flocculation, although filters are not required initially, it is considered prudent to size them in order to allow sufficient space at the treatment works for future construction in the event of raw water quality deterioration

Type of filter	Rapid gravity Constant rate rising level	
Filtration rate	5 m/hr	
Filter media	single media	
Effective sand size	0.8	mm
Uniformity coefficient	<1.5	
Sand thickness	750	mm
Maximum water depth	2,000	mm
Number of filter units	4	
Required bed are per unit (11000/24/4/5)	23	m^2
Length	6	m
Breadth	4	m

Clear Water Reservoir

Live storage requirement	30	mins
Dead storage for minimum chlorine contact time	10	mins
Required capacity (11,000/24/60 x 40)	305	m^3
Assume depth of water in reservoir	3.0	m
Plan area of tank (305/3.0)	102	m^2
Assume single compartment tank, therefore most economical configuration is squre, with side length of (say)	10	m

Sludge concentrators

These are not required for the first phase development but require sizing so that sufficient land will be allocated in case they may be needed in the future		
Allow for two concentrators, each with a capacity in terms of plant throughput of	30	min
Required volume per tank (11,000/24/2)	230	m3
Assume depth of tank	3	m
Required radius $(230/(Pi \times 3))^{0.5}$	4.9 (say 5.0)	m

Sludge drying beds

These are also not required for the first phase development but require sizing so that sufficient land will be allocated in case they may be needed in the future		
Bed area required for sludge drying beds, assuming previous sludge concentration	0.06	$m^2/m^3/d$
Therefore total bed area required (for average design demand)	600	m^2

Chemical Dosing	Chlorine	Alum	Lime	Units
Flow	20,000	10,000	10,000	m^3/day
Maximum dosage	2	50	5	mg/l
Dosing concentration	2%	5%	1.5%	%
Concentration in g/l	20	50	1.5	g/l
Mixing tank retention	.5	.5	.5	days
Number of mixing tanks	2	2	2	
Chemical packaging	50	50	50	kg bags
Storage of bags in piles of	4	4	4	bags high
Required storage period	90	9	90	days
Weight of chemical per day	40	500	50	kg
Mixing tank volume	2	10	3.3	m^3
Maximum dosage rate	83	417	139	l/hr
Nr of bags of chemical per day	.8	10	1	
Storage area required	3.6	45	4.5	m^2

Slow Sand Filters

Sized to obtain cost comparison with Rapid Sand Filters

Type of filter	Slow san filter	
Filtration rate	0.15 m/hr	
Filter media	single media	
Effective sand size	0.2	mm
Uniformity coefficient	<2	
Sand thickness	750	mm
Maximum water depth	2,000	mm
Number of filter units	4	
Required bed area per unit (11,000/24/4/.15)	764	m^2
Length	32	m
Breadth	24	m

MERU WATER SUPPLY PROJECT

COMPARISON OF TREATMENT PLANT OPTIONS - FILTERS

		Phase 1	Phase 2	
Development phasing		Phase 1	Phase 2	
Works capacity		10,000	20,000	m3/d
Number of treatment plant modules		4	8	units
Slow Sand Filter comparativve investment costs	Civil	1,372,083	1,372,083	US $
	E&M	72,215	72,215	US $
Rapid sand filter comparative investment costs	Civil	274,047	274,047	US $
	E&M	48,361	48,361	US $
Maintenance & repair of civil works as % of investments			1.0%	
Maintenance and repair of E&M works as % of investments			5.0%	
Design life of civil works			30	yr
Design life of E&M works			15	yr
SSF Labour requirements	Phase 1	13	Phase 2 15	staff
RSF labour requirements	Phase 1	11	Phase 2 12	staff
Average annual salary			1,000	US $

Chemicals:

	Dosage	Cost/kg	cost
	mg/l	US $	US $/m3
Alum	10	0.45	0.0045
Lime	10	0.25	0.0025

Backwash pumping rate	173.6	l/s
Backwash pumping head	10	m
Overall efficiency (including 0.8 Power factor allowance)	55.0%	
Power required	31.0	kW
Pumping time per day per filter module	12	mins
Electricity costs	0.08	US $/kWhr

Discount	Net Present Values US $ x 1,000	
Factor	SSF	RSF
12.5%	2,015	678
10.0%	2,151	766
7.5%	2,295	877
5.0%	2,438	1,021

		Slow Sand Filters					Rapid Sand Filters						
Year	Req'd Water Prod'n m3/d	Investment costs: Costs Civil US $	Investment costs: Costs E&M US $	Recurrent Costs: Maint & Repair US $	Recurrent Costs: Labour US $	Total Comp Costs US $	Investment costs: Civil US $	Investment costs: E&M US $	Recurrent costs: Maint & Repair US $	Recurrent costs: Labour US $	Recurrent costs: Chemicals US $	Recurrent costs: Power US $	Total Comp Costs US $
1997													
1998	3,194	1,372,083	72,215	17,332	13,000	1,474,630	274,047	48,361	5,159	11,000	7,096	362	346,024
1999	3,253			17,332	13,000	30,332			5,159	11,000	7,227	362	23,748
2000	3,654			17,332	13,000	30,332			5,159	11,000	8,118	362	24,638
2001	4,616			17,332	13,000	30,332			5,159	11,000	10,256	362	26,776
2002	5,589			17,332	13,000	30,332			5,159	11,000	12,417	362	28,938
2003	6,657			17,332	13,000	30,332			5,159	11,000	14,790	362	31,310
2004	7,824			17,332	13,000	30,332			5,159	11,000	17,383	362	33,903
2005	9,097	1,372,083	72,215	34,663	13,000	1,491,961	274,047	48,361	10,317	11,000	20,211	362	364,298
2006	10,482			34,663	13,000	47,663			10,317	11,000	23,288	362	44,967
2007	12,533			34,663	13,000	47,663			10,317	11,000	27,856	362	49,535
2008	14,779			34,663	15,000	49,663			10,317	12,000	32,835	723	55,875
2009	17,217			34,663	15,000	49,663			10,317	12,000	38,252	723	61,292
2010	19,861			34,663	15,000	49,663			10,317	12,000	44,126	723	67,166
2011	22,725			34,663	15,000	49,663			10,317	12,000	50,489	723	73,529
2012	22,725			34,663	15,000	49,663			10,317	12,000	50,489	723	73,529
2013	22,725		72,215	34,663	15,000	121,878		48,361	10,317	12,000	50,489	723	121,891
2014	22,725			34,663	15,000	49,663			10,317	12,000	50,489	723	73,529
2015	22,725			34,663	15,000	49,663			10,317	12,000	50,489	723	73,529
2016	22,725			34,663	15,000	49,663			10,317	12,000	50,489	723	73,529
2017	22,725	(1,143,403)	(52,958)	34,663	15,000	(1,146,697)	(228,372)	(35,465)	10,317	12,000	50,489	723	(190,308)

Intake Facilities Design

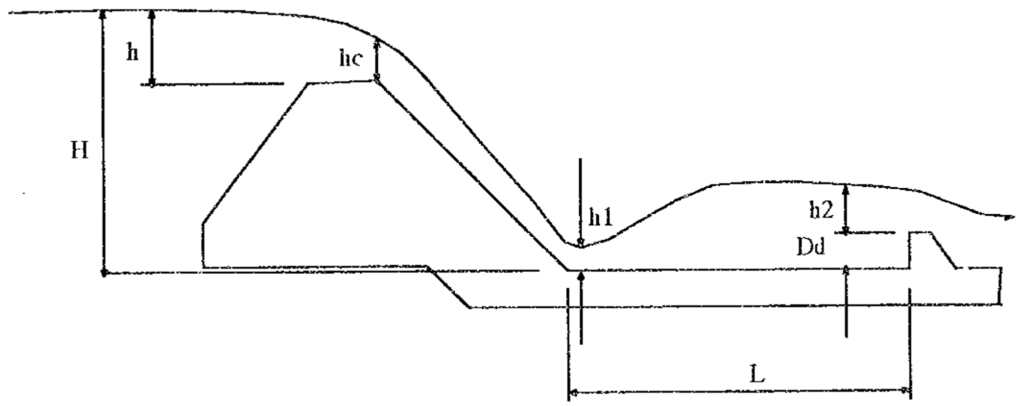
On the design of intake facilities, the following matter should be considered:

- Site investigation
- River and hydrological condition
- Topographic condition and Geological condition
- Raw water pipeline route

(1) Design condition

- Design inflow	255 L/sec (=22,000m3/day)
- Design flood volume	38 m3/sec (based on " The National Water Resources Master Plan")
- Design trapped sand size	0.2 mm

(2) Design of Settling basin



$$hc = h2 = \sqrt[3]{\frac{Q^2}{gB^2}} = \sqrt[3]{\frac{38^2}{9.8 \times 7^2}} = 1.443 \text{ m}$$

$$Vc = \frac{Q}{h_c B} = \frac{38}{1.443 \times 7} = 3.762 \text{ m/sec}$$

$$h = \frac{V_c^2}{2g} + h_c = \frac{3.762^2}{2 \times 9.8} + 1.443 = 1.515 \text{ m} = 1.5 \text{ m}$$

$$h1 = \frac{Q}{0.95B\sqrt{2gH}} = \frac{38.0}{0.95 \times 7.0\sqrt{2 \times 9.8 \times 3.5}} = 0.690 \text{ m}$$

$$F1 = \frac{Q}{B\sqrt{gh1^3}} = \frac{38.0}{7.0\sqrt{9.8 \text{x} 0.690^3}} = 3.026$$

$$hj = \frac{h1}{2}\sqrt{1+8F^2} = \frac{0.690}{2} x(\sqrt{1+8x3.026^2} -1) = 2.628 \text{ m}$$

Settling basin length L:

L = 4.5 hj = 4.5 x 2.628 = 11.826 -> 12 m

Subdam height:

$$Dd = h1\left(\frac{\left(1+2F_1^{\,2}\right)x\sqrt{1+8F_1^{\,2}} - 5F_1^{\,2} - 1}{1+4F_1^{\,2} - \sqrt{1+8F_1^{\,2}}} - \frac{3}{2}F_1^{\,3/2}\right)$$

$$= 0.690 \text{ x } \left(\frac{\left(1+2\times 3.026^2\right)x\sqrt{1+8\times 3.026^2} - 5\times 3.026^2 - 1}{1+4\times 3.026^2 - \sqrt{1+8\times 3.026^2}} - \frac{3}{2}\times 3.026^{3/2}\right)$$

= 0.68m = 0.7m

(3) Design of connection pipe diameter between intake and sand trap

$$r = \sqrt{\frac{A}{\pi}}$$

where,

r : pipe diameter (m)

A : required pipe area (m2)

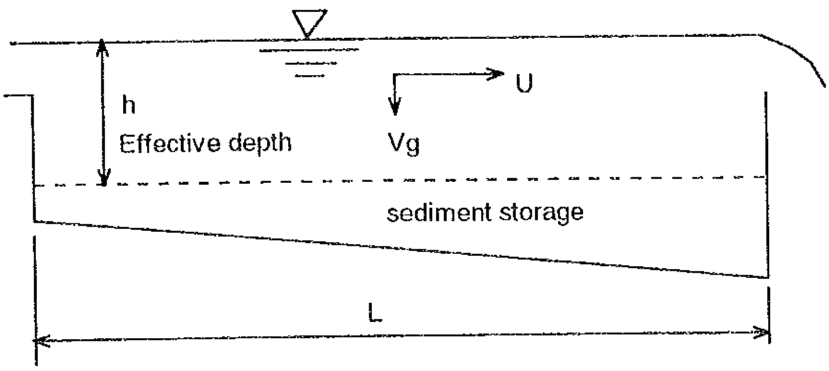
$$= \frac{Q}{V} = \frac{0.255}{0.8} = 0.3188 \text{ m2}$$

Q : design volume (= 0.255 m3/sec)

V : velocity in pipe (= 0.8m/sec)

$$= \sqrt{\frac{0.3188}{3.14}} = 0.319$$ -> 0.3m --> D = 600 mm

(4) Design of sand trap



Channel width 3 m

Channel length L

$$L = K\frac{h}{V_g}U = K\frac{Q}{BV_g} = 1.2\times\frac{0.255}{3\times0.01} = 10.2 = 10\text{m}$$

where, L: channel length (m)

K: coefficient (=1.2)

h: channel depth (=1m)

V_g : settling velocity of sand (=0.01m/sec at D = 0.2mm)

U: water velocity (=Q/Bh, m/sec)

Q: Design discharge (=0.255m3/sec)

B: channel width (= 3m)

So, sand trap dimension is 10m length x 3 m width x 1 m effective depth.

THE STUDY ON WATER SUPPLY FOR
SEVEN TOWNS IN EASTER PROVINCE
IN THE REPUBLIC OF KENYA

APPENDIX P

TRANSMISSION AND DISTRIBUTION FACILITY PLAN FOR SEVEN TOWNS

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1 GENERAL

To prepare master plan for seven towns, namely Meru, Nkubu, Isiolo, Chuka, Chogoira, Maua, and Tigania, in target year of 2010, this supporting report presents transmission and distribution facility plan.

Concepts for planning of transmission and distribution facilities have mainly referred to the 1986 Ministry of Water Development (MOWD) Design Manual.

2 DESIGN CRITERIA

2.1 Water Transmission and Distribution

The transmission and distribution systems have been planned using the following principals:

(1) Distribution pipelines from storage tanks to be planned with a peak factor of 2.

(2) Transmission mains delivering to storage tanks to be planned to pass the projected average daily water demand, plus the peak flow to any areas supplied directly from the pipeline.

(3) Friction losses in pipelines to be calculated with the Colebrook-White (universal) formula, with roughness (K) of 0.1 mm for uPVC and 1.0 mm for steel pipe.

(4) Pressure to be kept as low as practicable to limit losses by the inclusion of suitably located break pressure tanks, with a minimum pressure of 10 m in pipeline sections.

(5) Careful alignment of pipelines to avoid high and low points, and the location of service connections at high points to aid release of air and drainage from kiosks.

2.2 Storage

Storage will be provided at strategic locations throughout the supply area. For rural areas, the storage tanks will be for balancing peak flows and will be sized to provide a capacity amounting to 12 hours average water demand for the area it supplies. For urban areas, supplied by gravity, an additional 12 hours storage will be provided as an emergency supply.

3 TRANSMISSION AND DISTRIBUTION FACILITY PLAN

3.1 Basic Consideration

For planning purposes, pipe diameters of 63 mm and larger have been classified as transmission and distribution mains, and other small diameter pipes have been defined as service mains. Unplasticised polyvinyl chloride (uPVC) pipes are proposed for the majority of transmission and distribution mains with diameters less than 350 mm. Steel pipes are proposed for pipes of diameters 350 mm and more, and pipes for some sectors such as road and river crossings. Transmission and distribution mains have been planned for each scheme based on the projected water demand in 2010 described in ***Section 5.3*** **"Water Demand Projection"** and existing supply conditions. Existing transmission and distribution facilities have been incorporated into the proposed water supply systems as appropriate.

The water demand and required storage capacity at target year of 2010 for the seven schemes are summarised in ***Table P-1***.

Table P-1 Water Demand and Required Storage Capacity

Scheme	Study Area (Original)	Supply Area (Actual)	Demand in 2010	Supply Demand	Demand for Urban Area	Required Storage Capacity*
	(km^2)	(km^2)	(m^3/day)	(m^3/day)	(m^3/day)	(m^3)
	A	B	C	D	E	F
Meru	185.3	185.3	22,725	22,725	13,794	18,260
Nkubu	3.5	3.5	1,915	1,915	1,295	1,605
Isiolo	44.9	44.9	10,671	10,671	5,617	8,144
Chuka	88.0	88.0	4,403	4,403	1,315	2,859
Chogoria	57.5	57.5	2,886	2,886	335	1,611
Maua	15.0	11.2	2,011	1,500	945	1,223
Tigania	99.1	92.5	3,778	3,674	0	1,837
Total	493.3	482.9	48,389	47,774	23,301	35,537

* : Required storage capacity amounts to 12 hours demand for Items D and E.

The difference between totals of the Study Area (Column A) and the Supply Area (Column B) is due to part of the Study Areas in Maua and Tigania being unable to receive water supplies for the following reasons;

(1) Because of limited raw water yield and the topography of the Study Area for Maua, the west part of approximately 3.8 km^2 will not be covered by the proposed water supply system.

(2) In Tigania, because of high ground in the north part of Kitheo sub-location, of approximately 6.6 km^2, will not be covered by the proposed water supply system.

3.2 Proposed Transmission and Distribution Facilities

3.2.1 Meru

The projected water demand for Meru in 2010 is estimated at 22,725 m^3/day. Existing water production capacity is 3,172 m^3/day covering area of approximately 12 km^2, so that an additional capacity of 19,558 m^3/day is needed to be treated and distributed to the supply area. All water produced in the existing treatment plant will be used for Upper Igoki sub-location in which the urban center of Meru Town is located. The supply area to be covered by the existing plant in 2010 is estimated at 3.1 km^2 of Upper Igoki. Other existing supply area not to be covered by the existing plant will be covered by the proposed system. Therefore, the balance of demand in Upper Igoki, and demands in other sub-locations, will be supplied from the proposed treatment plant. ***Table P-2*** shows details of the projected water demand and required storage capacity for each sub-location. Almost half of the demand in Meru will be consumed at Upper Igoki. Projected water demand for each sub-location is also shown in ***Figure P-1*** visually.

Table P-2 Projected Water Demand and Required Storage Capacity in Meru

Sub-Location	Study Area	Demand in 2010	Demand for Urban Area	Required Storage Capacity
	(km^2)	(m^3/day)	(m^3/day)	(m^3)
U.Igoki	12.2	11,811	11,566	11,689
Ntakira	10.2	1,271	581	926
L.Igoki	6.0	645	261	453
Nthimbiri	6.8	500	-	250
Mpuri	5.1	417	-	209
Ngonyi	8.1	480	-	240
Mulathankare	4.0	1,442	1,386	1,414
Thura	29.5	852	-	426
Chungu	19.4	1,224	-	612
Munithu	14.0	807	-	404
Nkabune	7.2	352	-	176
Katheri	29.2	1,364	-	682
Githongo	13.8	712	-	356
Kithrune	19.8	850	-	425
Total	185.3	22,725	13,794	18,261

Proposed routes for transmission and distribution mains and locations of storage tanks for the target year of 2010 have been planned and are shown in ***Figure P-2***. The supply area is divided into two major distribution zones by two main pipelines discharging from the proposed treatment plant. One zone covers the north part of the Area , and another zone covers the south part of the Area. ***Figure P-3*** shows allocated water demands by distribution zones based on the proposed pipeline routes and water demand for each sub-location. ***Figure P-4*** shows the results of hydraulic calculation of each proposed pipeline, which mentions flow rate, length, diameter, hydraulic gradient, and flow velocity. The results are also shown in ***Attachment*** in detail. ***Figure P-5*** shows summary of the proposed plan for transmission and distribution facilities schematically.

Total proposed storage capacity is 17,850 m^3, and the total length of proposed transmission and distribution mains is 139.9 km. The resultant total storage tank capacity in 2010 will be 19,061 m^3, including the existing storage capacity of 1,211 m^3. Breakdowns of these figures for proposed storage tanks and pipeline are listed in ***Table P-3*** and ***Table P-4*** respectively.

Table P-3 Proposed Storage Tanks in Meru

Tank No.	Capacity (m3)	Tank No.	Capacity(m3)
ST-WTP	800	ST-9	100
ST-1	9,000	ST-10	600
ST-2	300	ST-11	500
ST-3	500	ST-12	800
ST-4	150	ST-13	200
ST-5	1,500	ST-14	200
ST-6	100	ST-15	250
ST-7	400	ST-EX1	2,250
ST-8	250		

Table P-4 Proposed Pipeline in Meru

Diameter (mm)	Length (km)
400 SP	3.8
350 SP	6.8
315 PVC	8.5
280 PVC	5.8
225 PVC	19.0
160 PVC	37.8
110 PVC	34.7
90 PVC	23.5
Total	139.9

3.2.2 Nkubu

The projected water demand for Nkubu in 2010 is estimated at 1,915 m^3/day. The existing 400 m^3/day water treatment plant, built in 1952, will be abandoned. All water will be, therefore, treated and distributed from proposed treatment plant to the supply area, which consists of one sub-location, with an area of 3.5 km^2. ***Table P-5*** shows the required storage capacity for Nkubu Water Supply System.

Table P-5 Required Storage Capacity for Nkubu

Supply Area (km^2)	Demand in 2010 (m^3/day)	Demand for Urban Area (m^3/day)	Required Storage Capacity (m^3)
3.5	1,915	1,295	1,605

Proposed routes for transmission and distribution mains and locations of storage tanks for the target year of 2010 are shown in ***Figure P-6***. ***Figure P-7*** shows allocated water demands by distribution zones based on the proposed pipeline routes and water demand. ***Figure P-8*** shows the results of hydraulic calculation of each pipeline, which mentions flow rate, length, diameter, hydraulic gradient, and flow velocity. More details information are shown in ***Attachment***. ***Figure P-9*** shows the proposed plan for transmission and distribution facilities schematically.

Total proposed storage volume is 1,550 m^3, and total length of proposed transmission and distribution mains is 5.9 km. Consequently, the total storage capacity in 2010 will be 1,625 m^3, including the existing storage capacity of 75 m^3. This provides the required storage capacity of 1,605 m^3. A breakdown of these figures is listed in ***Table P-6***.

Table P-6 Breakdown of Storage Tanks and Distribution Main in Nkubu

Storage Tanks	Capacity (m^3)	Unit	Total (m^3)
	500	2	1,000
	300	1	300
	250	1	250
	Total		1,550
Distribution Main	diameter	length	
	dia.225	1.3 km	
	dia.160	2.3 km	
	dia.90	2.0 km	
	dia.63	0.3 km	
	Total	5.9 km	

3.2.3 Isiolo

The projected water demand for Isiolo in 2010 is estimated at 10,671 m^3/day. Existing water production capacity is 2,800 m^3/day, so that an additional 7,871 m^3/day will be required for distribution to the supply area. The proposed raw water source and storage tank are planned to be located in the south of the Study Area. It has been assumed that all the production from the existing treatment plant will be used for the urban area of Isiolo. The balance of urban demand and the rural demand will be supplied by the proposed system. ***Table P-7*** shows details of projected water demand for urban and rural areas and institutional use mainly for three military camps around Isiolo Town. The proposed system is divided into two major distribution zones supplied by two different storage tanks respectively. One zone covers the west part of the Study Area, and another zone covers the east part of the Area.

Table P-7 Projected Water Demand and Required Storage Capacity in Isiolo

	Area	Demand			Required Storage
		in 2010	Existing	Balance	Capacity
	(km^2)	(m^3/day)	(m^3/day)	(m^3/day)	(m^3)
Urban	14.9	5,617	2,800	2,817	5,617
Rural	30.0	1,405	0	1,405	703
Institutional	-	3,649	-	3,649	1,824
Total	49.0	10,671	2,800	7,871	8,144

Proposed routes for distribution mains and locations of storage tanks for the target year of 2010 are shown in ***Figure P-10***. ***Figure P-11*** shows allocated water demands by distribution zones based on the proposed pipeline routes and water demand. ***Figure P-12*** shows the results of hydraulic calculation of each pipeline, which mentions flow rate, length, diameter, hydraulic gradient, and flow velocity. More details information are shown in ***Attachment***. ***Figure P-13*** shows the proposed plan for the distribution facilities schematically.

The total length of proposed distribution mains is 30.7km. The proposed storage volume has been planned to be 6,000 m^3, consisting of two 3,000m^3 tanks. Consequently, the total storage capacity in 2010 will be 8,150 m^3, including the existing storage capacity of 2,150 m^3, and which provides the required storage capacity of 8,144 m^3. A breakdown of distribution mains is listed in ***Table P-8***.

Table P-8 Breakdown of Distribution Mains in Isiolo

diameter	length
dia.280	6.7 km
dia.225	9.4 km
dia.160	2.9 km
dia.110	2.7 km
dia.63	9.0 km
Total	30.7 km

3.2.4 Chuka

The projected water demand for Chuka in 2010 is estimated at 4,403 m^3/day. As discussed in ***Section 6.1.4***, water from the existing 3,260 m^3/day water treatment plant will be diverted to other areas outside the Study Area. Therefore, all water from the proposed new 4,000 m^3/day treatment plant will be supplied to the Study Area, even those areas which have been covered by the existing system. The transmission and distribution system in Chuka has been quite extensively developed by the existing water supply system. Therefore, the current requirements are only for strengthening the existing system and replacement of the existing main pipelines where necessary. ***Table P-9*** shows details of the projected water demand and required storage capacity for each sub-location.

Table P-9 Required Storage Capacity for Each Sub-location in Chuka

	Study Area (km^2)	Demand in 2010 (m^3/day)	Demand for Urban Area (m^3/day)	Required Storage Capacity (m^3)
Mugiriwa	13.5	902	-	451
Muiru	8.5	724	-	362
Mariani	28.7	63	-	32
Ndagani	13.3	565	-	283
Chuka T	5.5	1,668	1,315	1,492
Kinangondu	8.7	441	-	221
Kithangani	9.8	40	-	20
Total	88.0	4,403	1,315	2,859

Proposed routes for the transmission and distribution mains and the locations of storage tanks for the target year of 2010, including existing mains, are shown in ***Figure P-14***. ***Figure P-15*** shows allocated water demands by distribution zones based on the proposed pipeline routes and water demand for each sub-location. ***Figure P-16*** shows the results of hydraulic calculation of each proposed pipeline, which mentions flow rate, length, diameter, hydraulic gradient, and flow velocity. More details information are shown in ***Attachment***. ***Figure P-17*** shows the proposed plan for the transmission and distribution facilities schematically.

Total proposed storage volume has been planned to be 2,850 m^3, and total length of proposed transmission and distribution mains is 8.3 km. Consequently, the total storage capacity in 2010 will be 2,940 m^3, including the existing storage capacity of 90 m^3, which provides the required storage capacity of 2,859 m^3. A breakdown of these figures is listed in ***Table P-10.***

Table P-10 Breakdown of Storage Tanks and Pipelines in Chuka

Storage Tanks	Capacity (m^3)	Unit	Total (m^3)
	750	1	750
	500	1	500
	400	1	400
	300	1	300
	200	3	600
	150	2	300
	Total		2,850
Pipeline	diameter	length	
	dia.280	2.9 km	
	dia.225	2.8 km	
	dia.160	2.6 km	
	Total	8.3 km	

3.2.5 Chogoria

Chogoria's existing water supply system depends on the Mwimbi Water Supply System which is located in neighboring Meru District and which has insufficient capacity to supply water to its own District. It is, therefore, necessary for Chogoria to develop its own independent water supply system in order to secure a reliable water supply.

The projected water demand for Chogoria in 2010 is estimated at 2,886 m^3/day. Chogoria Town has three sub-locations i.e. Chogoria, Kiraro and Murugi. ***Table P-11*** shows details of the projected water demand and required storage capacity for each sub-location.

Table P-11 Projected Water Demand and Storage Capacity in Chogoria

	Study Area (km²)	Demand in 2010 (m^3/day)	Demand for Urban Area (m^3/day)	Required Storage Capacity (m^3)
Chogoria	25.2	1,246	335	791
Kiraro	6.4	334	-	167
Murugi	25.9	1,306	-	653
Total	57.5	2,886	335	1,611

Proposed routes for transmission and distribution mains, and locations of storage tanks for the target year of 2010, are shown in ***Figure P-18***. ***Figure P-19*** shows allocated water demands by distribution zones based on the proposed pipeline routes and water demand for each sub-location. ***Figure P-20*** shows the results of hydraulic calculation of each proposed pipeline, which mentions flow rate, length, diameter, hydraulic gradient, and flow velocity. More details information are shown in ***Attachment***. ***Figure P-21*** shows the proposed plan for the transmission and distribution facilities schematically. The supply area is divided into two major distribution zones. One zone covers the north part of the Area including Chogoria and Kiraro sub-locations, and the other covers the south part of the Area including Murugi sub-location. It is, however, noted that it might not be able to supply some parts of the west side of the supply area by gravity from the proposed plant, due to topographic features. At present, a water supply project covering the south part of the Area is under implementation. Therefore it is recommended that the Study Area is economically and topographically divided into two systems form different raw water sources.

Total proposed storage volume is 1,500 m^3, and total length of proposed transmission and distribution mains is 39.1 km. Consequently, the total storage capacity in 2010 will be 1,735 m^3, including the existing storage capacity of 235 m^3, which provides the required storage capacity of 1,611 m^3. A breakdown of these figures is listed in ***Table P-12***.

Table P-12 Breakdown of Proposed Storage Tanks and Pipelines in Chogoria

Storage Tanks	Capacity (m^3)	Unit	Total (m^3)
	300	2	600
	250	2	500
	200	2	400
	Total		1,500
Distribution Main	diameter	length	
	dia.225	5.0 km	
	dia.160	11.6 km	
	dia.110	2.8 km	
	dia.63	15.2 km	
	Total	39.1 km	

3.2.6 Maua

The projected water demand for Maua in 2010 is estimated at 2,011 m^3/day. The existing 200 m^3/day water treatment plant, built in 1956, will not be expected to be used for the proposed water supply system. All the demand in 2010 will therefore be treated and distributed from the proposed water treatment plant to the supply area. Because of source constraints and topography of the Study Area, however, the west part, estimated at approximately 3.8 km^2, can not be covered by the proposed water supply system. The proposed system will, therefore, be limited to supply only the urban areas around Maua to a maximum demand of 1,500 m^3/day, which is less than the originally estimated total demand of 2,011 m^3/day. ***Table P-13*** shows details of the projected water demand and required storage capacity for supply area and the area not to be supplied.

Table P-13 Projected Water Demand and Required Storage Capacity in Maua

	Study Area (km^2)	Demand in 2010 (m^3/day)	Demand for Urban Area (m^3/day)	Required Storage Capacity (m^3)
Supply	11.2	1,500	945	1,223
Non-supply	3.8	511	-	256
Total	15.0	2,011	945	1,478

Proposed routes for transmission and distribution mains and locations of storage tanks for the target year of 2010 are shown in ***Figure P-22***. ***Figure P-23*** shows allocated water demands by distribution zones based on the proposed pipeline routes and water demand. **Figure P-24** shows the results of hydraulic calculation of each proposed pipeline, which mentions flow rate, length, diameter, hydraulic gradient, and flow velocity. More details information are shown in ***Attachment***. ***Figure P-25*** shows the proposed plan for the transmission and distribution facilities schematically.

Total proposed storage volume is 1,300 m^3, and total length of proposed transmission and distribution mains is 8.4 km. Consequently, the total storage capacity in 2010 will be 1,345 m^3, including the existing storage capacity of 45 m^3, which provides the required storage capacity of 1,233 m^3. A breakdown of these figures is listed in ***Table P-14***.

Table P-14 Breakdown of Proposed Storage Tanks and Pipelines in Maua

Storage Tanks	Capacity (m^3)	Unit	Total (m^3)
	500	2	1,000
	150	2	300
	Total		1,300
Pipeline	diameter	length	
	dia.225	1.5 km	
	dia.160	4.2 km	
	dia.110	1.7 km	
	dia.63	1.0 km	
	Total	8.4 km	

3.2.7 Tigania

The projected water demand for Tigania in 2010, excluding the existing supply area called Old Tigania, is estimated at 3,778 m^3/day. Because of the topography of the Study Area, however, the north part of Kitheo sub-location, estimated at approximately 6.6 km^2, can not be covered by gravity from the proposed water supply system. ***Table P-15*** shows details of the projected water demand and required storage tank capacity for each sub-location.

Table P-15 Projected Water Demand and Required Storage Capacity in Tigania

	Study Area		Supply Area		
	Area (km^2)	Demand (m^3/day)	Area (km^2)	Demand (m^3/day)	Required Storage Capacity (m^3/day)
Nkomo	27.6	719	27.6	719	360
Miathene	17.2	948	17.2	948	474
Kiguchwa	18.1	1,230	18.1	1,230	615
Athwana	5.3	236	5.3	236	118
Antwamburi	11.0	332	11.0	332	166
Kitheo	19.9	313	13.3	209	105
Total	99.1	3,778	92.5	3,674	1,837

Proposed routes for transmission and distribution mains and locations of storage tanks for the target year of 2010 are shown in ***Figure P-26***. ***Figure P-27*** shows allocated water demands by distribution zones based on the proposed pipeline routes and water demand for each sub-location. ***Figure P-28*** shows the results of hydraulic calculation of each proposed pipeline, which mentions flow rate, length, diameter, hydraulic gradient, and flow velocity. More details information are shown in ***Attachment***. ***Figure P-29*** shows the proposed plan for the transmission and distribution facilities schematically. The west end of the proposed main will be connected to the existing pipeline at Nkomo sub-location in order to cover its area by the proposed scheme.

Total proposed storage volume is 1,900 m^3, and total length of proposed transmission and distribution mains is 51.4 km. Consequently, the total storage capacity in 2010 will be 1,950 m^3, including the existing storage capacity of 50 m^3, which provides the required storage capacity of 1,837 m^3. A breakdown of these figures is listed in ***Table P-16***.

Table P-16 Breakdown of Proposed Storage Tanks and Pipeline in Tigania

Storage Tanks	Capacity (m^3)	Unit	Total (m^3)
	500	1	500
	400	1	400
	200	2	400
	150	4	600
	Total		1,900
Pipeline	**diameter**	**length**	
	dia.280	11.8 km	
	dia.225	8.9 km	
	dia.160	7.1 km	
	dia.110	10.6 km	
	dia.63	13.0 km	
	Total	51.4 km	

3.3 Service Mains

Service pipeline requirements have been estimated after consideration of the existing conditions of service pipelines in each scheme. Existing lengths of service pipelines and the number of house connections for each scheme are mentioned in ***Chapter III*** **"Existing Water Supply in the Study Area"**. Service pipelines are tentatively defined as pipe diameters less than 63 mm in this Study. Existing lengths of service pipelines and numbers of house connection for each scheme, including unit length of service pipeline per house connection, are summarised in ***Table P-17***.

Table P-17 Existing Service Pipeline Length and Number of House Connection

	Pipe Length (m)	Number of Connection	Unit Length (m/conn.)
Meru	61,500	2,519	24.4
Nkubu	-	325	-
Isiolo	15,600	2,771	5.6
Chuka	-	590	-
Chogoria	4,500	270	16.7
Maua	2,700	465	5.8
Tigania	39,000	1,686	23.1
Total*	123,300	7,711	16.0

* :excluding figures of Nkubu and Chuka, because of no data for pipe length

There is no available data on pipe length for Nkubu and Chuka. In case of Isiolo and Maua, the existing service areas are estimated to be limited mainly to cover the center of the towns. Other schemes i.e. Meru, Chuka and Chogoria include both urban and rural areas. Whereas Tigania is predominantly rural in character. Therefore, the unit length of service pipeline per connection has been estimated from data of the following representative schemes. ***Table P-18*** shows the estimation of unit length of service pipeline per connection for these existing schemes.

Table P-18 Unit Length of Service Pipeline

	Pipe Length (m)	Number of Connection	Unit Length (m/conn.)
Meru	61,500	2,519	24.4
Chogoria	4,500	270	16.7
Tigania	39,000	1,686	23.1
Total	105,000	4,475	23.5

Service pipeline lengths in the low population density areas is usually longer than that in high density areas, if all connections are individual house connection. Actually, public taps (Kiosks) are often the more appropriate water supply service facility in rural areas or with low population density. It is, however, impossible to plan all necessary public taps at the Master Plan Stage, since there is not sufficient and detailed data for distribution and location of houses. And all public water points should only be located after discussion and approved with local communities. For the purpose of the Master Plan, therefore, 23.5 m per connection as the average length has been applied to the unit length of the service pipeline.