Case A When the available water is sufficient:

A1 Combination with the 2nd Sabaki P/L

A2 Combination with the 2nd Mzima P/L

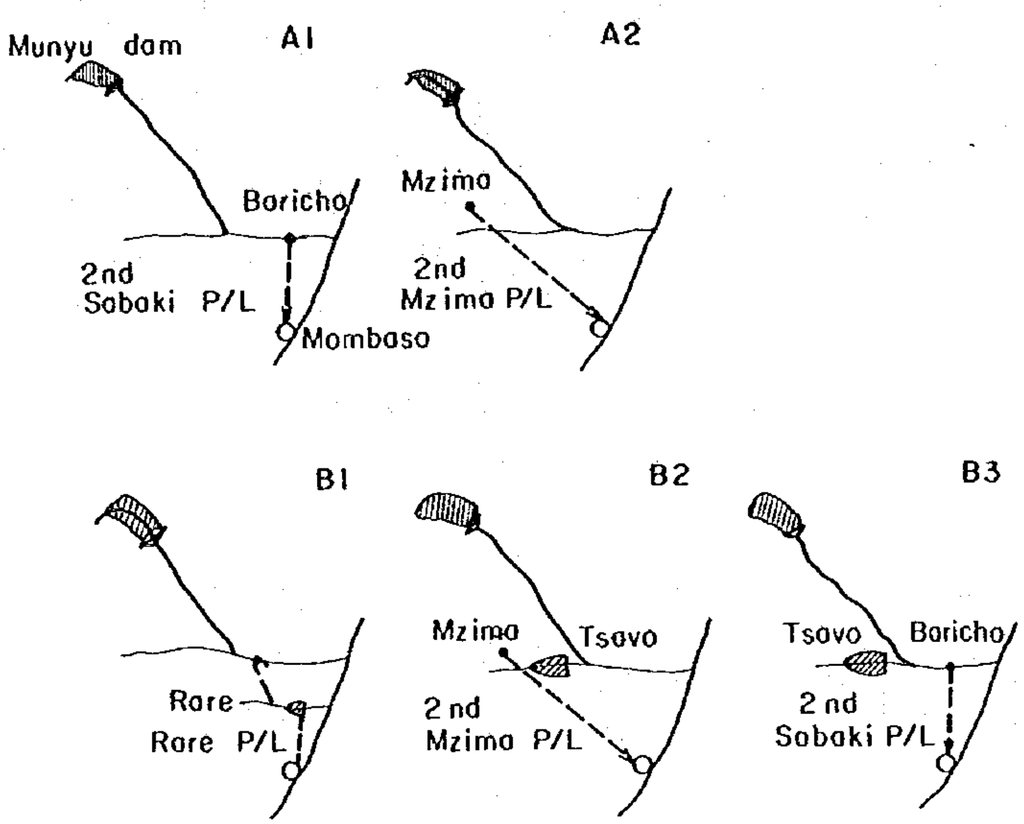
Case B When the available water is not sufficient, the deficit will have to be supplemented by other reservoir or water source. Examples are as shown below and their conceptual figures are presented in the attached sheet:

B1 Combination with Rare reservoir plus Rare P/L (deficit is supplied by Rare reservoir)

B2 Combination with 2nd Mzima P/L plus Tsavo reservoir (deficit is supplied by Tsavo reservoir)

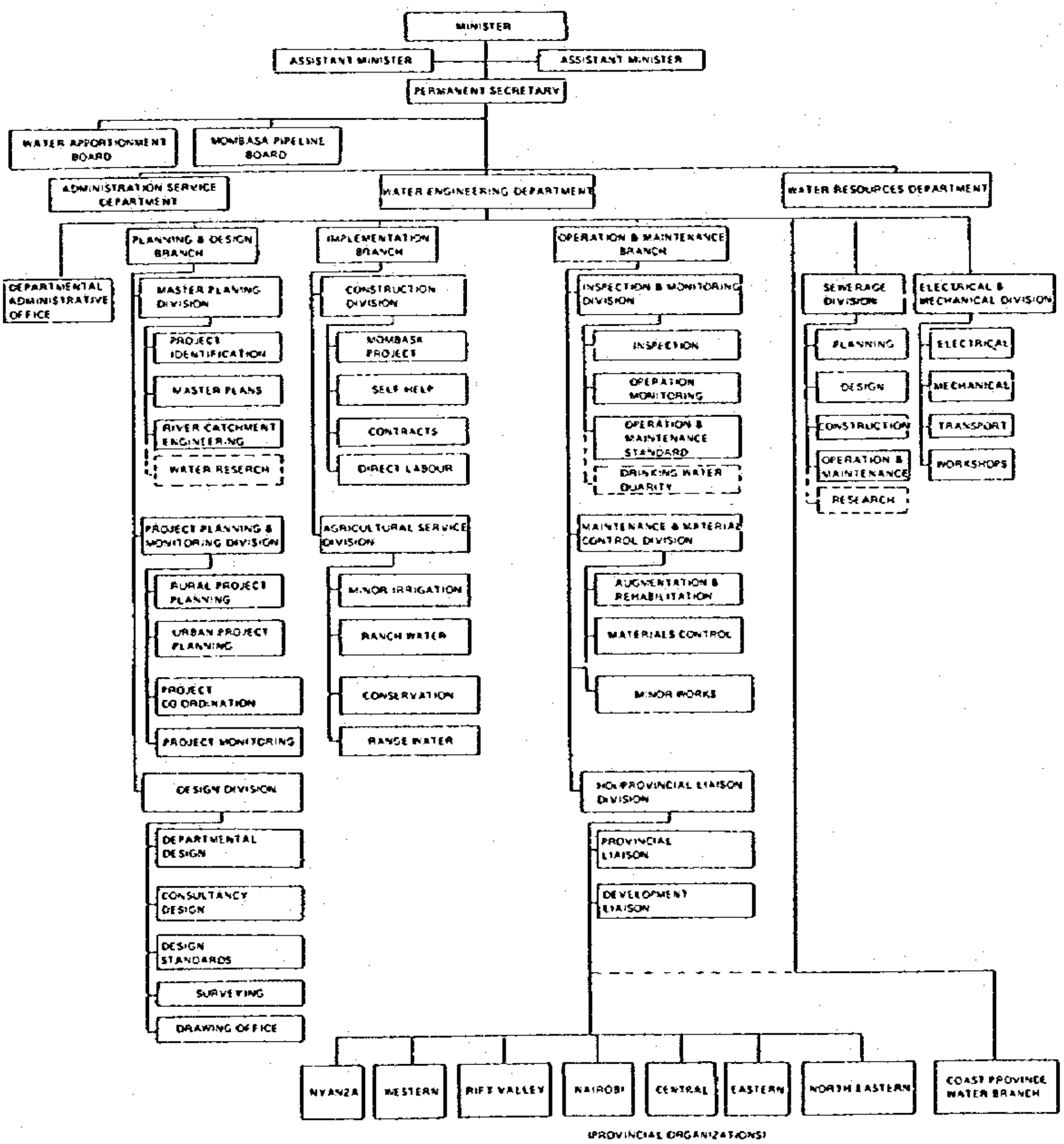
B3 Combination with 2nd Sabaki P/L plus Tsavo reservoir (deficit is supplied by Tsavo reservoir)

There might be other means of supplementing the deficit such as the combination with other water sources like local rivers and/or groundwater. Situation being as such, a thorough study will be needed in future to select the best plan. In this connection, the selected plans in this study should be retained as those to represent the objective situations as of present. Reconsideration will have to be performed newly under the new situation with the water resources development on the Athi River added.




EXAMPLES OF CONCEIVABLE PLANS WITH MUNYU SCHEME

# ORGANIZATION CHART OF WATER ENGINEERING DEPARTMENT IN THE MINISTRY OF WATER DEVELOPMENT




Note The above chart shows a draft organization chart as of August 1980

Source Water Engineering Department

ORS No PSD/129

EXISTING BULK WATER SUPPLY SOURCES

| | Descriptions | (1) Marere Springs | (2) Pemba Intake | (3) Mzima Springs |
|---|---|---|---|---|
| 1. | Type of Source | Spring | Pemba River | Spring |
| 2. | Time of Construction | 1916 | 1973 | 1952-56 |
| 3. | Design Capacity | 2,500 $m^3$/day | 6,540 $m^3$/day | 36,000 $m^3$/day |
| 4. | Time of Expansion | (1) 1930's<br>(2) 1950's | 1979 | |
| 5. | Expanded Capacity | (1) 10,500 $m^3$/day<br>(2) 13,500 $m^3$/day | - | - |
| 6. | Facilities | | | |
| | a) Intake pumps | - | 2 pumps | - |
| | b) Transmission pumps | - | 3 pumps (Booster pumps for filters) | - |
| | c) Treatment Facilities | Sedimentation basins and Chlorination equipment | Sedimentation basins, filters & chlorination equipment | Chlorination facility (not used now) |
| | d) Power | - | Fuel Engine | - |
| 7. | Estimated Production Capacity | 10,000 $m^3$/day | 2,000 $m^3$/day | 36,000 $m^3$/day |
| 8. | Others | | | Potential intake capacity: 72,000 $m^3$/day |

EXISTING BULK WATER SUPPLY SOURCES (CONTINUED)

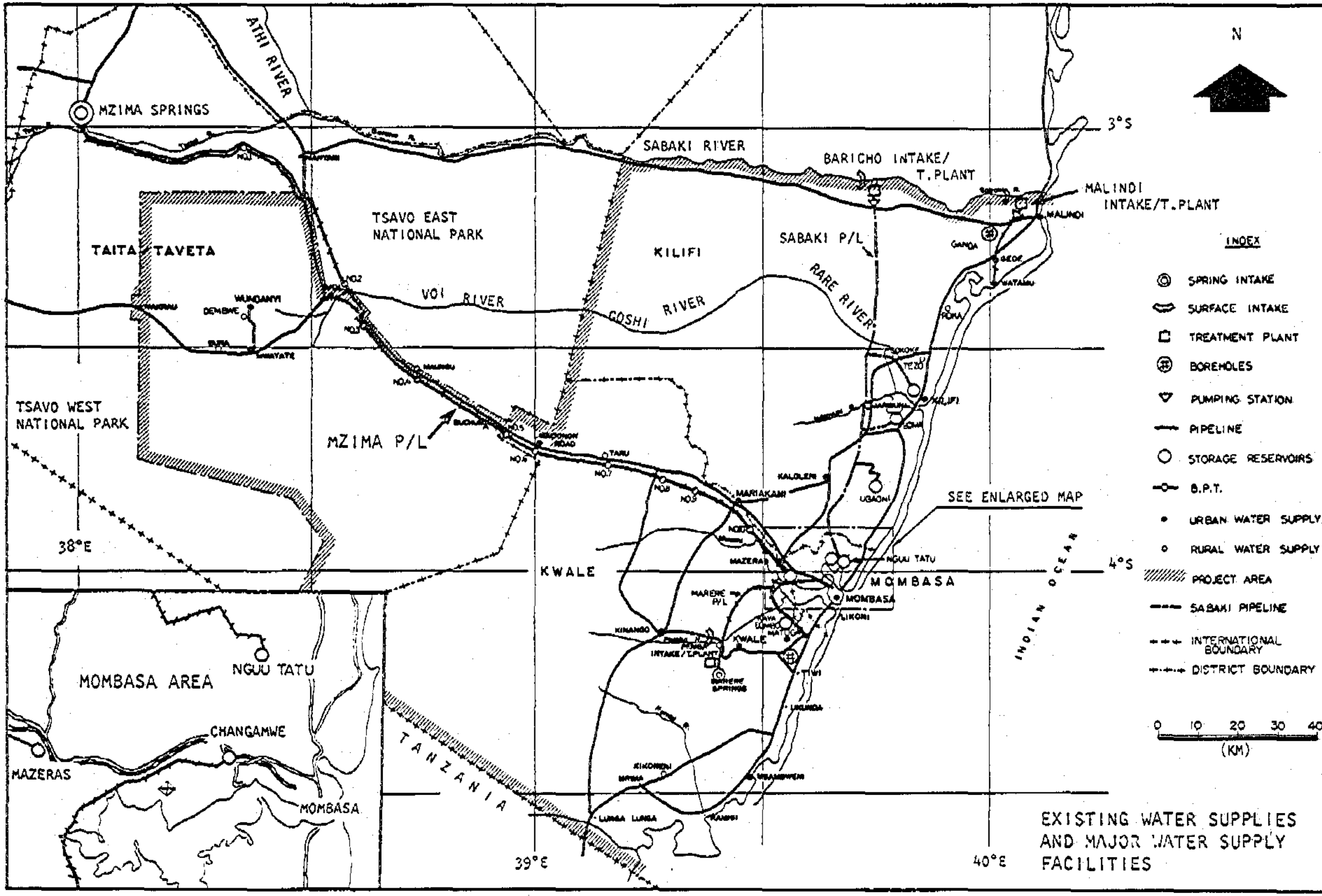
| Description | (4) Tiwi B.H. No 1 | (5) Tiwi B.H. No 2 | (6) Tiwi B.H. No 4 | (7) Malindi Intake |
|---|---|---|---|---|
| 1. Type of Source | Ground Water | Ground Water | Ground Water | Sabaki River |
| 2. Time of Construction | - | - | - | 1961 |
| 3. Design Capacity | 45 $m^3$/hr. | 67.5 $m^3$/hr. | 80 $m^3$/hr. | 1,800 $m^3$/day |
| 4. Time of Expansion | 1976 | 1979-80 | 1979 | 1970's |
| 5. Expanded Capacity | - | - | - | 2,000 $m^3$/day |
| 6. Facilities | | | | |
| a) Intake pumps | Submersible pump | Submersible pump | Submersible pump | 2 pumps |
| b) Transmission pumps | - | - | - | 2 pumps |
| c) Treatment Facilities | Chlorination equipment | Chlorination equipment | Chlorination equipment | Presettling basins, Sedimentation basins, filters and chlorination facilities. |
| d) Power | Electricity | Electricity | Electricity | Electricity |
| 7. Estimated Production Capacity | 1,000 $m^3$/day | 1,200 $m^3$/day | 1,700 $m^3$/day | 2,200 $m^3$/day |
| 8. Others | | | | |

EXISTING BULK WATER SUPPLY FACILITIES

| Facilities | (1) Marere Pipeline | (2) Mzima Pipeline | (3) Pemba Water Works | (4) Mazeras-Jaribuni pipeline |
|---|---|---|---|---|
| 1. Spring Intake | Marere Springs | Mzima Springs | - | - |
| 2. River Intake | - | - | Pemba River Intake | - |
| 3. Boreholes | - | - | - | - |
| 4. Treatment Plant | Sedimentation, limining chamber & chlorination facility. | Chlorination facility. | Sedimentation basins, filters & chlorination facility. | - |
| 5. Transmission Main | D300mm-D250mm: 41km | D530mm-D760mm: 219 km | Connection to Marere Pipeline | D200mm-D180mm: 50 km |
| 6. Booster Pumping Station | Mile 8 booster pumping station | - | - | Mazeras booster pumping station |
| 7. Reservoirs | Changamwe & Kaya Bombo reservoirs: 29,600 $m^3$ & 1,100 $m^3$ | Mazeras reservoirs: 81,000 $m^3$ | - | Ribe, Kaloleni & Ditzoni reservoirs: 450 $m^3$ x 3nos. Jaribuni Water Tank: 45 $m^3$ |
| 8. Others | - | 10 Break pressure tanks on Mzima Pipeline | Intake pumps & high lift pumps for filters | - |

EXISTING WATER SUPPLY FACILITIES (CONTINUED)

| Facilities | (5) North Mainland Pipeline | (6) Marere Kaya Bombo Pipeline | (7) Tiwi Boreholes | (8) Malindi Pipeline |
|---|---|---|---|---|
| 1. Spring Intake | - | - | - | - |
| 2. River Intake | - | - | - | Sabaki River Intake |
| 3. Boreholes | - | - | No. 1,2,3, & 4 Boreholes with pumps | 2 Boreholes in Ganda with pumps |
| 4. Treatment Plant | - | - | Chlorination facilities | Presettling basins, sedimentation basins, filters & chlorination facilities |
| 5. Transmission Main | D250mm 19 km | D200mm-D150mm 10 km | D200mm | D300mm- D100mm |
| 6. Booster Pumping Station | - | - | - | Malindi T. Plant booster pumps |
| 7. Reservoirs | Nguu Tatu reservoirs: 4,550 $m^3$ and 18,000 $m^3$ | Kaya Bombo reservoir: 1,100 $m^3$ | Tiwi water tank: 2,200 $m^3$ | Garalani reservoir: 1,135 $m^3$ & Ganda reservoirs: 1,600 $m^3$ |
| 8. Others | - | - | - | - |




EXISTING WATER SUPPLIES
AND MAJOR WATER SUPPLY
FACILITIES

# MOMBASA WATER SUPPLY

## ANNUAL AVERAGE DAILY WATER DELIVERED

Unit: $m^3$/day

| WATER SUPPLY ZONE | 1977 | 1978 | 1979 | | 6th February 1980 |
|---|---|---|---|---|---|
| Mombasa Island | 20,335 | 22,781 | 23,632 | | 24,670 |
| North Mainland | 4,800 | 5,663 | 5,400 | | 6,332 |
| South Mainland | 2,634 | 2,909 | 3,300 | (1 | 3,780 |
| West Mainland | 8,393 | 8,971 | 9,300 | | 11,230 |
| Sokoke/Kilifi | 748 | 714 | 946 | | 1,211 |
| Marere Pipeline in route | 2,158 | 2,144 | 2,568 | | 2,568 |
| Subtotal | 39,068 | 43,182 | 45,146 | | 49,801 |
| Consumers in route | | | | | |
| Mzima Pipeline | 2,929 | 3,225 | 2,865 | (1 | 4,328 |
| TOTAL | 41,997 | 46,407 | 48,011 | | 54,129 |

Remarks: (1 Extrapolated figures.

# MOMBASA WATER SUPPLY
## WATER AVAILABLE OR PRODUCED

Unit: $m^3$/day

| Water Supply Source | 1977 | 1978 | 1979 | 6th February 1980 |
|---|---|---|---|---|
| Mzima at Mazeras | 32,036 | 32,884 | 33,636 | 32,181 |
| Marere Headwork | 8,536 | 10,067 | 10,975 | 10,800 |
| Pemba Treatment Plant | 947 | 696 | NIL (1 | 2,195 |
| South Coast Boreholes + NM Wells | 1,700 | 1,768 | 1,578 | 3,611 |
| Subtotal | 43,219 | 45,415 | 46,189 | 48,787 |
| Available/Consumers in route Mzima PL. | 2,929 | 3,225 | 2,865 | 4,328 |
| TOTAL | 46,148 | 48,640 | 49,054 | 53,115 |

Remarks: (1 Plant stopped due to dam construction.

Source: Statistic Unit
Chief Operation & Maintenance Engineer
D & M Division
Coast Province Water Branch

PRESENT CONSUMERS BY WATER USE CATEGORIES

| Name of Water Supply | Class 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1. Kilifi | 304 | 0 | 0 | 21 | 0 | 45 | 0 | 0 | 370 nos |
| | 82 | 0 | 0 | 6 | 0 | 12 | 0 | 0 | 100 (%) |
| 2. Tezo Roka | 193 | 0 | 0 | 31 | 0 | 3 | 0 | 0 | 227 |
| | 85 | 0 | 0 | 14 | 0 | 1 | 0 | 0 | 100 |
| 3. Kaloleni | 222 | 0 | 0 | 11 | 0 | 19 | 0 | 0 | 252 |
| | 88 | 0 | 0 | 4 | 0 | 8 | 0 | 0 | 100 |
| 4. Malindi | 1672 | 0 | 0 | 42 | 0 | 74 | 3 | 10 | 1809 |
| | 92 | 0 | 0 | 2 | 0 | 4 | 0 | 1 | 100 |
| 5. Gede Watamu | 218 | 1 | 0 | 21 | 2 | 18 | 30 | 4 | 294 |
| | 74 | 0 | 0 | 7 | 1 | 16 | 10 | 1 | 100 |
| 6. Voi | 514 | 0 | 0 | 4 | 3 | 9 | 0 | 0 | 530 |
| | 97 | 0 | 0 | 1 | 1 | 2 | 0 | 0 | 100 |
| 7. Wundanyi | 275 | 5 | 0 | 2 | 0 | 2 | 0 | 0 | 284 |
| | 97 | 2 | 0 | 1 | 0 | 1 | 0 | 0 | 100 |
| 8. Mwajika-Teri | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 25 |
| | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 |
| 9. Dembwa | 59 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 62 |
| | 95 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 100 |
| 10. Mazeras-Rabai | 109 | 25 | 13 | 13 | 5 | 11 | 7 | 0 | 183 |
| | 60 | 14 | 7 | 7 | 3 | 6 | 4 | 0 | 100 |
| 11. Mariakani | 257 | 10 | 0 | 8 | 2 | 10 | 13 | 0 | 300 |
| | 86 | 3 | 0 | 3 | 1 | 3 | 4 | 0 | 100 |
| 12. Mackinnon Road | 8 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 10 |
| | 80 | 0 | 0 | 20 | 0 | 0 | 0 | 0 | 100 |
| 13. Kwale | 145 | 0 | 0 | 4 | 0 | 33 | 0 | 0 | 182 |
| | 80 | 0 | 0 | 2 | 0 | 18 | 0 | 0 | 100 |
| 14. Msambweni | 43 | 0 | 0 | 2 | 7 | 13 | 8 | 0 | 67 |
| | 64 | 0 | 0 | 3 | 1 | 19 | 12 | 0 | 100 |
| 15. Kinango | 52 | 0 | 0 | 11 | 0 | 10 | 0 | 0 | 73 |
| | 71 | 0 | 0 | 15 | 0 | 14 | 0 | 0 | 100 |
| 16. South Mainland | 685 | 153 | 91 | 43 | 9 | 51 | 49 | 5 | 1,086 |
| | 63 | 14 | 8 | 4 | 1 | 5 | 5 | 0 | 100 |
| 17. North Mainland | 1781 | 104 | 36 | 71 | 16 | 38 | 44 | 14 | 2104 |
| | 85 | 5 | 2 | 3 | 1 | 2 | 2 | 1 | 100 |
| 18. Mombasa Island | 9788 | 1333 | 1814 | 1191 | 368 | 425 | 22 | 1 | 14942 |
| | 66 | 9 | 12 | 8 | 2 | 3 | 0 | 0 | 100 |
| 19. West Mainland | 1911 | 84 | 307 | 134 | 107 | 69 | 67 | 0 | 2679 |
| | 71 | 3 | 11 | 5 | 4 | 3 | 3 | 0 | 100 |
| Total | 19421 | 1715 | 1161 | 1659 | 513 | 898 | 245 | 42 | 26755 nos. |
| | 73 | 6 | 8 | 6 | 2 | 3 | 1 | 0 | 100 (%) |

Remarks: (1 Upper figures show numbers of service connection.

(2 Lower figures show ratio in percentage to the total.

(3 Number of class stands for following categories:

1: Single family

2: Multiple

3: Flats

4: Commercial

5: Industrial

6: Institution

7: Kiosks

8: Beach hotels

Source: CPWB Office, data of February, 1979.

# LEAKAGE AND LOSSES

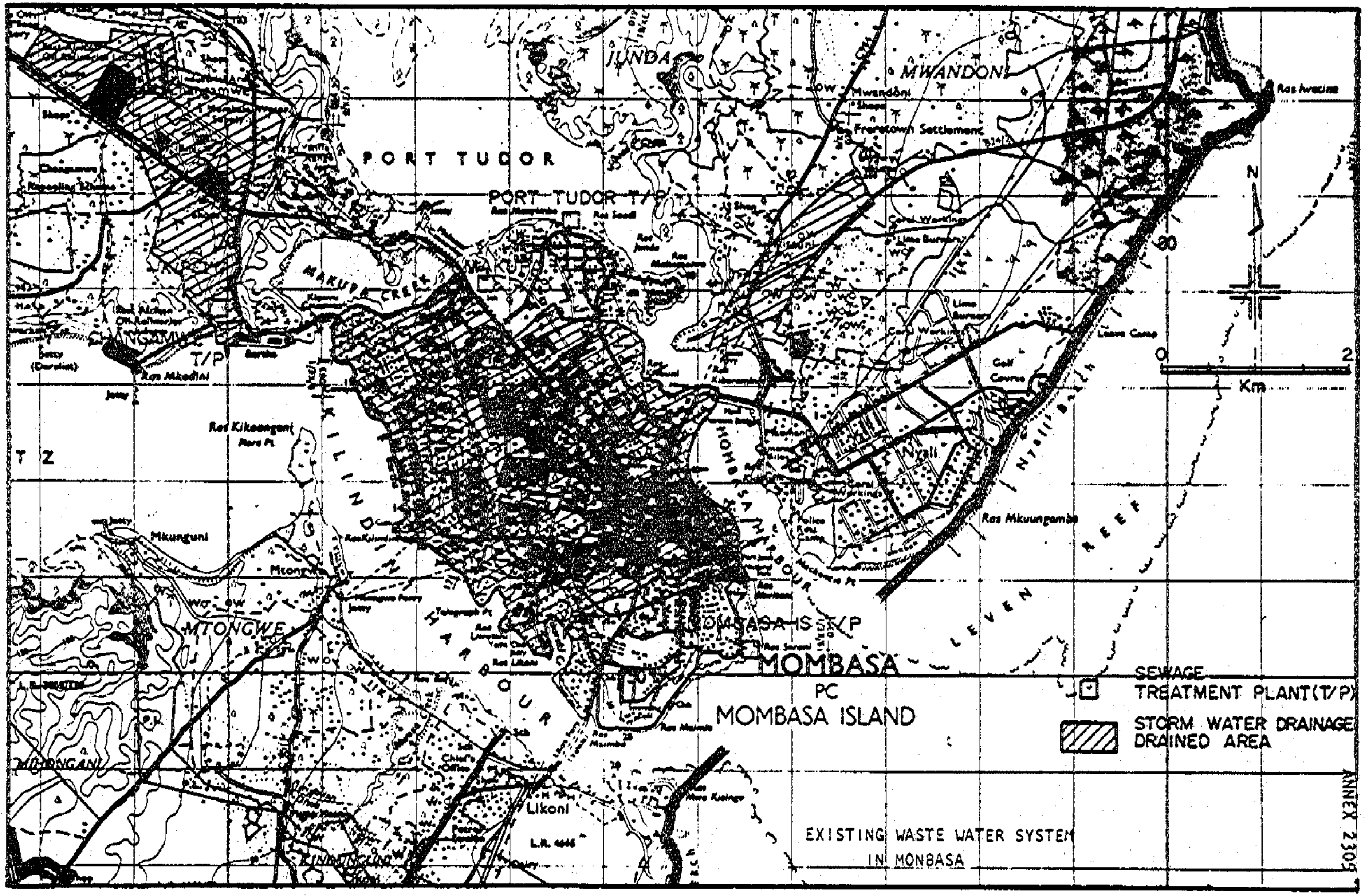
Unit: $m^3$/day

| | | 1977 | 1978 | 1979 |
|---|---|---|---|---|
| 1. | Water Available or Produced | 46,148 | 48,640 | 49,054 |
| 2. | Annual Average Daily Water Delivered | 41,997 | 46,407 | 48,011 |
| 3. | Balance/Leakage and Losses | 4,151 | 2,233 | 1,043 |
| 4. | Percentage of Total Production | 9.0% | 4.6% | 2.1% |

Source: Statistic Unit.

Chief Operations and Maintenance Engineer.

Design and Maintenance Division, Coast Province Water Branch.


ANNEX 2309
PORT TUDOR
PORT TUDOR T/P
JUNDA
MWANDONI
Mwandoni
Freretown Settlement
MAKUPA CREEK
T/P
Ras Mkadini
Ras Kikaangani
KILINDINI HARBOUR
Mkunguni
MTONGWE
MOMBASA HARBOUR
MOMBASA IS T/P
MOMBASA
PC
MOMBASA ISLAND
Nyali
Nyali Beach
Ras Mkuungombe
LEVEN REEF
Golf Course
Likoni
Ras Iwatine
N
0
1
2
Km
SEWAGE TREATMENT PLANT(T/P)
STORM WATER DRAINAGE DRAINED AREA
EXISTING WASTE WATER SYSTEM
IN MONBASA

HISTORICAL CENSUS POPULATION OF COAST PROVINCE

| | 1962 | | 1969 | | 1979 | |
|---|---|---|---|---|---|---|
| | Population ($10^3$) | % to Nation (%) | Population ($10^3$) | % to Nation (%) | Population ($10^3$) | % to Nation (%) |
| Total Kenya | 8,636 | 100 | 10,943 | 100 | 15,322 | 100 |
| Coast Province | 727 | 8.42 | 943 | 8.62 | 1,339 | 8.74 |
| Project Area | 625 | 7.24 | 815 | 7.45 | 1,123 | 7.33 |
| Kilifi District | 212 | 2.45 | 266 | 2.43 | 372 | 2.42 |
| Southern Division | (94) | (1.08) | (113) | (1.03) | (151) | (0.99) |
| Northern Division | (38) | (0.44) | ( 47) | (0.43) | ( 64) | (0.42) |
| Central Division | (43) | (0.50) | ( 57) | (052) | ( 85) | (0.55) |
| Malindi Division | (37) | (0.43) | ( 49) | (045) | ( 72) | (0.47) |
| Gede Location | ( 5) | | ( 11) | | ( 17) | |
| Ganda Location | (27) | | ( 31) | | ( 44) | |
| Jilore Location | ( 5) | | ( 7) | | ( 10) | |
| Kwale District | 158 | 1.83 | 206 | 1.88 | 287 | 1.87 |
| Mombasa District | 180 | 2.08 | 247 | 2.26 | 342 | 2.23 |
| Taita Taveta District | 75 | 0.87 | 96 | 0.88 | 123 | 0.80 |
| Voi Division | (19) | (0.22) | ( 30) | (0.27) | ( 38) | (0.25) |
| Wundanyi Division | (56) | (0.65) | ( 66) | (0.60) | ( 85) | (0.55) |

| | 1962 | | 1969 | | 1979 | |
|---|---|---|---|---|---|---|
| | Population | % to Nation | Population | % to Nation | Population | % to Nation |
| | ($10^3$) | (%) | ($10^3$) | (%) | ($10^3$) | (%) |
| Non-Project Area | 104 | 1.20 | 130 | 1.19 | 216 | 1.41 |
| Kilifi District | | | | | | |
| Malindi Division | 36 | 0.42 | 42 | 0.38 | 57 | 0.37 |
| Taita-Taveta District | | | | | | |
| Taveta Division | 15 | 0.17 | 15 | 0.14 | 25 | 0.16 |
| Lamu District | 23 | 0.27 | 22 | 0.20 | 42 | 0.27 |
| Tana River District | 30 | 0.35 | 51 | 0.47 | 92 | 0.60 |

Source: Population Census

N.B. Administrative boundary change was adjusted to that of 1979 Population Census based on information of Central Bureau of Statistics.

PROJECTED POPULATION OF COAST PROVINCE

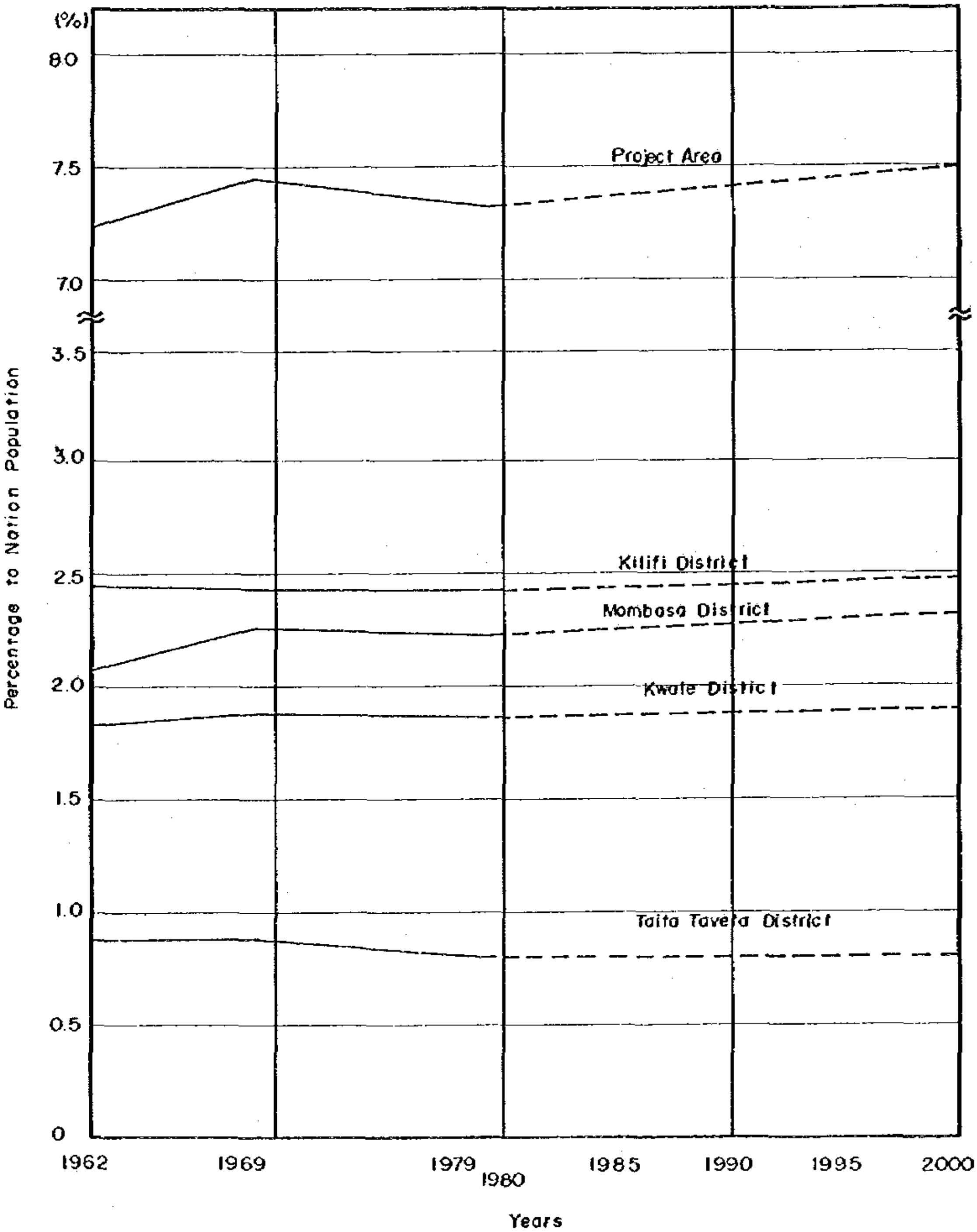
AS PERCENTAGE OF NATION POPULATION

Unit: %

| | Historical | Projected | | | | |
|---|---|---|---|---|---|---|
| | 1979 | 1980 | 1985 | 1990 | 1995 | 2000 |
| Coast Province | 8.72 | 8.74 | 8.83 | 8.89 | 8.94 | 8.96 |
| Project Area | 7.32 | 7.33 | 7.38 | 7.42 | 7.46 | 7.50 |
| Kilifi District (1 | 2.42 | 2.42 | 2.44 | 2.45 | 2.47 | 2.48 |
| Kwale District | 1.87 | 1.87 | 1.88 | 1.89 | 1.89 | 1.90 |
| Mombasa District (2 | 2.23 | 2.24 | 2.26 | 2.28 | 2.30 | 2.32 |
| Taita-Taveta District | 0.80 | 0.80 | 0.80 | 0.80 | 0.80 | 0.80 |
| Non Project Area | 1.40 | 1.41 | 1.45 | 1.47 | 1.48 | 1.46 |
| Kilifi District | 0.37 | 0.37 | 0.36 | 0.34 | 0.33 | 0.31 |
| Taita-Taveta District | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 |
| Lamu District | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 |
| Tana River District | 0.60 | 0.61 | 0.66 | 0.70 | 0.72 | 0.72 |

Remarks: (1 Excluding Malindi Division of northern bank of the Sabaki River

(2 Excluding Taveta Division




PROJECTED POPULATION OF PROJECT AREA
ASPERCENTAGE OF NATION POPULATION

# PROJECTED POPULATION OF THE PROJECT AREA BY DISTRICT

Unit: $10^3$

| | Historical | Projected | | | | |
|---|---|---|---|---|---|---|
| | 1979 | 1980 | 1985 | 1990 | 1995 | 2000 |
| A. Project Area | | | | | | |
| Kilifi District (1 | 371 | 382 | 457 | 542 | 646 | 765 |
| Kwale " | 287 | 296 | 352 | 418 | 494 | 587 |
| Mombasa " | 342 | 355 | 423 | 505 | 601 | 716 |
| Taita-Taveta District (2 | 123 | 128 | 150 | 177 | 209 | 247 |
| Total | 1,123 | 1,161 | 1,382 | 1,642 | 1,950 | 2,315 |
| B. Non-Project Area | | | | | | |
| Kilifi District | 57 | 59 | 67 | 75 | 86 | 96 |
| Taita Taveta District | 25 | 25 | 30 | 35 | 42 | 49 |
| Lamu District | 42 | 43 | 51 | 60 | 71 | 83 |
| Tana River District | 92 | 97 | 124 | 156 | 189 | 223 |
| Total | 216 | 224 | 272 | 326 | 388 | 451 |
| C. Coast Province Total | 1,339 | 1,385 | 1,654 | 1,968 | 2,338 | 2,766 |

Remarks: (1 Including Malindi division of southern bank of the Sabaki River

(2 Excluding Taveta Division

HISTORICAL POPULATION OF URBAN CENTRES

| | 1962 | | 1969 | | 1979 | |
|---|---|---|---|---|---|---|
| | Population | % to Province | Population | % to Province | Population | % to Province |
| Coast Province | 727,844 | 100 | 944,082 | 100 | 1,339,000 | 100 |
| Malindi | 5,818 | 0.80 | 10,757 | 1.14 | 23,306 | 1.74 |
| Voi | 2,533 | 0.35 | 5,313 | 0.56 | 7,329 | 0.55 |
| Kilifi | 2,081 | 0.29 | 2,662 | 0.28 | 5,861 | 0.44 |
| Mariakani | 1,454 | 0.20 | 3,956 | 0.42 | 2,853 | 0.21 |
| Wundanyi | 3,717 | 0.51 | 4,385 | 0.46 | 6,075 | 0.45 |
| Kwale | 1,008 | 0.14 | 1,092 | 0.12 | 2,193 | 0.16 |
| Kinango | 1,599 | 0.22 | 2,450 | 0.26 | 3,647 | 0.27 |
| Total | 18,210 | 2.51 | 30,615 | 3.24 | 51,264 | 3.82 |

## PROJECTED POPULATION OF URBAN CENTRES

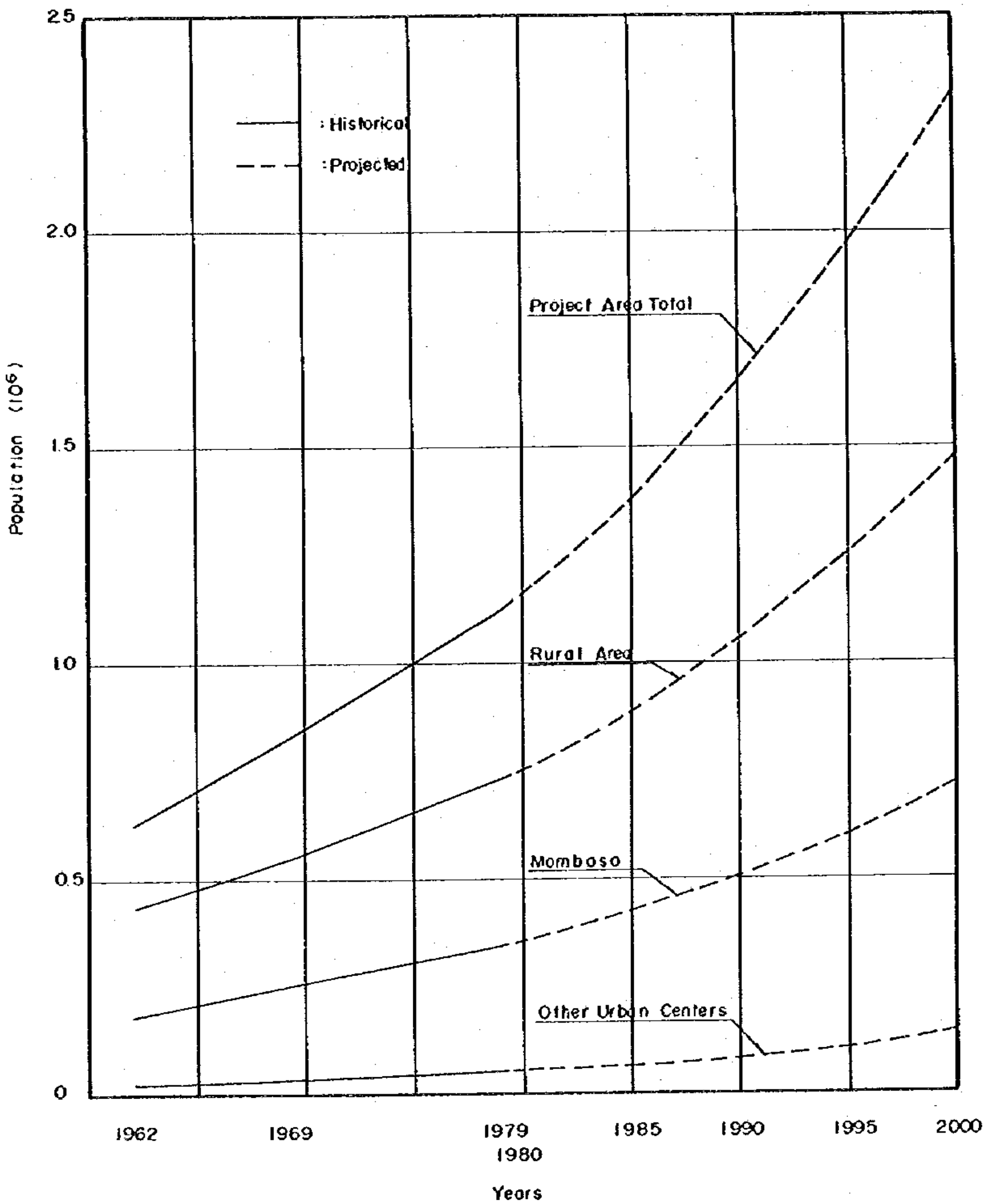
| | Historical | Projected | | | | |
|---|---|---|---|---|---|---|
| | 1979 | 1980 | 1985 | 1990 | 1995 | 2000 |
| **Coast Province** | | | | | | |
| Population ($10^3$) | 1,339 | 1,385 | 1,654 | 1,968 | 2,338 | 2,766 |
| % to Nation (%) | 8.72 | 8.74 | 8.83 | 8.89 | 8.94 | 8.96 |
| **Urban Centers** (1 | | | | | | |
| Population ($10^3$) | 51.3 | 53.6 | 67.8 | 84.6 | 105.0 | 128.4 |
| % to Province (%) | 3.82 | 3.87 | 4.10 | 4.30 | 4.49 | 4.64 |

Remarks: (1 Total of seven urban centres i.e. Malindi, Voi, Kilifi, Mariakani, Wundanyi, Kwale and Kinango

# HISTORICAL AND PROJECTED POPULATION OF PROJECT AREA

## MEDIUM GROWTH PROJECTION (ADOPTED)

| | MOMBASA | | | | URBAN CENTER | | | RURAL | | | TOTAL PROJECT AREA | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | % to Nation | Population | Growth Rate | % to Province | Population | Growth Rate | % to Nation | Population | Growth Rate | % to Nation | Population | % to Nation |
| Historical | (%) | ($10^3$) | (%) | (%) | ($10^3$) | (%) | (%) | ($10^3$) | (%) | (%) | ($10^3$) | (%) |
| 1962 | 2.08 | 180 | - | 2.51 | 18 | - | 0.21 | 427 | - | 4.94 | 625 | 7.24 |
| 1969 | 2.26 | 247 | 4.62 | 3.24 | 31 | 7.70 | 0.28 | 537 | 3.33 | 4.91 | 815 | 7.45 |
| 1979 | 2.23 | 342 | 3.31 | 3.82 | 51 | 5.29 | 0.33 | 730 | 3.12 | 4.76 | 1,123 | 7.32 |
| Projected | | | | | | | | | | | | |
| 1980 | 2.24 | 355 | 3.80 | 3.87 | 54 | 4.54 | 0.34 | 752 | 3.01 | 4.75 | 1,161 | 7.33 |
| 1985 | 2.26 | 423 | 3.57 | 4.10 | 68 | 4.82 | 0.36 | 891 | 3.45 | 4.76 | 1,382 | 7.38 |
| 1990 | 2.28 | 505 | 3.61 | 4.30 | 85 | 4.53 | 0.38 | 1,052 | 3.38 | 4.75 | 1,642 | 7.41 |
| 1995 | 2.30 | 601 | 3.54 | 4.49 | 105 | 4.40 | 0.40 | 1,244 | 3.41 | 4.76 | 1,950 | 7.46 |
| 2000 | 2.32 | 716 | 3.56 | 4.64 | 128 | 4.11 | 0.41 | 1,471 | 3.41 | 4.76 | 2,315 | 7.49 |
| Growth (1979-2000) | | | 3.56% p.a. | | | 4.48% p.a. | | | 3.39% p.a. | | 3.50% p.a. | |




HISTORICAL AND PROJECTED POPULATION
OF THE PROJECT AREA

# POPULATION PROJECTION OF PROJECT AREA
## (HIGH AND LOW GROWTH)

Unit: $10^3$

1. Nation Population

| | 1980 | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|---|
| A. High Projection (1 | 15,880 | 19,100 | 23,050 | 27,910 | 33,930 |
| B. Medium " (2 | 15,850 | 18,730 | 22,140 | 26,150 | 30,870 |
| C. Low " | 15,840 | 18,580 | 21,560 | 24,730 | 28,060 |

2. Population of Project Area

| | 1980 | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|---|
| **% To Nation (%)** | | | | | |
| Mombasa | 2.24 | 2.26 | 2.28 | 2.30 | 2.32 |
| Other Urban Area | 0.34 | 0.36 | 0.38 | 0.40 | 0.41 |
| Rural Area | 4.75 | 4.76 | 4.75 | 4.76 | 4.76 |
| Project Area Total | 7.33 | 7.38 | 7.41 | 7.46 | 7.49 |
| **A. High Projection** | | | | | |
| Mombasa | 356 | 432 | 526 | 642 | 787 |
| Other Urban Area | 54 | 69 | 88 | 112 | 139 |
| Rural Area | 754 | 909 | 1,095 | 1,329 | 1,615 |
| Project Area Total | 1,164 | 1,410 | 1,709 | 2,083 | 2,541 |
| **B. Medium Projection** | | | | | |
| Mombasa | 355 | 423 | 505 | 601 | 716 |
| Other Urban Area | 54 | 67 | 84 | 105 | 127 |
| Rural Area | 753 | 892 | 1,052 | 1,245 | 1,469 |
| Project Area Total | 1,162 | 1,382 | 1,641 | 1,951 | 2,312 |
| **C. Low Projection** | | | | | |
| Mombasa | 355 | 420 | 492 | 569 | 651 |
| Other Urban Area | 54 | 67 | 82 | 99 | 115 |
| Rural Area | 752 | 884 | 1,024 | 1,177 | 1,336 |
| Project Area Total | 1,161 | 1,371 | 1,598 | 1,845 | 2,102 |

Remarks: (1 Based on Case A projection made by Central Bureau of Statistics, June, 1971

(2 Based on Case B projection of the above

HOTELS AND BEDS AVAILABLE BY AREA

| | | 1976 | | 1977 | | 1978 | |
|---|---|---|---|---|---|---|---|
| | | No. of Hotels | Beds Available | No. of Hotels | Beds Available | No. of Hotels | Beds Available |
| 1. | Beach | | ($10^3$) | | ($10^3$) | | ($10^3$) |
| | South | 14 | 552.6 | 14 | 590.9 | 14 | 695.4 |
| | North Mombasa | 16 | 945.2 | 16 | 992.4 | 15 | 1,045.9 |
| | Kilifi/Watamu | 7 | 310.8 | 7 | 299.8 | 7 | 346.9 |
| | Malindi/Lamu | 11 | 393.8 | 12 | 285.3 | 15 | 435.2 |
| | Sub-total | 48 | 2,202.5 | 49 | 2,268.3 | 51 | 2,523.4 |
| 2. | Mombasa Island | 30 | 506.7 | 30 | 509.9 | 33 | 531.4 |
| 3. | Coast Hinterland | | | | | | |
| | East | 5 | 84.2 | 4 | 80.5 | 5 | 90.8 |
| | West | 6 | 189.8 | 6 | 184.3 | 6 | 179.8 |
| | Sub-total | 11 | 274.0 | 10 | 264.8 | 11 | 270.6 |
| | Total | 89 | 2,983.2 | 89 | 3,043.0 | 95 | 3,325.4 |
| cf. | Total Kenya | 228 | 6,983.1 | 227 | 7,028.3 | 272 | 7,358.0 |

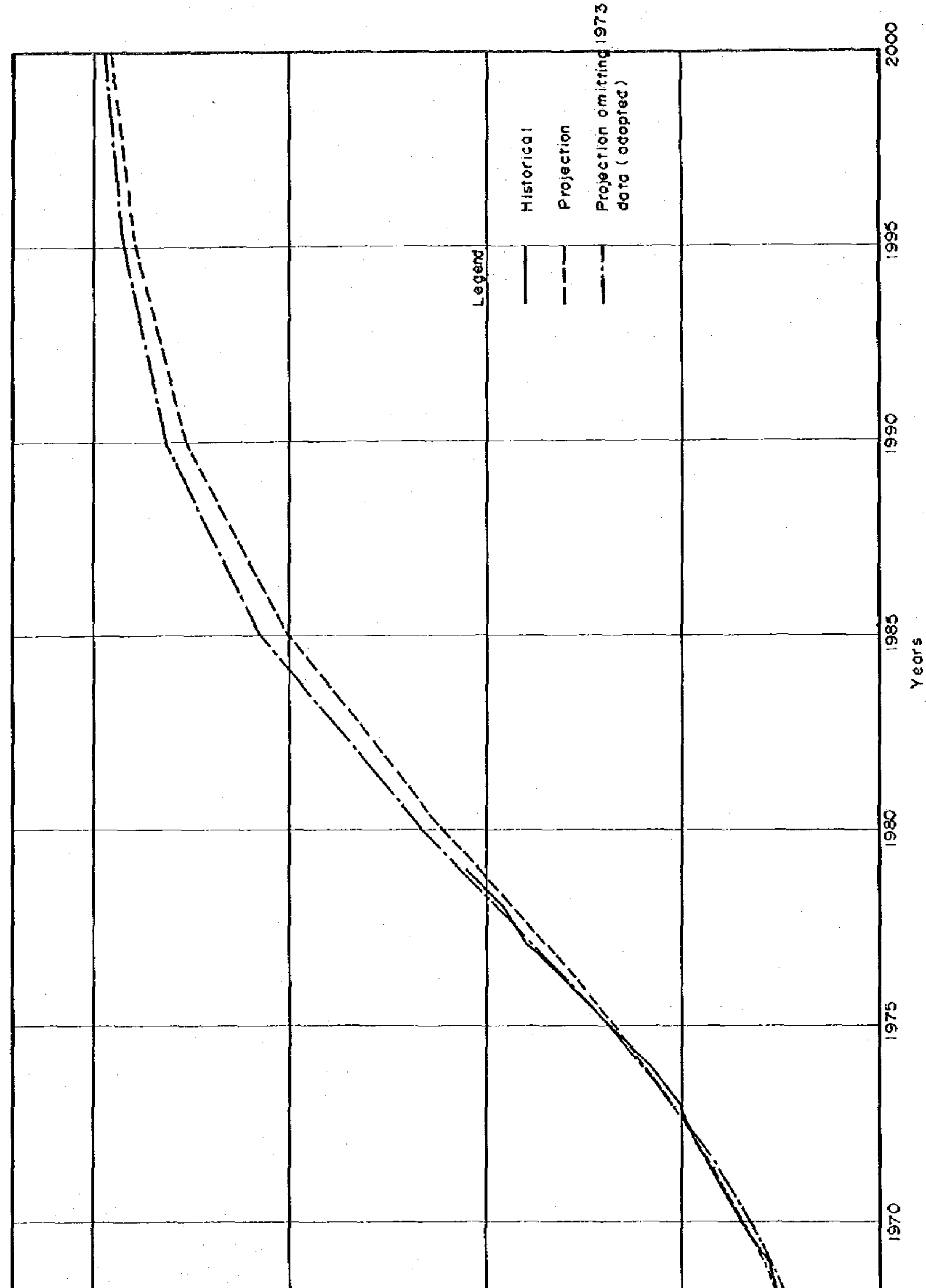
## HISTORICAL AND PROJECTED HOTEL-BEDS OCCUPIED IN COASTAL AREA

Unit: $10^3$ night-bed

| Year | Hotel Night-beds | Growth (%) | Mombasa | Kilifi/Watamu | Malindi/ Lamu |
|---|---|---|---|---|---|
| Historical | | | | | |
| 1968 | 508.2 | - | | | |
| 1969 | 569.0 | 12.0 | | | |
| 1970 | 696.7 | 22.4 | | | |
| 1971 | 815.4 | 17.0 | | | |
| 1972 | 923.9 | 14.4 | | | |
| 1973 | 1,008.4 | 8.1 | 739.9 | 122.0 | 146.5 |
| 1974 | 1,173.6 | 16.4 | 868.4 | 148.3 | 156.9 |
| 1975 | 1,371.6 | 16.9 | 1,051.4 | 146.6 | 173.6 |
| 1976 | 1,575.2 | 14.8 | 1,242.9 | 148.6 | 183.6 |
| 1977 | 1,778.6 | 12.9 | 1,415.6 | 167.8 | 195.1 |
| 1978 | 1,908.4 | 7.3 | 1,508.1 | 174.7 | 225.7 |
| 1979 | 2,111.1 | 10.6 | | | |
| Growth (1968-79) | 13.8% p.a. | | | | |
| Growth (1973-78) | 13.6% p.a. | | 15.3% p.a. | 7.4% p.a. | 9.0% p.a. |
| Projected | | | | | |
| 1980 | 2,331.4 | 10.4 | | | |
| 1985 | 3,152.2 | 6.2 | | | |
| 1990 | 3,632.9 | 2.9 | | | |
| 1995 | 3,853.7 | 1.2 | | | |
| 2000 | 3,943.7 | 0.5 | | | |

Growth (1979-2000) 3.0%p.a.

N.B. Coastal Area Covers: Mombasa Island, North Mainland, South Mainland Malindi/Lamu and Kilifi/Watamu




Historical and Projected Trend of Night- Beds of Tourists in Coastal Area

# WATER DEMAND PROJECTION OF DOMESTIC USE IN MOMBASA AND URBAN CENTRES

## 1. Estimate of Income Group Composition

### 1.1 Weighting Factor by Income Group

| Income Group | 1972 KSh/Month | Group Average | Weighting Factors |
|---|---|---|---|
| High income | 6,000 + | 8,500 | 0.644 |
| Medium " | 2,000 - 6,000 | 3,500 | 0.265 |
| Low " | 0 - 2,000 | 1,200 | 0.091 |
| | | 13,200 | 1.000 |

### 1.2 Estimated Income

1979

| Income Group | % of Population | Weighting Factors | Total Average Income (Index) |
|---|---|---|---|
| High income | 5% | 0.644 | 3.220 |
| Medium " | 45 | 0.265 | 11.925 |
| Low " | 50 | 0.091 | 4.550 |
| | 100 | 1.000 | 19.695 |

Mombasa Income Total: 19.695 x 0.342 mil. person = 6.736

2000

| Income Group | % of Population | Weighing Factors | Total Average Income (Index) |
|---|---|---|---|
| High income | 10% | 0.644 | 6.440 |
| Medium " | 80 | 0.265 | 21.200 |
| Low " | 10 | 0.091 | 0.910 |
| | 100 | 1.000 | 28.550 |

Mombasa Income Total: 28.550 x 0.716 mil. person = 20.442

Growth rate of Mombasa Income in 1979-2000 : 5.43% p.a.

2. Estimate of Daily Per capita Domestic Use

1979

| Income Group | % of Population | Per cap. Demand (1 | Average Demand |
|---|---|---|---|
| High income | 5% | 200 lpcd | 10 |
| Medium " | 45 | 100 | 45 |
| Low " | 50 | 50 | 25 |
| | 100 | | 80 lpcd |

(1 Based on "MOWD Design Manual"

Daily maximum demand inclusive of loss and leakage:

High cost housing : 300 lpcd

Medium " " : 150

Low " " : 75

Assuming daily maximum demand being 50% more than annual average demand.

2000

| Income Group | % of Population | Per cap. Demand | Average Demand |
|---|---|---|---|
| High income | 10 % | 240 lpcd | 24 |
| Medium " | 80 | 120 | 96 |
| Low " | 10 | 60 | 6 |
| | 100 | | 126 lpcd |

WATER DEMAND BY USE IN MOMBASA IN 1979

(Estimated based on CPWB data)

Unit: CMD

| Location | Domestic | Industrial | Tourism | Commercial Public & Others | Total |
|---|---|---|---|---|---|
| Mombasa Island | 17,490 | 1,180 | - | 4,960 | 23,630 |
| North Mainland | 3,560 | 110 | 430 | 1,300 | 5,400 |
| South Mainland | 1,420 | 30 | 760 | 1,090 | 3,300 |
| West Mainland | 2,230 | 3,350 | - | 3,720 | 9,300 |
| Total | 24,700 | 4,670 | 1,190 | 11,070 | 41,630 |
| % to Total | (59) | (11) | (3) | (27) | (100) |
| Per capita (lpcd) | 72 | 14 | 3 | 32 | 122 |

# WATER DEMAND PROJECTION BY USE OF CATEGORIES

## 1. Domestic Demand

Unit: CMD

| Year | Mombasa | Urban | Rural | Total |
|---|---|---|---|---|
| Present Potential | | | | |
| 1979 | 27,360 | 4,080 | 18,980 | 50,420 |
| Projected | | | | |
| 1980 | 29,110 | 4,430 | 20,300 | 53,840 |
| 1985 | 38,490 | 6,190 | 27,620 | 72,300 |
| 1990 | 51,010 | 8,590 | 35,770 | 95,370 |
| 1995 | 67,910 | 11,870 | 48,520 | 128,300 |
| 2000 | 90,220 | 16,130 | 64,720 | 171,070 |
| Growth (1979/2000) | 5.85% | 6.76% | 6.00% | 5.99% |
| Per cap. (2000) | 126 lpcd | 126 lpcd | 44 lpcd | |

## 2. Industrial Demand

| Year | Mombasa | Urban | Rural | Total |
|---|---|---|---|---|
| 1979 | 4,670 | 140 | - | 4,810 |
| Projected | | | | |
| 1980 | 5,220 | 160 | - | 5,380 |
| 1985 | 9,100 | 270 | - | 9,370 |
| 1990 | 15,870 | 480 | - | 16,350 |
| 1995 | 27,660 | 830 | - | 28,490 |
| 2000 | 48,230 | 1,450 | - | 49,680 |
| Growth (1979/2000) | 12% | 12% | | |
| Per ha (2000) | 24 $m^3$/d.ha | 16 $m^3$/d.ha | | |

3. Tourism Demand

Unit: CMD

| Year | Mombasa | Urban [1] | Rural | Total |
|---|---|---|---|---|
| Present Potential | | | | |
| 1979 | 4,540 | 1,520 | - | 6,060 |
| Projected | | | | |
| 1980 | 5,010 | 1,680 | - | 6,690 |
| 1985 | 6,780 | 2,270 | - | 9,050 |
| 1990 | 7,810 | 2,620 | - | 10,430 |
| 1995 | 8,290 | 2,780 | - | 11,070 |
| 2000 | 8,480 | 2,840 | - | 11,320 |
| Growth (1979/2000) | 3.02% | 3.02% | | 3.02% |

4. Commercial, Public and Other Demand

| Year | Mombasa | Urban | Rural | Total |
|---|---|---|---|---|
| Present Potential | | | (Including Livestock Use) | |
| 1979 | 13,840 | 2,050 | 33,000 | 48,890 |
| Projected | | | | |
| 1980 | 14,670 | 2,170 | 34,140 | 50,980 |
| 1985 | 19,630 | 2,900 | 39,250 | 61,780 |
| 1990 | 26,270 | 3,890 | 44,450 | 74,610 |
| 1995 | 35,160 | 5,200 | 51,330 | 91,690 |
| 2000 | 47,050 | 6,960 | 58,840 | 112,850 |
| Growth (1979/2000) | 6.00% | 6.00% | 2.80% | |

Remarks: (1 Including Coast Hinterland of East and West

5. Total Water Demand

Unit: CMD

| Year | Mombasa | Other Urban | Rural | Total |
|---|---|---|---|---|
| Present Potential | | | | |
| 1979 | 50,410 | 7,790 | 51,980 | 110,180 |
| Projected | | | | |
| 1980 | 54,010 | 8,440 | 54,440 | 116,890 |
| 1985 | 74,000 | 11,630 | 66,870 | 152,500 |
| 1990 | 100,960 | 15,580 | 80,220 | 196,760 |
| 1995 | 139,020 | 20,680 | 99,850 | 259,550 |
| 2000 | 193,980 | 27,380 | 123,560 | 344,920 |
| Growth (1979/2000) | 6.63% p.a. | 6.17% p.a | 4.2%p.a. | 5.58% p.a. |
| Per cap. 2000 | 271 lpcd | 214 lpcd | 84 lpcd | |

6. Water Demand by Use

6.1 Mombasa

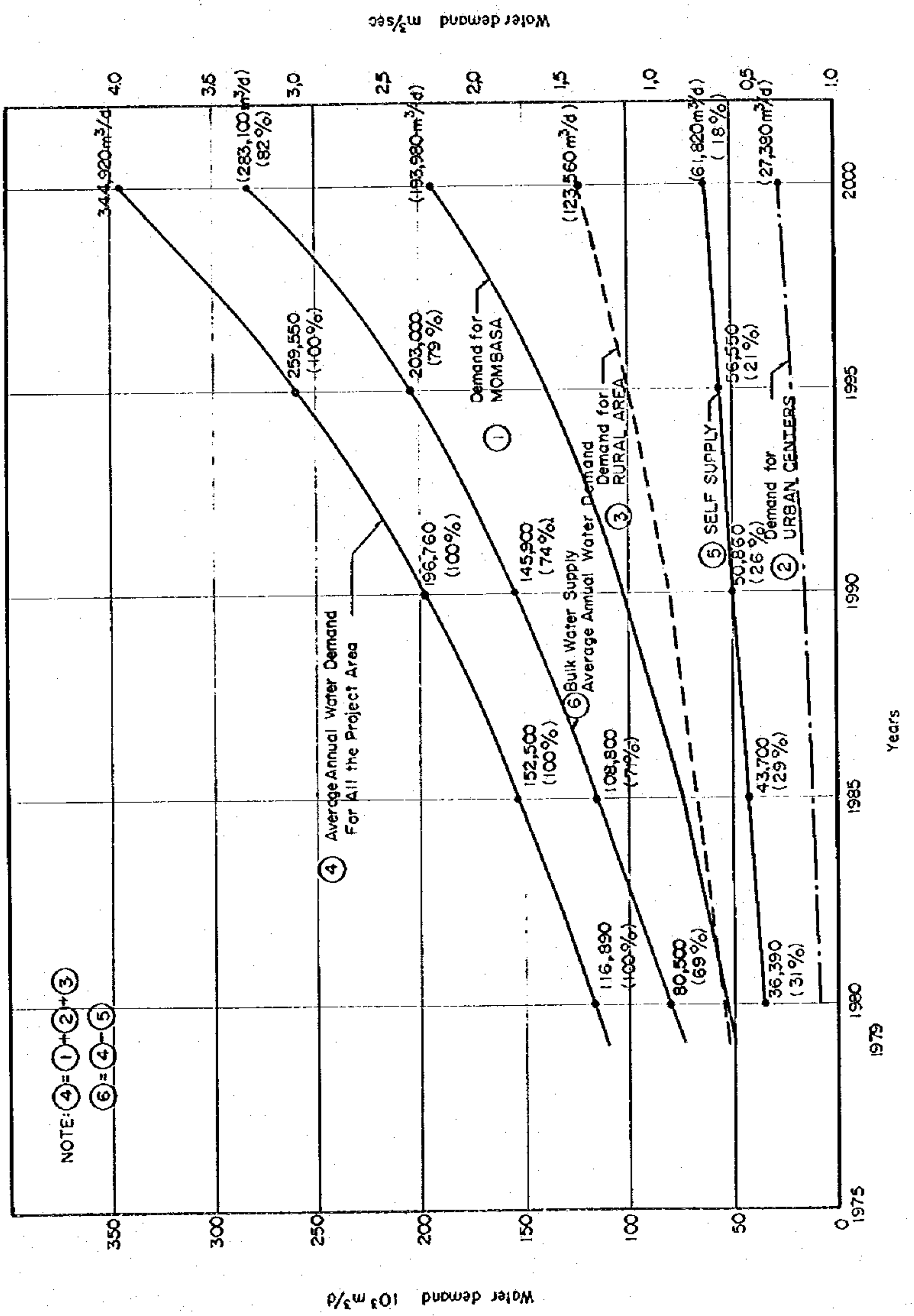
| Year | Domestic | Industrial | Tourism | C.P. & Others | Total |
|---|---|---|---|---|---|
| 1979 | 27,360 (54) | 4,670 (9) | 4,540 (9) | 13,840 (28) | 50,410 (100) |
| 2000 | 90,220 (47) | 48,230 (25) | 8,480 (4) | 47,050 (24) | 193,980 (100) |

6.2 Urban Centers

| Year | Domestic | Industrial | Tourism | C.P. & Others | Total |
|---|---|---|---|---|---|
| 1979 | 4,080 (52) | 140 (2) | 1,520 (20) | 2,050 (26) | 7,790 (100) |
| 2000 | 16,130 (59) | 1,450 (5) | 2,840 (11) | 6,960 (25) | 27,380 (100) |

6.3 Rural Areas

| Year | Domestic | Livestock | Tourism | C.P. & Others | Total |
|---|---|---|---|---|---|
| 1979 | 18,980 (37) | 25,200 (48) | - | 7,800 (15) | 51,980 (100) |
| 2000 | 64,720 (52) | 40,310 (33) | - | 18,530 (15) | 123,560 (100) |




Water Demand Projection

# HIGH AND LOW GROWTH WATER DEMAND PROJECTION

## 1. High Growth Water Demand

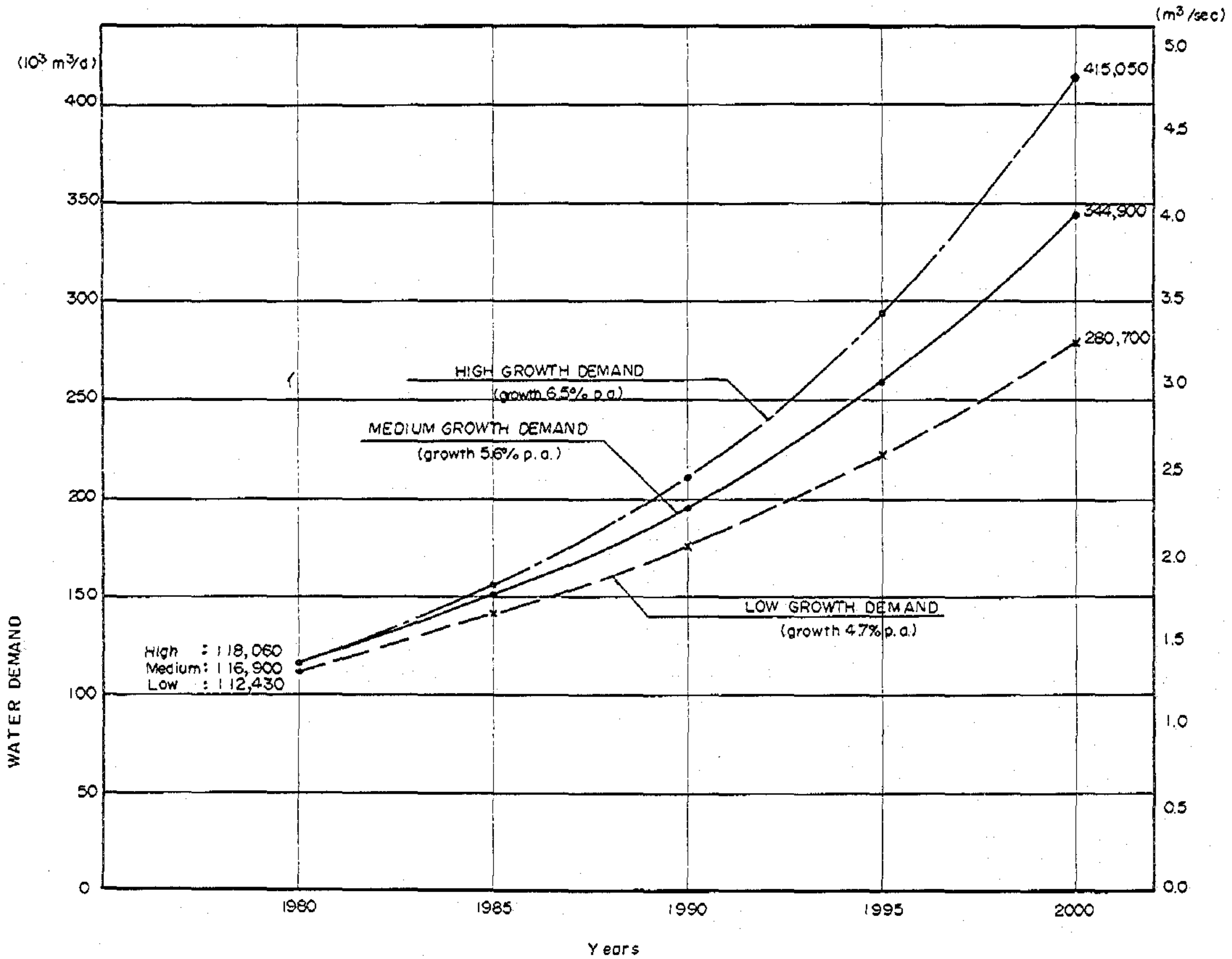
Unit: CMD

| Year | Mombasa | Other | Rural | Total |
|---|---|---|---|---|
| 1980 | 54,830 | 8,630 | 54,600 | 118,060 |
| 1985 | 78,220 | 12,240 | 68,500 | 158,960 |
| 1990 | 111,640 | 16,840 | 86,000 | 214,480 |
| 1995 | 161,810 | 23,130 | 111,100 | 296,040 |
| 2000 | 241,330 | 31,720 | 142,000 | 415,050 |
| Growth p.a. (1979/2000) | 7.7% | 6.7% | 4.9% | 6.5% |
| Per Cap. 2000 | 307 lpcd | 228 lpcd | 88 lpcd | |

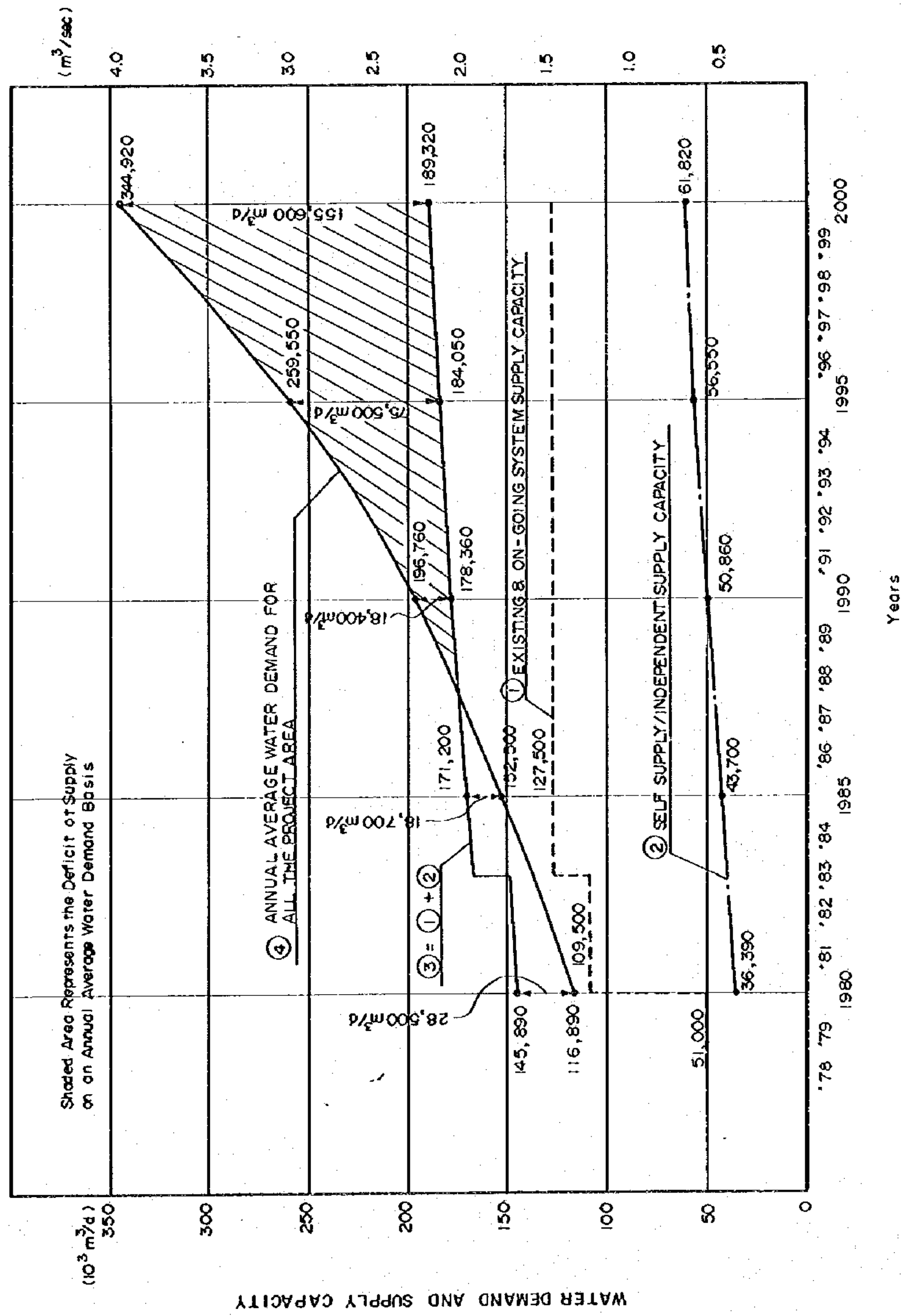
## 2. Low Growth Water Demand

Unit: CMD

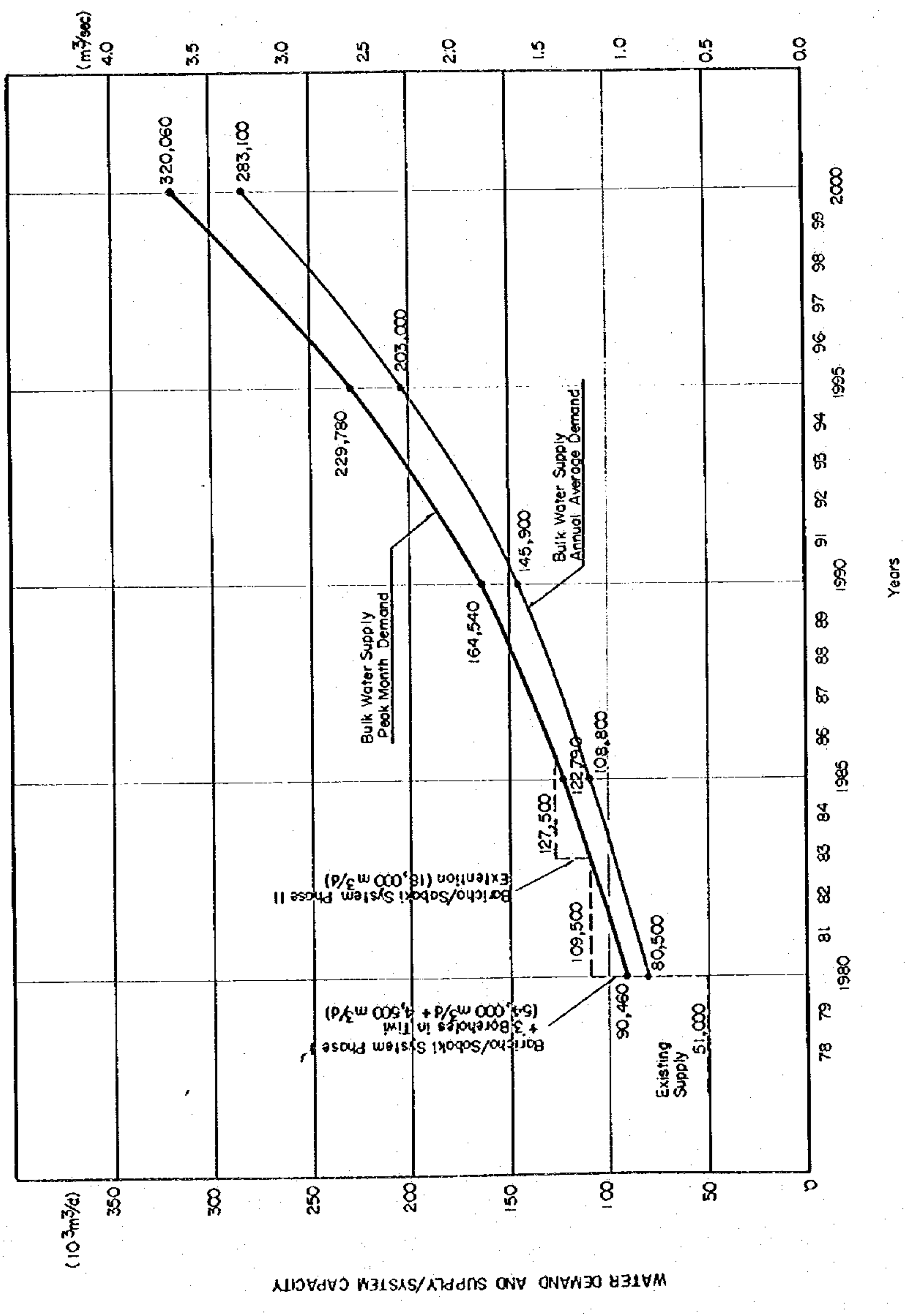
| Year | Mombasa | Other | Rural | Total |
|---|---|---|---|---|
| 1980 | 53,290 | 8,240 | 50,900 | 112,430 |
| 1985 | 70,730 | 11,070 | 61,400 | 143,200 |
| 1990 | 92,740 | 14,390 | 70,800 | 177,930 |
| 1995 | 121,730 | 18,500 | 85,900 | 226,130 |
| 2000 | 158,890 | 23,110 | 98,700 | 280,700 |
| Growth p.a. (1979/2000) | 5.6% | 5.3% | 3.4% | 4.7% |




ANNUAL AVERAGE WATER DEMAND HIGH AND LOW PROJECTION




NET WATER DEMAND PROJECTION



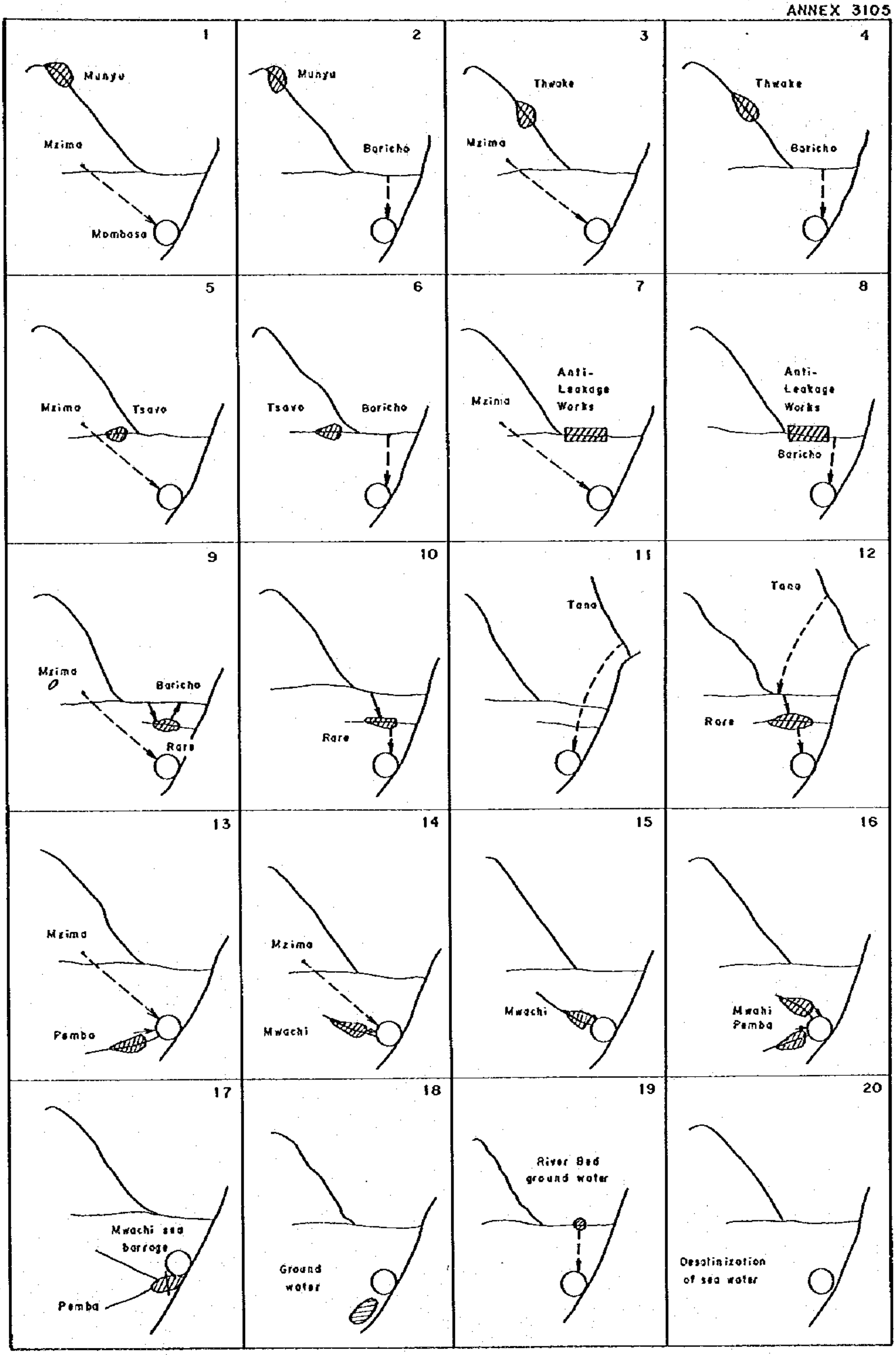

WATER DEMAND VERSUS EXISTING AND ON-GOING SYSTEM SUPPLY CAPACITY

# PEAK MONTH DEMAND PROJECTION FOR ALL AREAS

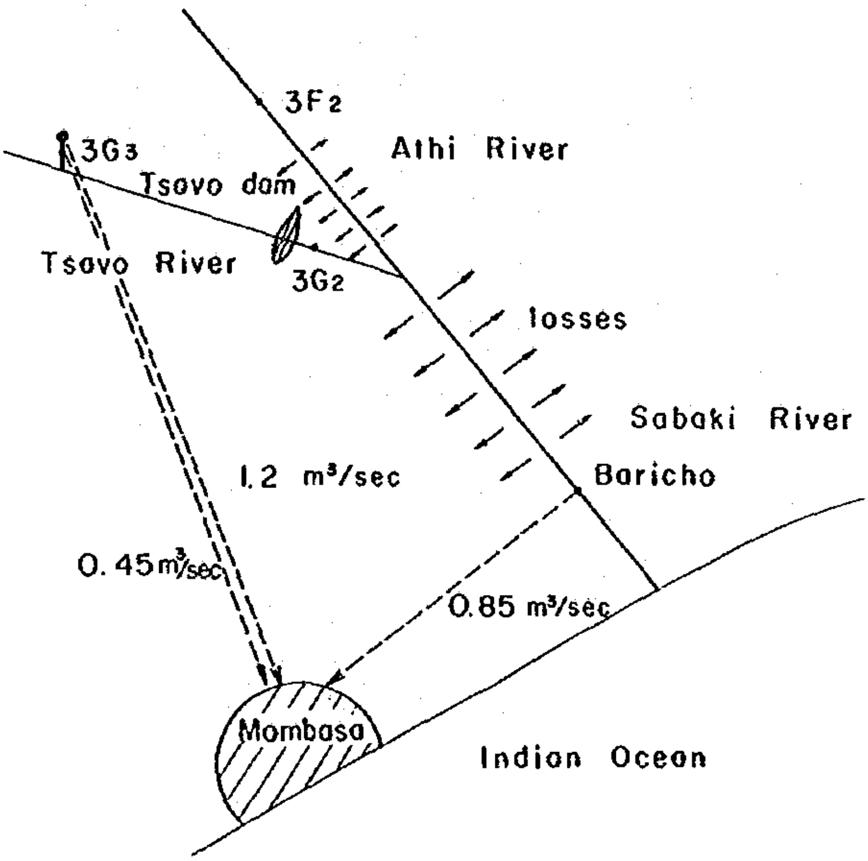
Unit: $m^3$/day

| DEMAND AREAS | 1980 | | 1985 | | 1990 | | 1995 | | 2000 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (1) | (2) | (1) | (2) | (1) | (2) | (1) | (2) |
| 1. Kirifi | | | | | | | | | | |
| (1) Urban center | 5,650 | 7,350 | 7,680 | 9,990 | 10,190 | 13,200 | 13,630 | 17,710 | 17,160 | 22,310 |
| (2) Rural | 8,500 | 9,960 | 12,010 | 14,180 | 16,350 | 19,300 | 22,870 | 27,210 | 31,420 | 37,650 |
| 2. Kwale | | | | | | | | | | |
| (1) Urban center | 640 | 830 | 870 | 1,130 | 1,150 | 1,500 | 1,540 | 2,000 | 2,080 | 2,700 |
| (2) Rural | 8,760 | 9,440 | 10,410 | 11,480 | 12,400 | 13,670 | 19,980 | 22,310 | 30,550 | 34,240 |
| 3. Taita/Traveta | | | | | | | | | | |
| (1) Urban center | 1,200 | 1,560 | 1,640 | 2,130 | 2,180 | 2,800 | 2,900 | 3,770 | 3,920 | 5,100 |
| (2) Rural | 1,760 | 1,960 | 2,170 | 2,450 | 2,630 | 2,970 | 3,230 | 4,070 | 3,960 | 4,620 |
| 4. Sub-total | | | | | | | | | | |
| (1) Urban center | 7,490 | 9,740 | 10,190 | 13,250 | 13,520 | 17,500 | 18,070 | 23,480 | 23,160 | 30,110 |
| (2) Rural | 19,020 | 21,360 | 24,590 | 28,110 | 31,380 | 35,940 | 46,080 | 53,590 | 65,930 | 76,510 |
| 5. Mombasa | 53,960 | 59,360 | 74,030 | 81,430 | 101,000 | 111,100 | 138,830 | 152,710 | 194,040 | 213,440 |
| 6. Grand-total | 80,470 | 90,460 | 108,810 | 122,790 | 145,900 | 164,540 | 202,980 | 229,780 | 283,130 | 320,060 |
| | (0.93$m^3$/sec) | (1.05$m^3$/sec) | (1.26$m^3$/sec) | (1.42$m^3$/sec) | (1.69$m^3$/sec) | (1.90$m^3$/sec) | (2.35$m^3$/sec) | (2.66$m^3$/sec) | (3.28$m^3$/sec) | (3.70$m^3$/sec) |

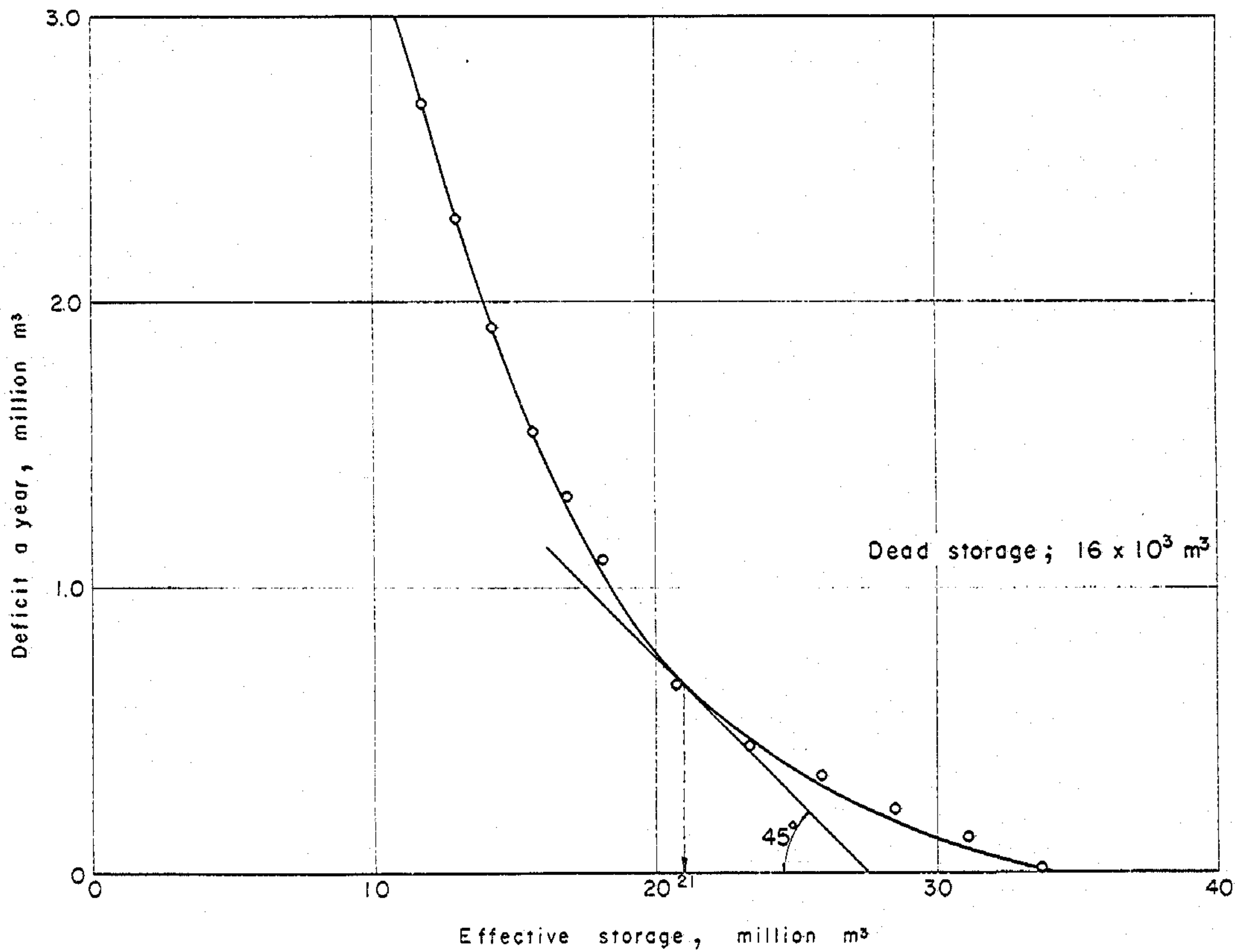
Notes: (1) Annual Average Base
(2) Peak Month Base



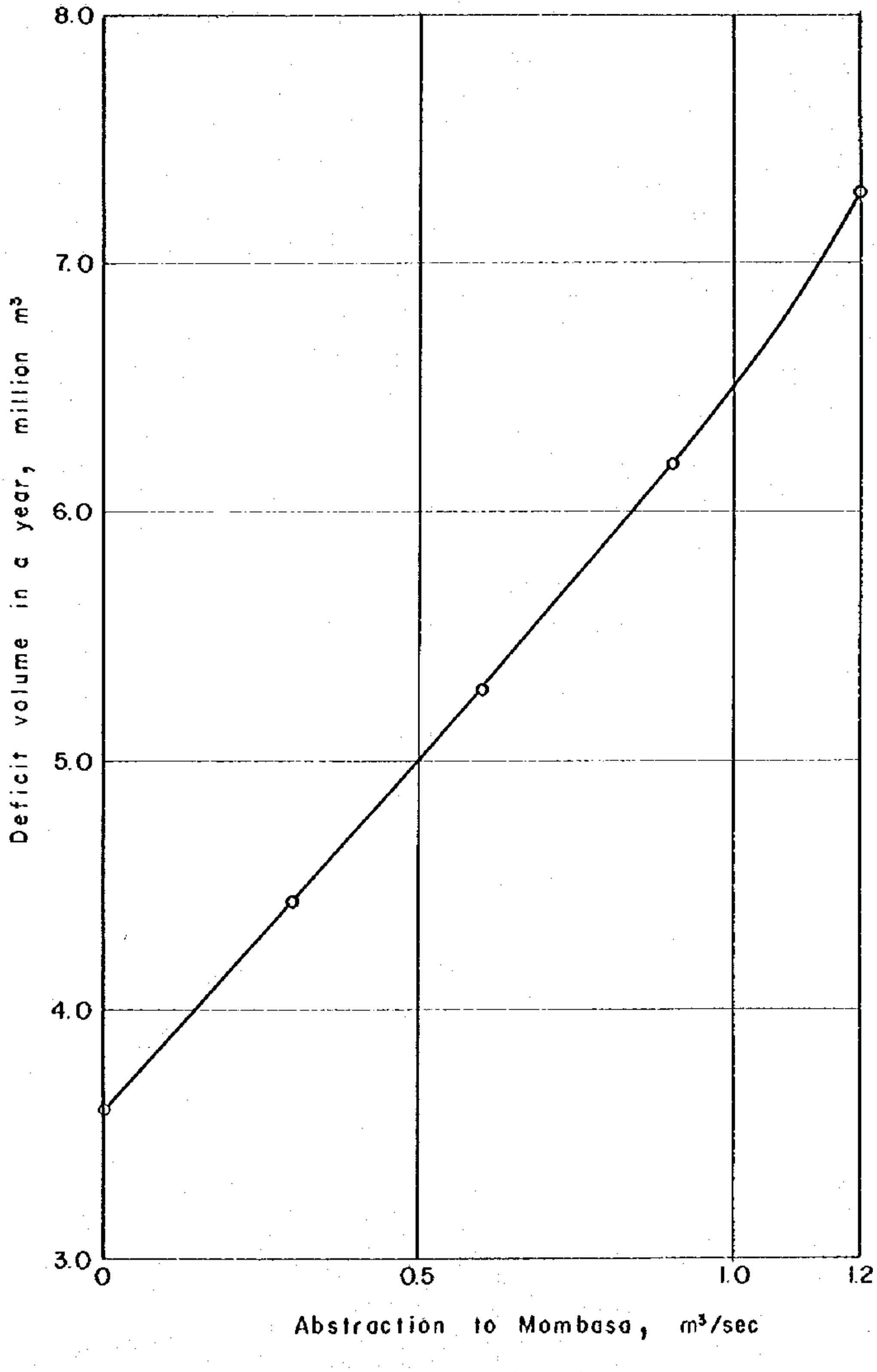

CONCEIVABLE PLANS



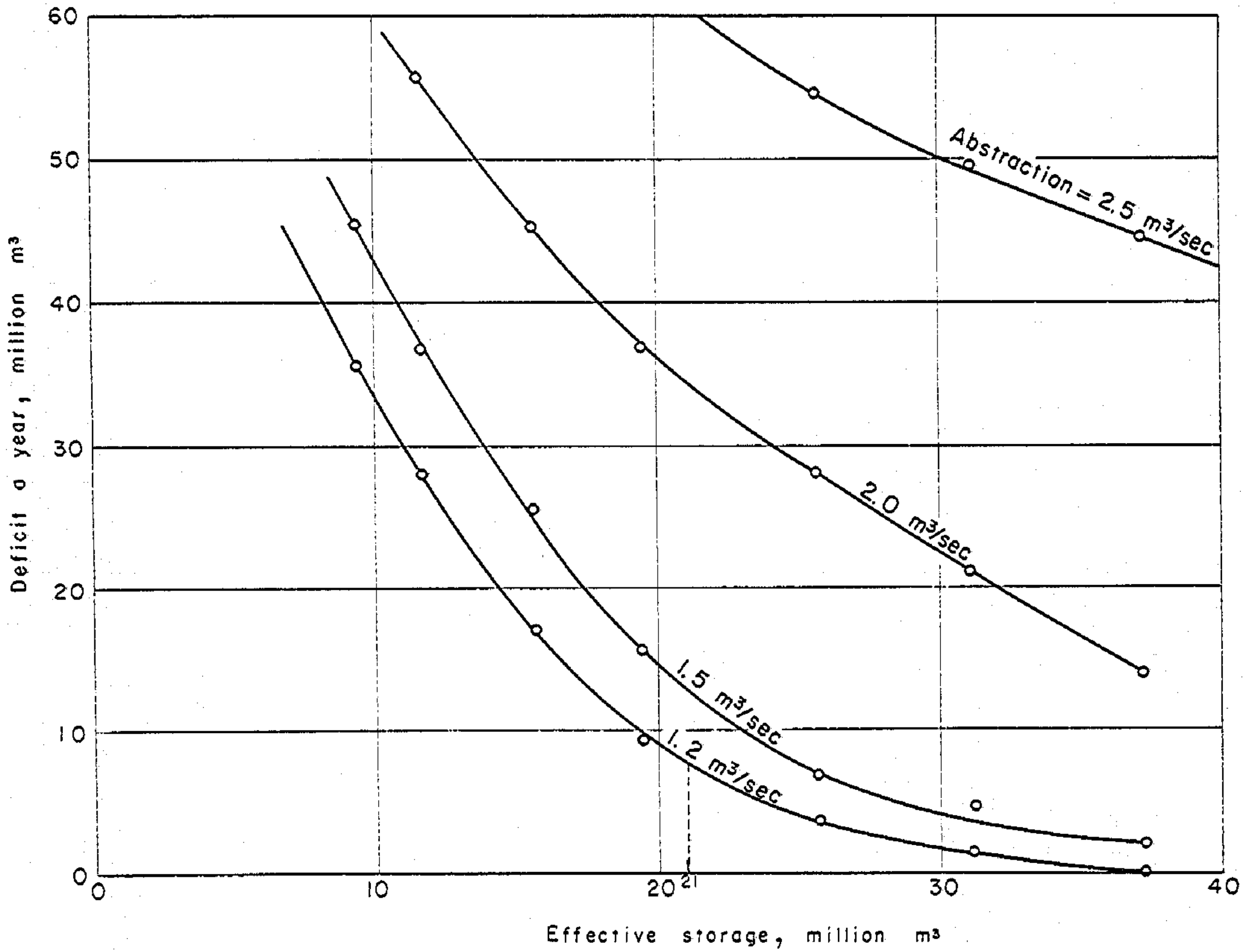

A Simulation Model to Estimate Reservoir Capacity Required for the Tsavo Reservoir



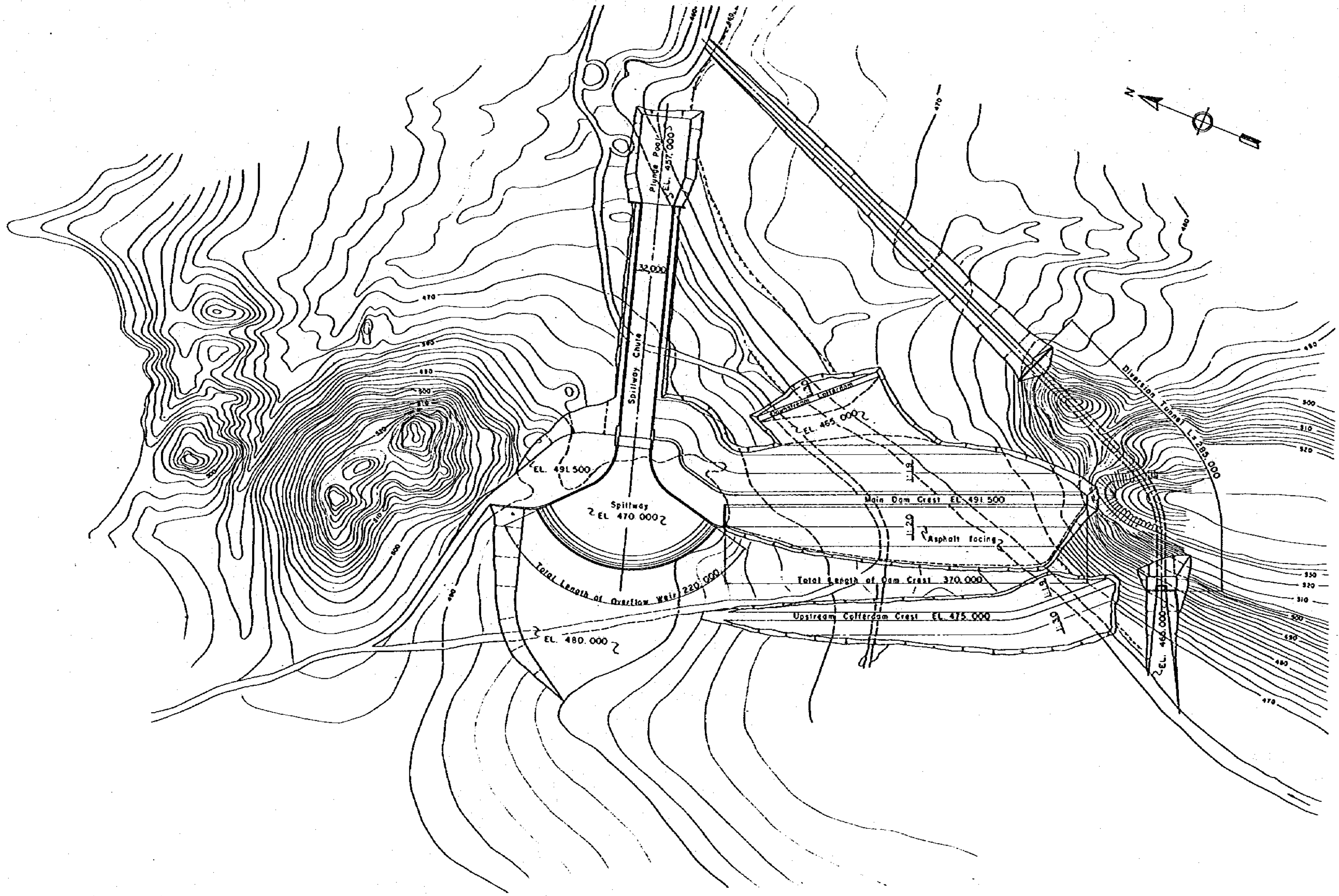

Reservoir Capacity Required for the Tsavo Reservoir



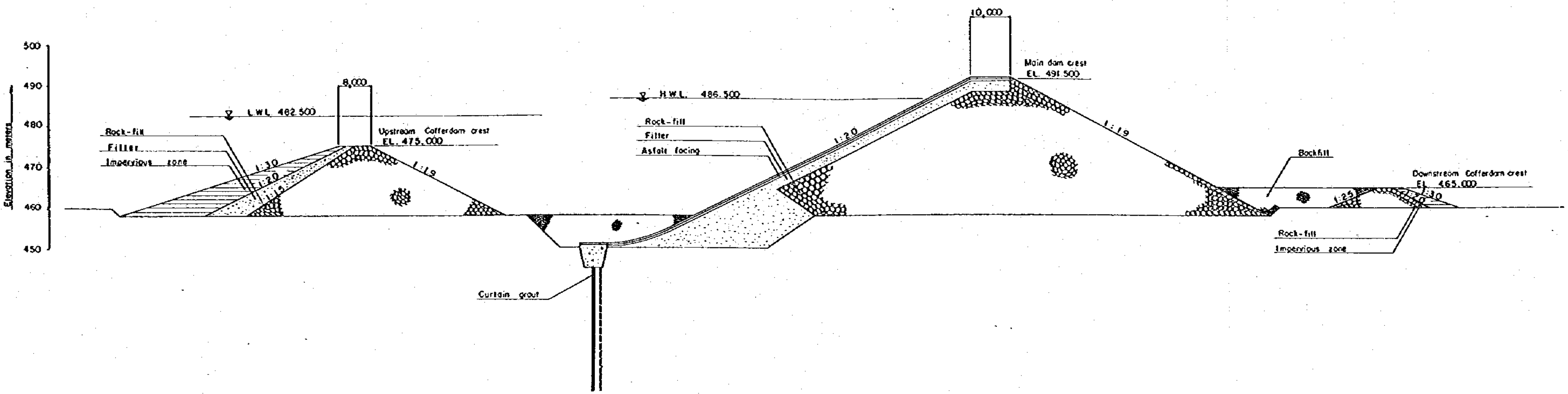

Deficit on the Sabaki River by Changing Abstraction to Mombasa without the Tsavo Dam



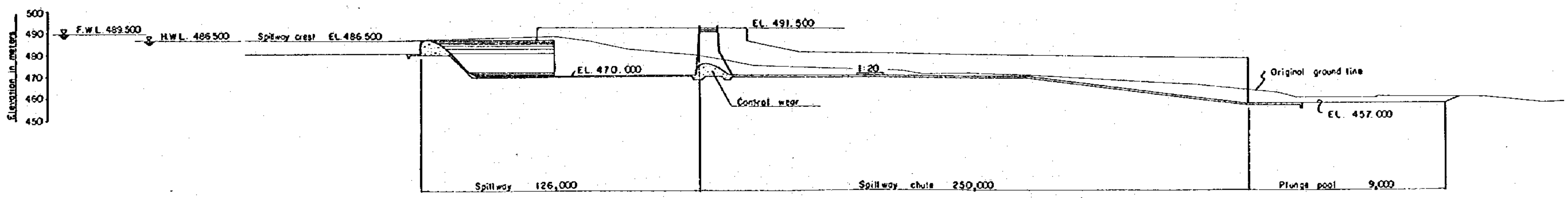

Reservoir Capacity Required for the Tsavo Reservoir
(Abstraction is made from the reservoir)




PLAN OF TSAVO DAM SCALE 1: 2,000




CROSS SECTION OF TSAVO DAMS SCALE 1:500




PROFILE OF SPILLWAY SCALE 1:1000

# FLOOD ESTIMATES AT TSAVO DAM SITE

## A. General

1. Monthly mean discharge at the dam site (3G2) is collected for the development of water resources as mentioned in Chapter 6 of the Inventory Report. Flood runoff is estimated for the design of spillway and diversion facilities. The prediction of flood discharge is made based on the relationship between rainfall and discharge, since flood peak is not well estimated by reading the gauge height once a day.

## B. Frequency Analysis

### a. Rainfall

2. There are three rainfall gauging stations in and around the watershed. Those are the stations near the Mzima Springs (93-38-17), Ngulia lodge (93-38-27) and Tsavo gate (93-38-28). Measurement of the first station was started on March 1950 and maximum daily rainfall in a year is available, while measurement of remaining two stations was started on January 1971. Rainfall data for the two stations are not long enough for the frequency analysis. Thus, rainfall data of the only one station are available for the whole basin.

3. Annual maximum daily rainfall data of the three stations are collected from the Hydrology Section of MOWD as tabulated in page 5 of 9 of the ANNEX. Frequency analysis of rainfall is made by the above data.

b. Frequency Analysis

4. Several frequency distributions are adopted for determing the recurrence interval of the hydrologic event of a given magnitude x, because there is no information which distribution is well fitted to the hydrologic event. Frequency distributions applied are extremal distribution type I (Gumbel method), Pearson type III and log-normal (Iwai method).

5. The results of frequency analysis by the three methods are depicted in page 6 of 9 of the ANNEX. The biggest value among ones estimated by the three methods is adopted as the magnitude for each recurrence interval. Though the frequency analysis is made by the data of a station, namely point rainfall, it is assumed that rainfall of the station represents rainfall of this basin.

6. Probable maximum precipitation (PMP) at the station 93-38-17 is estimated based on the empirical method developed by Herschield. The formula is expressed as follows;

$$X \max = \mu + 15\sigma$$

where $\mu$ and $\sigma$ are mean and standard deviation of samples, X max is the extreme value of 24-hour point rainfall and 15 is empirically derived from records in the United States.

7. The statistical parameters, mean and standard deviation of records at 93-38-17 are 50.5 and 29.0 mm, respectively. The probable maximum precipitation is

$$X \max = 50.5 + 15 \times 29.0$$
$$= 485.5 \text{ mm}$$

8. The reduction factor which is the parameter to reduce from the point rainfall to the basin average rainfall is assumed to be 0.6, because hyetal maps of rainstorms are not prepared. PMP in the basin is obtained multiplying 0.6 by PMP of the point;

$$PMP_{basin} = 485.5 \times 0.6$$
$$= 291.3 \text{ mm}$$

C. Estimates of Flood

a. Unit Hydrograph

9. For predicting flood discharge from rainfall, the response function between rainfall (input) and discharge (output) is determined. Though there are several mathematical models to express the response function of a basin, the unit hydrograph method is applied for the estimate of flood discharge, because rainfall and flood discharge data are not enough for the identification of parameters included in the mathematical models.

10. The flood recorded on April 14, 1967 is selected as the flood to determine the unit hydrograph as depicted in page 7 of 9 of the ANNEX. The first peak of the flood might be caused by the rainstorm on April 12, 1967 which is shown in page 5 of 9 of the ANNEX. However, there is no information of the rainstorm caused the second peak of the flood. Thus, the second peak of the flood is eliminated by assuming that the recession limb on the first flood is exponentially regressed as shown in the dotted line.

11. For the estimate of rainfall excess on the flood, the drainage area in the upper reaches of the Loolturesh River is excluded, since flood discharge of the Loolturesh River is retained in seasonal swamps.

The drainage area for flood estimate is decided to be 4,050 $Km^2$, by which the runoff coefficient is calculated to be 0.23 for the flood on April 14, 1967. The rainfall excess is estimated to be 3.8 mm (0.023 x 163.3 mm).

12. If the rainfall excess of the unit hydrograph is defined to be 10 mm, the unit hydrograph is obtained as shown in page 8 of 9 of the ANNEX. Hydrographs of 10-year and 200-year recurrence intervals are depicted as shown in page 9 of 9 of the ANNEX assuming that the runoff factor of rainfall for each recurrence interval is 0.4. The 10-year flood is used as the design flood of the diversion facilities. According to the Code of Japan on fill-type dams, the design flood for the spillway is defined as the flood with 1.2 times discharge of the 200-year flood. Applying this Code, the design flood for the spillway and the probable maximum flood estimated from PMP are shown in page 9 of 9 of the ANNEX.

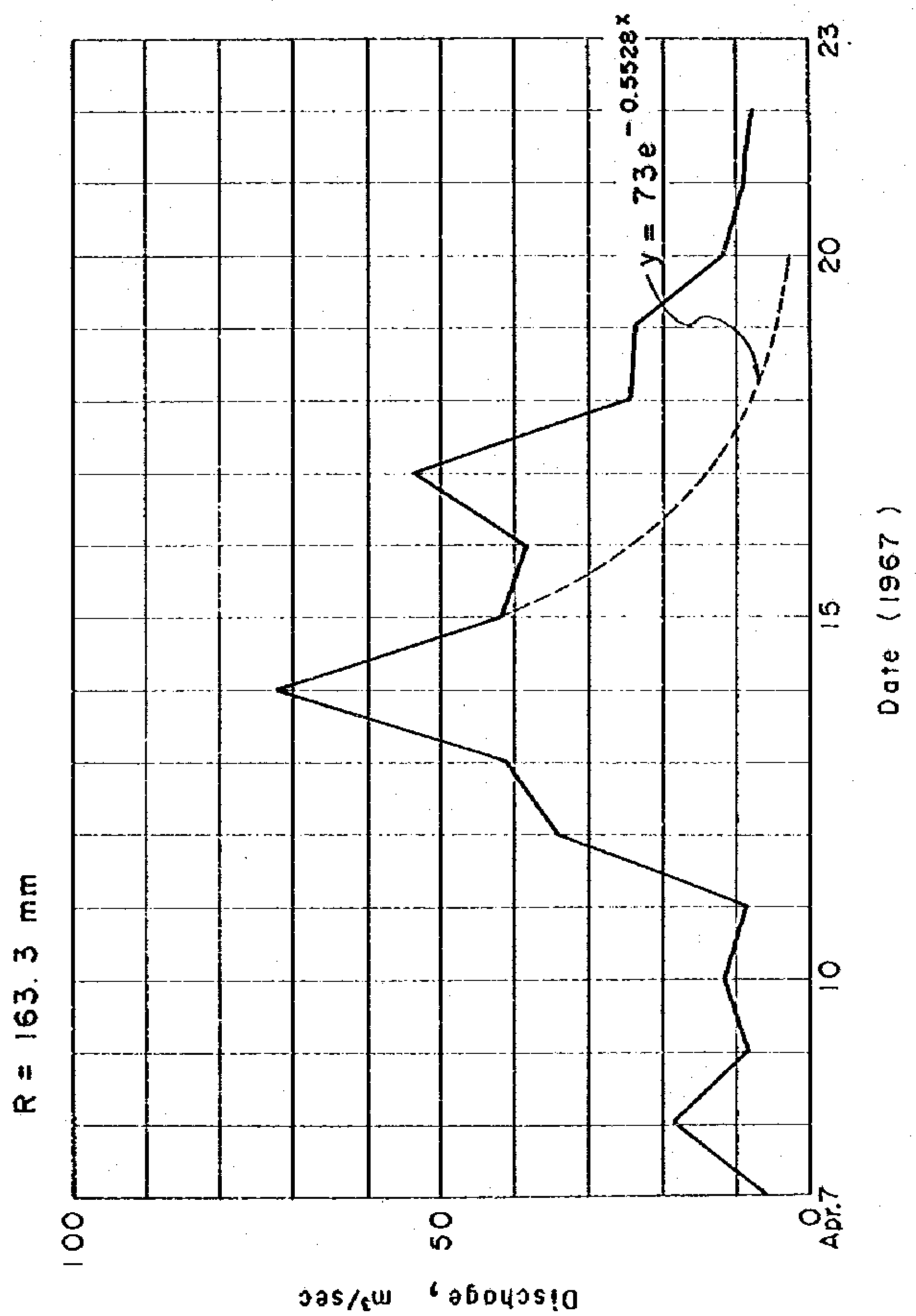
Annual Maximum Daily Rainfall

| Year | Station 93.38.17 max. daily rainfall, mm | 93.38.17 date | 93.38.27 max. daily rainfall, mm | 93.38.27 date | 93.38.28 max. daily rainfall, mm | 93.38.28 date |
|---|---|---|---|---|---|---|
| 1950 | 31.8 | Apr.27 | | | | |
| 51 | 46.0 | Apr.16 | | | | |
| 52 | 89.2 | Apr.13 | | | | |
| 53 | 36.1 | Jan. 1 | | | | |
| 54 | 89.4 | Apr. 8 | | | | |
| 55 | 41.9 | Dec.13 | | | | |
| 56 | - | - | | | | |
| 57 | 79.5 | Jan.23 | | | | |
| 58 | - | - | | | | |
| 59 | 11.4 | Nov.26 | | | | |
| 1960 | 42.7 | Jan.21 | | | | |
| 61 | 27.9 | Apr. 9 | | | | |
| 62 | 33.3 | Dec. 3 | | | | |
| 63 | 39.1 | - | | | | |
| 64 | 34.3 | - | | | | |
| 65 | 37.3 | Jan. 4 | | | | |
| 66 | 34.5 | | | | | |
| 67 | 163.3 | Apr.12 | | | | |
| 68 | 44.7 | Dec. 6 | | | | |
| 69 | 53.1 | Dec. - | | | | |
| 1970 | 37.6 | Mar. - | | | | |
| 71 | 39.9 | Dec. - | 55.8 | Dec. - | 81.0 | Apr. - |
| 72 | 47.6 | Feb. - | 60.6 | Nov. - | 77.2 | Dec. - |
| 73 | 50.8 | Apr. - | 88.2 | Nov. - | 30.3 | Jan. - |
| 74 | 33.7 | Mar. - | 38.5 | Apr. - | 40.0 | Oct. - |
| 75 | 38.3 | Apr. - | 30.0 | Nov. - | 35.2 | Nov. - |
| 76 | 45.5 | Apr. - | 66.5 | Nov. - | 47.5 | Sep. - |
| 77 | 60.0 | Jan. - | 71.3 | Dec. - | 44.8 | Apr. - |
| 78 | 74.7 | Jan. - | 59.4 | Nov. - | 86.3 | Dec. - |
| 79 | - | - | 34.0 | May - | 60.0 | Feb. - |

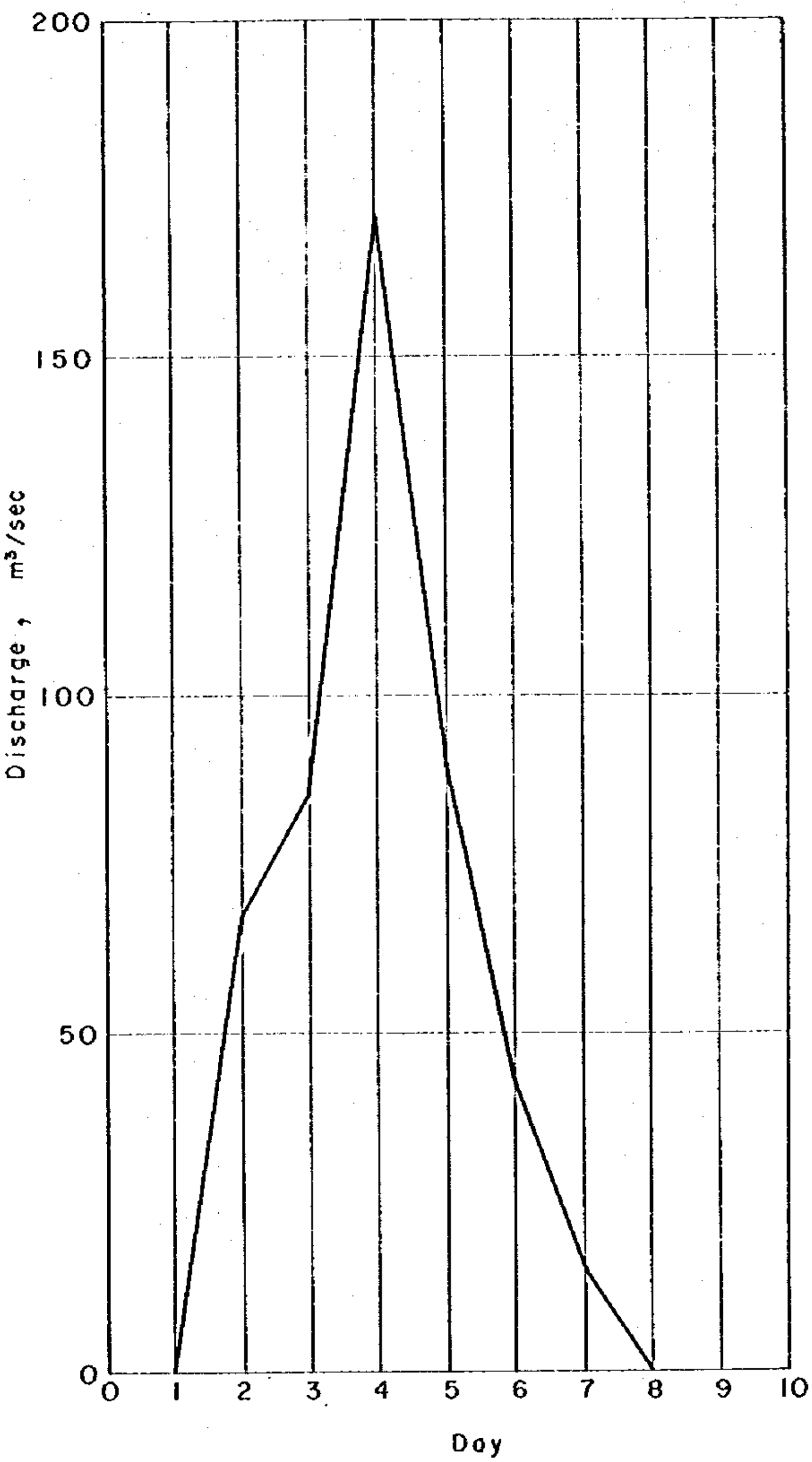
## Probable Daily Rainfall

Unit; mm/day

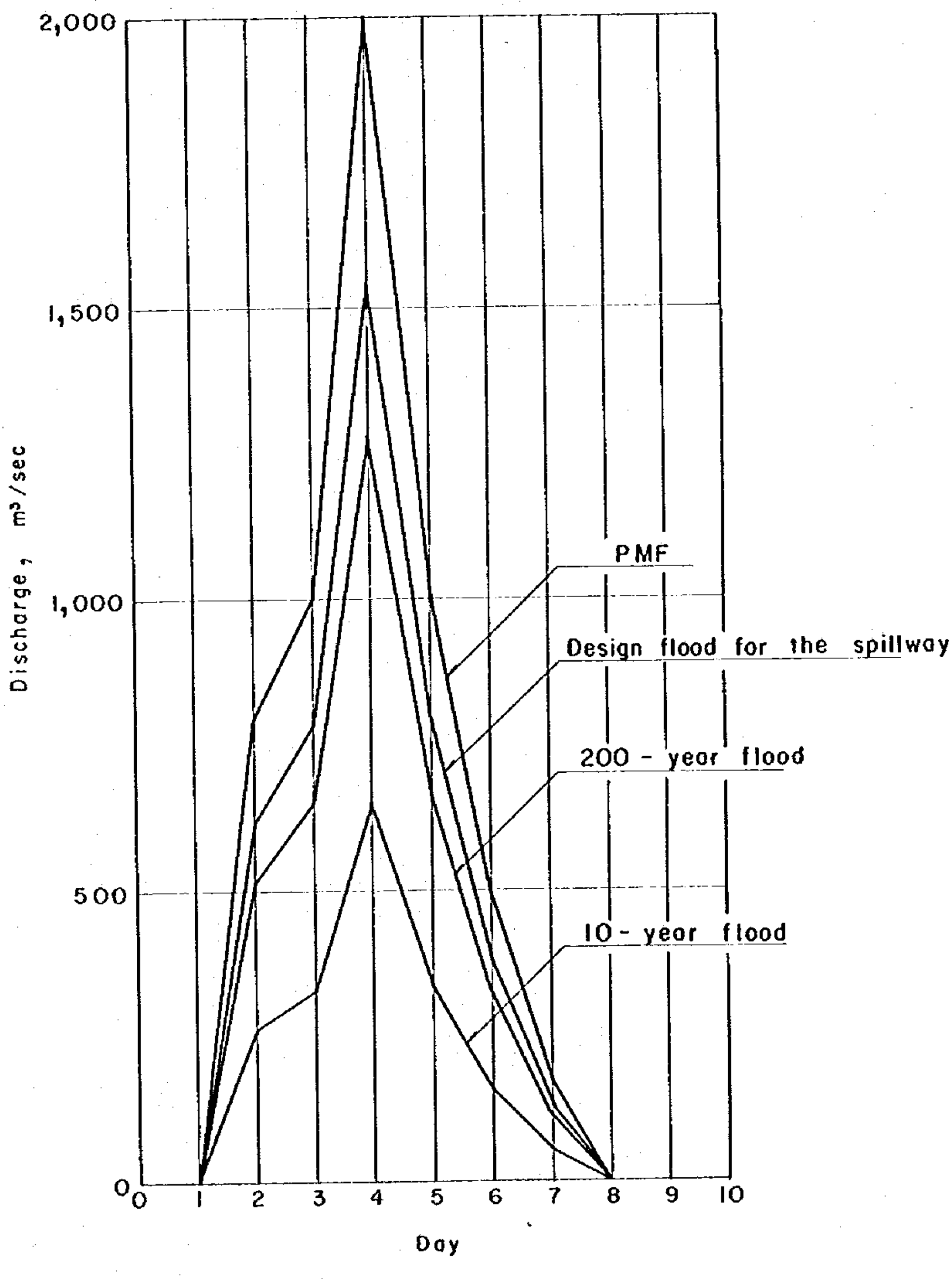
| Return period (Year) | Method applied | | |
|---|---|---|---|
| | Gumbel | Pearson III | Iwai |
| 2 | 46 | 40 | 45 |
| 5 | 76 | 66 | 67 |
| 10 | 95 | 87 | 83 |
| 20 | 114 | 109 | 99 |
| 25 | 119 | 116 | 104 |
| 50 | 138 | 140 | 121 |
| 100 | 156 | 163 | 138 |
| 200 | 174 | 188 | 155 |
| 500 | 198 | 223 | 180 |
| 1000 | 215 | 253 | 199 |



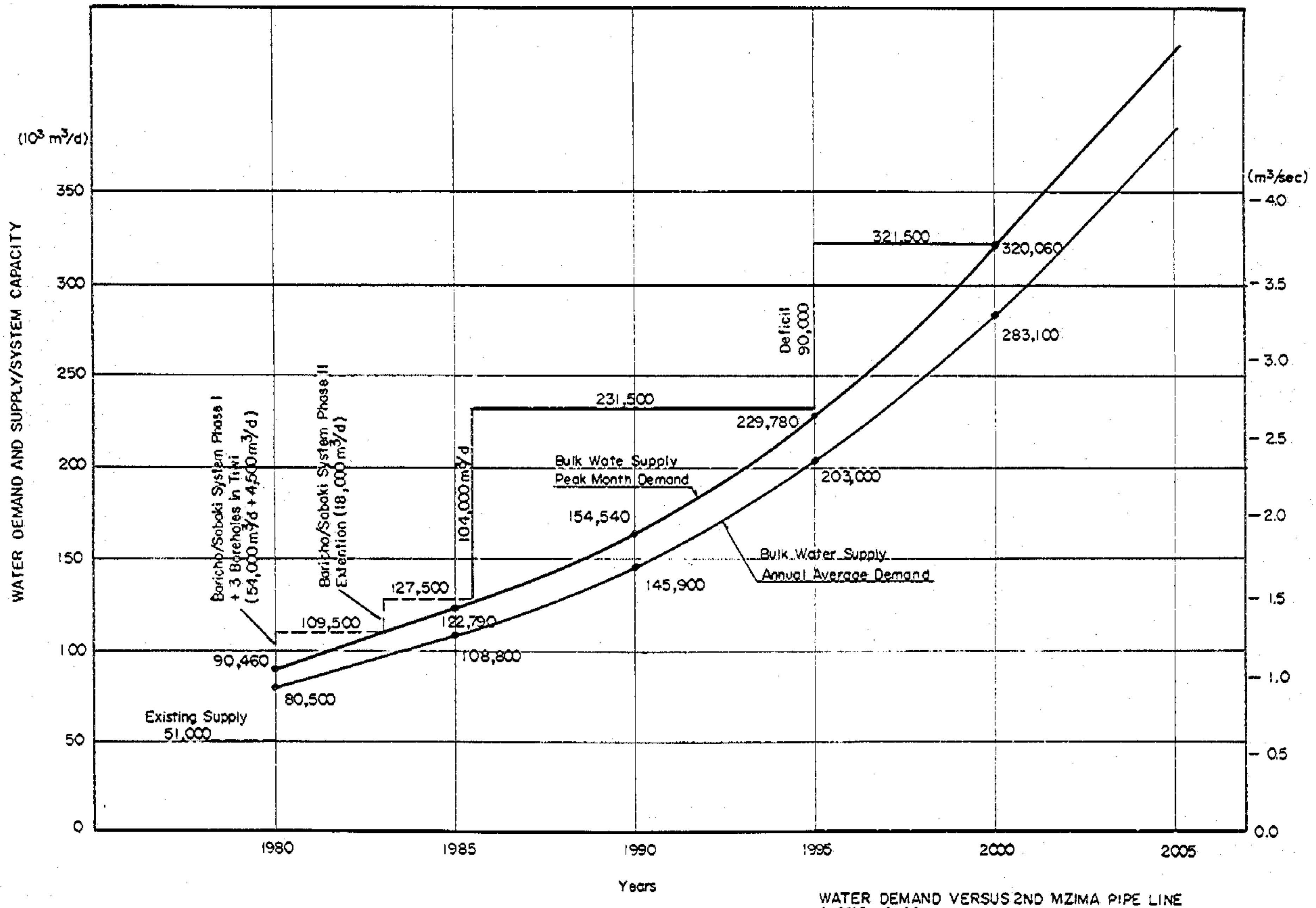

Flood Dated April 14, 1967




Unit Hydrograph at Tsavo Dam Site




Design Floods at Tsavo Dam Site




WATER DEMAND VERSUS 2ND MZIMA PIPE LINE SYSTEM SUPPLY CAPACITY

(2nd MZIMA P/L PLAN)

ESTIMATED 1995 DEMAND AND SOURCES OF SUPPLY

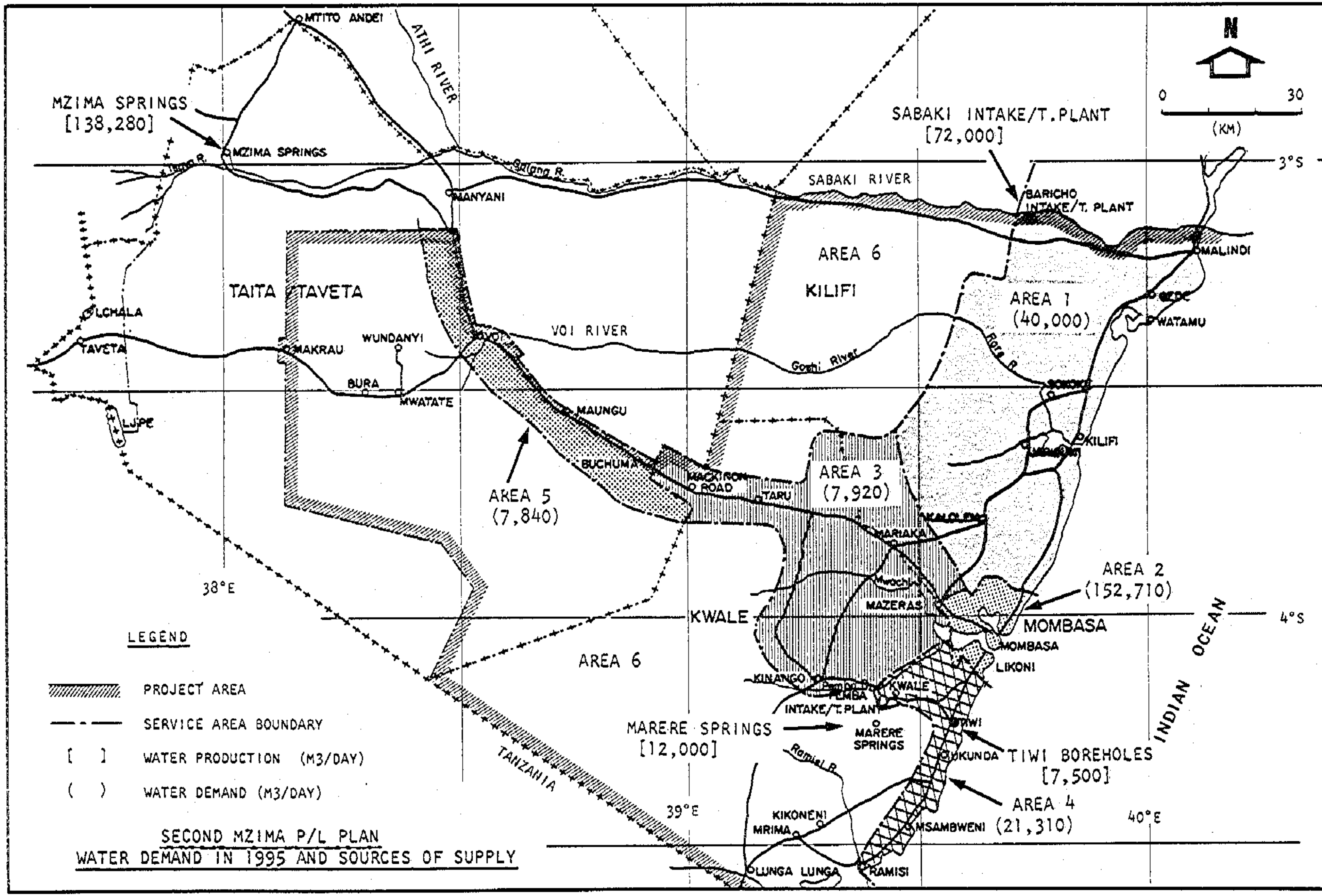
(PEAK MONTH DEMAND)

| AREA | Total Demand $m^3/d$ | SOURCES OF SUPPLY Mzima P/L I&II $m^3/d$ | Marere P/L $m^3/d$ | Tiwi B.H. P/L $m^3/d$ | Sabaki P/L $m^3/d$ |
|---|---|---|---|---|---|
| 1. Mombasa Is | 55,000 | 55,000 | - | - | - |
| 2. West Mainland | 42,710 | 42,710 | - | - | - |
| 3. North Mainland | 40,000 | 8,000 | - | - | 32,000 |
| 4. South Mainland | 15,000 | 15,000 | - | - | - |
| 5. Kilifi District | 40,000 | - | - | - | 40,000 |
| 6. Kwale District North | 500 | 500 | - | - | - |
| 7. Kwale District Central | 2,500 | 2,500 | - | - | - |
| 8. Kwale District South | 21,310 | 1,810 | 12,000 | 7,500 | - |
| 9. Taita District | 7,840 | 7,840 | - | - | - |
| 10. Kilifi South | 4,920 | 4,920 | - | - | - |
| | 229,780 | 138,280 | 12,000 | 7,500 | 72,000 |

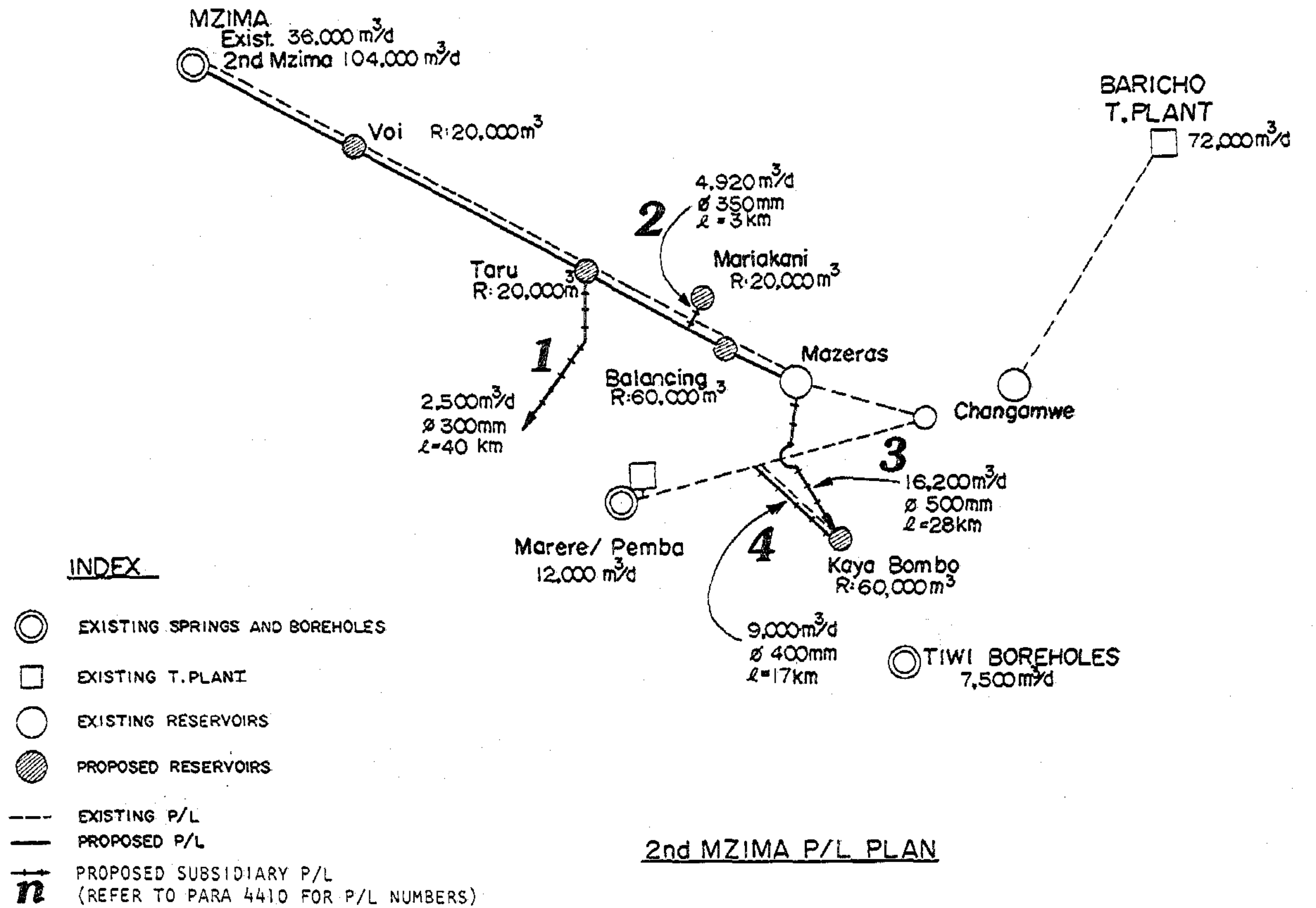
(2nd MZIMA P/L PLAN)

ESTIMATED 1990 DEMAND AND SOURCES OF SUPPLY

| AREA | Total Demand $m^3/d$ | SOURCES OF SUPPLY Mzima P/L I&II $m^3/d$ | Marere P/L $m^3/d$ | Tiwi B.H. P/L $m^3/d$ | Sabaki P/L $m^3/d$ |
|---|---|---|---|---|---|
| 1. Mombasa | 39,000 | 39,000 | - | - | - |
| 2. West Mainland | 33,100 | 33,100 | - | - | - |
| 3. North Mainland | 28,000 | - | - | - | 28,000 |
| 4. South Mainland | 11,000 | 4,670 | 6,330 | - | - |
| 5. Kilifi District | 29,500 | - | - | - | 29,500 |
| 6. Kwale District North | 500 | 500 | - | - | - |
| 7. Kwale District Central | 1,500 | 1,500 | - | - | - |
| 8. Kwale District South | 13,170 | - | 5,670 | 7,500 | - |
| 9. Taita District | 5,770 | 5,770 | - | - | - |
| 10. Kilifi South | 3,000 | 3,000 | - | - | - |
| | 164,540 | 87,540 | 12,000 | 7,500 | 57,500 |




SECOND MZIMA P/L PLAN
WATER DEMAND IN 1995 AND SOURCES OF SUPPLY




2nd MZIMA P/L PLAN

# Design Criteria for the Project

## 1. Design capacity

General

(1) Intake facilities including intake pumps:
peakmonth demand x 1.10 (loss of treatment 10%)

(2) Treatment plant: peakmonth demand x 1.10 (loss of treatment 10%)

(3) Transmission pumps: peakmonth demand x 1.0

(4) Transmission P/L: peakmonth demand x 1.0

(5) Distribution reservoirs:

(a) Mombasa area: average annual daily demand x 1 1/2 days

(b) For all other areas: average annual daily demand x 2 1/2 days

Capacity of Augmentation Plans

(2nd Mzima P/L)

(1) Intake: Max. 1.2 $m^3$/sec (103,680 $m^3$/d)

(2) Transmission main: ditto

(Rare P/L)

(1) Intake: Max. 3.18 $m^3$/sec (275,000 $m^3$/d)

(2) Treatment Plant: ditto

(3) Transmission main: Max. 2.89 $m^3$/sec (250,000 $m^3$/d)

## 2. Rare Treatment Plant Design Parameters Used

General

(1) Design output in 2000: 200,000 $m^3$/d (2.31 $m^3$/sec)

(2) Maximum design output: 250,000 $m^3$/d (2.89 $m^3$/sec)

Major Facilities

(1) Intake Pumps: a. @19.1 $m^3$/min x 2 units - 20% to Max.
b. @38.2 $m^3$/min x 4 units - 80% to Max.
c. Stand by @19.1 $m^3$/min x 1 unit
@38.2 $m^3$/min x 2 units
Stand by Total 50%

(2) Raw water main: Max. 3.18 $m^3$/sec flow capacity
Dia. 1,500 mm, C=130, v=1.8 m/sec, L=4.8 km

(3) Receiving/Distributing Tank: Detention time - 2 min.
Effective volume - 300 $m^3$
Diameter - 5 m
Depth of water - 4m

(4) Mixing chamber: Detention time - 1 min.
Baffle cone type

(5) Flocculation basin: Detention time - 30 min.
Vertical flocculators

(6) Sedimentation basins: Surface loading 1.0 $m^3/m^2h$
Conventional type 27 m x 85 m x 6 units
(including one unit stand by)
Detention time - 3 hrs

(7) Filtration: Flow rate 120 m/d (5 m/h)
Rapid sand filters 9.2 m x 10 m x 30 units
Total filter area = 2,760 $m^2$
(including 5 units stand by)
Wash water a. back washing 0.6 m/min
b. surface washing 0.2 m/min
Rate per filter = 0.8 x 92 = 73.6 $m^3$/min
Max. 6 min operation = 442 $m^3$
Wash water storage = 1,000 $m^3$

(8) Chemical dozing: a. Alum Max. 200 mg/l
Aveg. -
b. Chlorine Max. 5 mg/l
Normal 1 mg/l
c. Soda ash

(9) Transmission Pumps: a. @17.4 $m^3$/min x 2 units - 20% to Max.

b. @34.8 $m^3$/min x 4 units - 80% to Max.

c. Stand by

@17.4 $m^3$/min x 1 unit

@34.8 $m^3$/min x 2 units

Stand by Total 50%

# STUDY ON FLUCTUATIONS IN WATER DEMAND AND SYSTEM CAPACITY FOR THE PLAN

## 1. Demand Fluctuations

Since a water supply system should be designed to meet the peak consumption periods it is important to review the present demand fluctuations throughout a year. It is impossible, however, to determine true demand fluctuations in Mombasa from present consumption, therefore the projection for fluctuations in annual, monthly and daily demands are based on the past study made by consultants in 1972[/1] and compared with other similar cities in tropical climates.

Peaking factors studied in the said report are quoted and shown in the followings :

| Supply System | Average Peaking Factor | |
|---|---|---|
| | Peak Month | Peak Day |
| Mombasa Distribution System | 1.075 | 1.225 |
| North Mainland System (all areas) | 1.23 | 1.50 |
| North Mainland System (excluding industrial consumption) | 1.29 | 1.63 |
| Malindi System | 1.30 | 1.45 |
| Gedi/Watamu System | 1.30 | 1.85 |
| Malindi/Gedi/Watamu System (combined) | 1.30 | 1.55 |
| Kilifi System | 1.25-1.30 | - |

With careful analysis, in this planning, the peaking factors of 1.10 and 1.30, for peak month demands, were adopted for the further study for Mombasa area and other project areas respectively.

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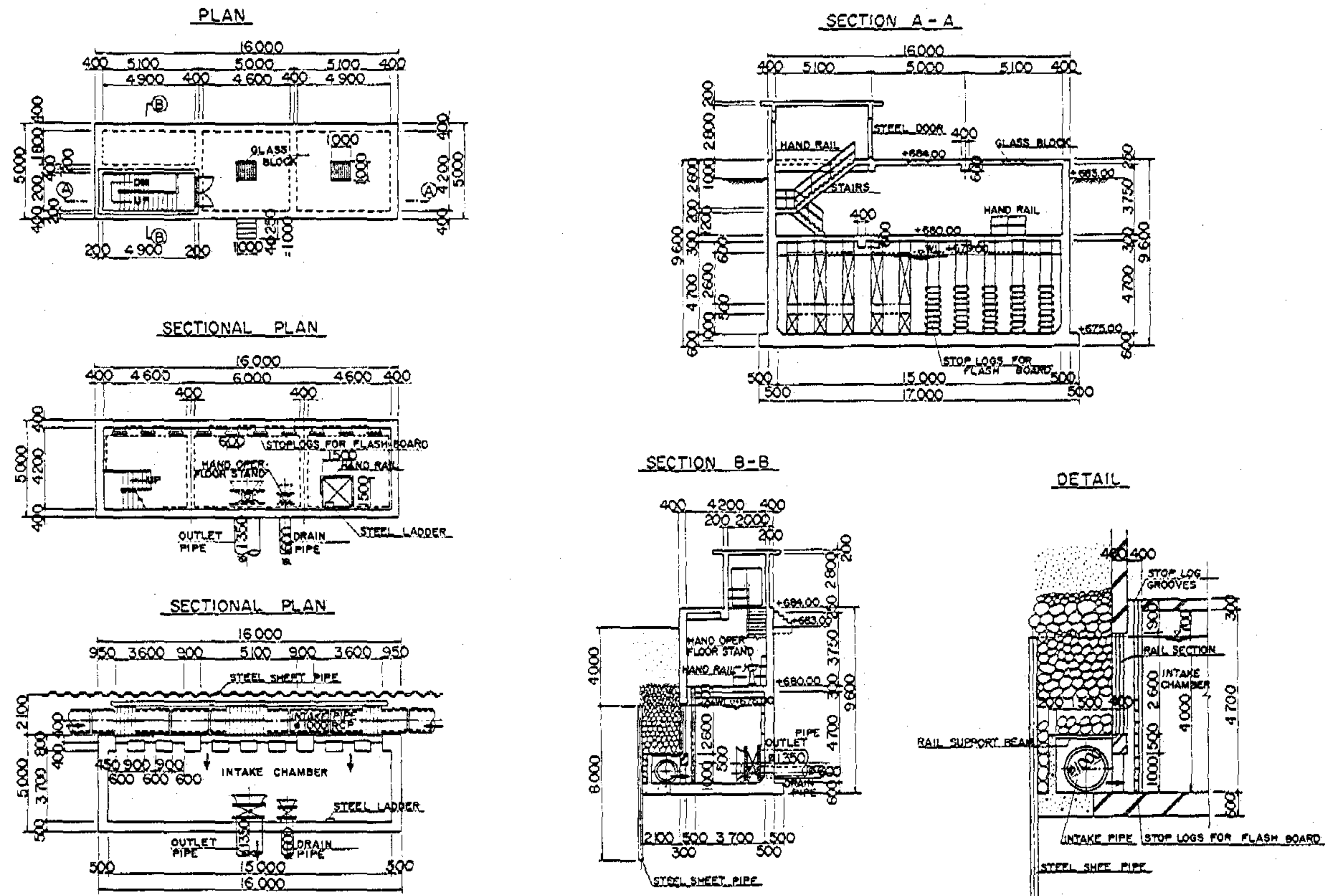
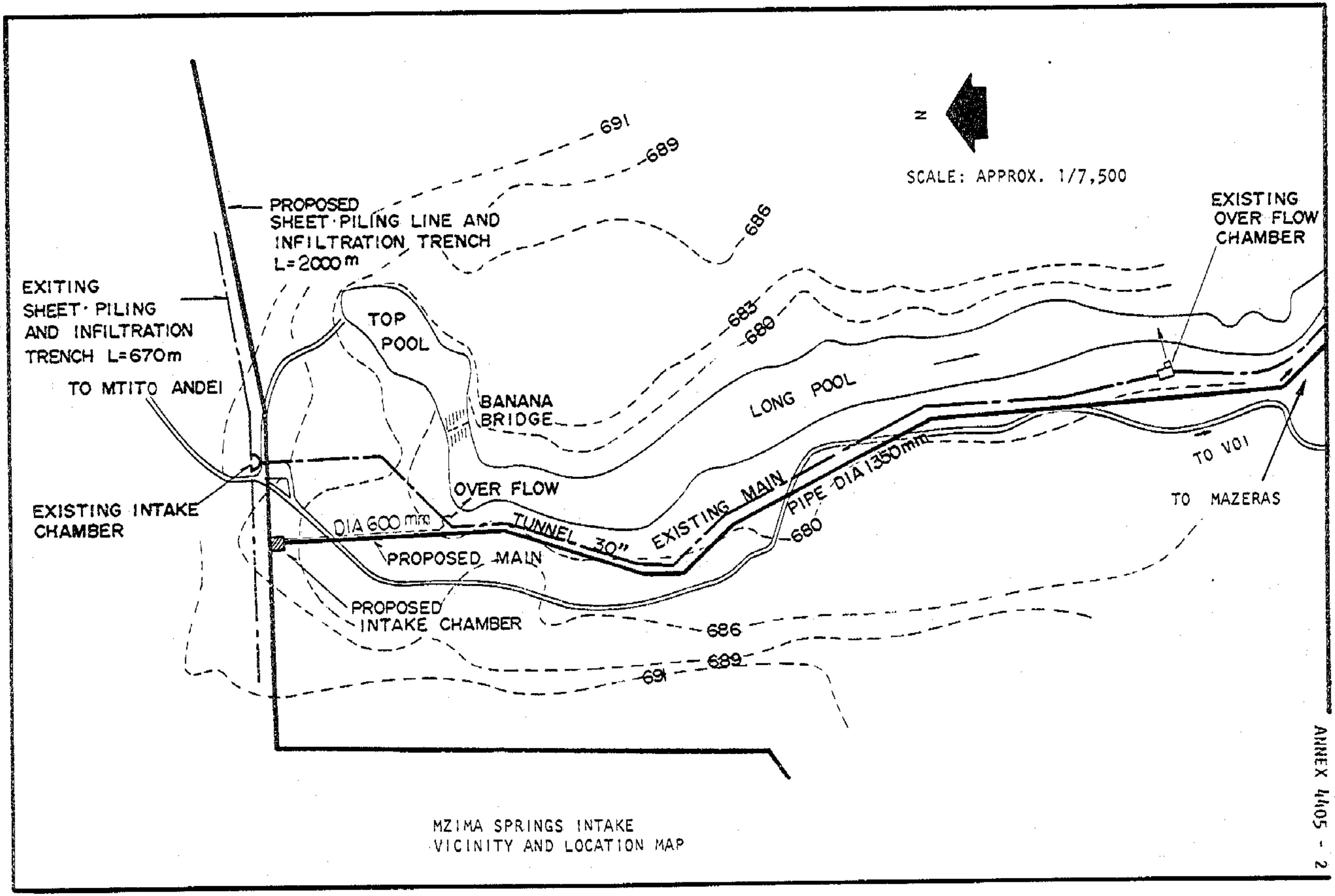
/1 Scott-Wilson Kirkpatrik and Partners, "Draft Supplementary Report and Alternative Schemes for Supplying Water to Mombasa and the North Coast", July 1972.

2. Design Capacity

Taking into consideration the close relation to the on-going Sabaki P/L system, the capacity for the plan in respect to a bulk water supply system is designed to meet the peak monthly demands. Peak monthly daily demands by area are projected and shown in ANNEX 2444-2.
(ref. ANNEX 4404-1 Design Criteria for the Project.)

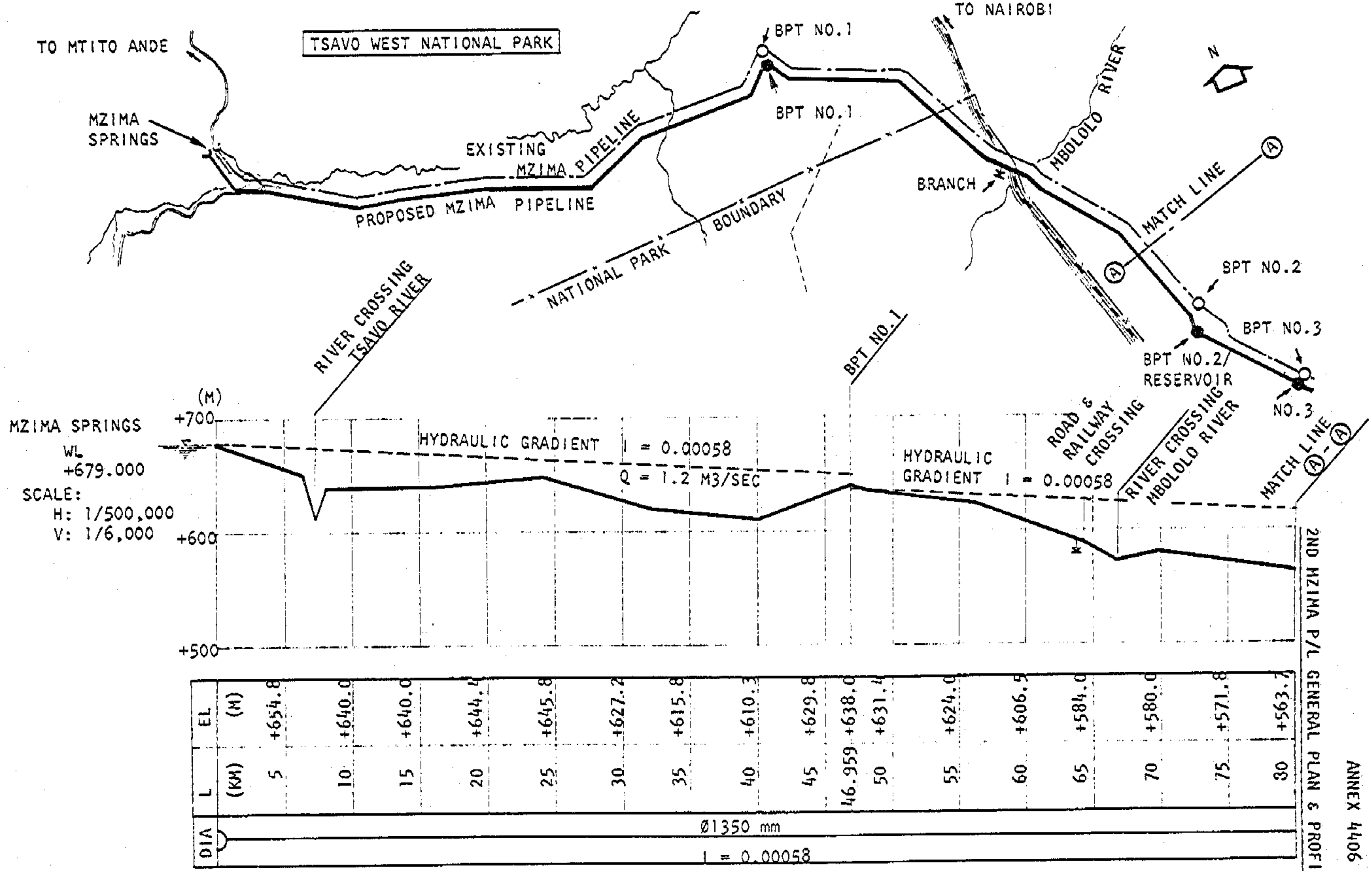



2ND MZIMA PIPELINE SPRING INTAKE (NOT TO SCALE)

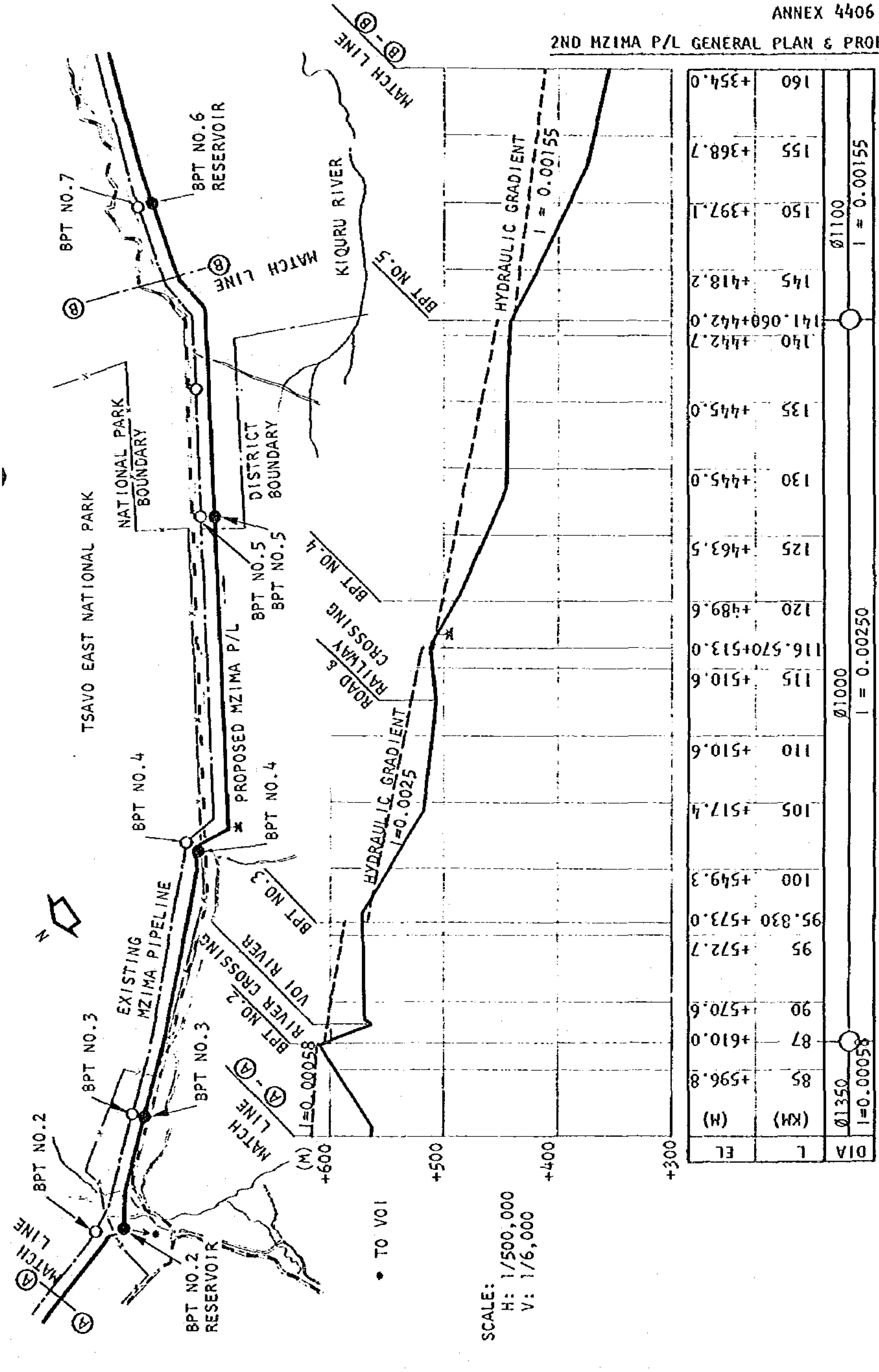



MZIMA SPRINGS INTAKE
VICINITY AND LOCATION MAP

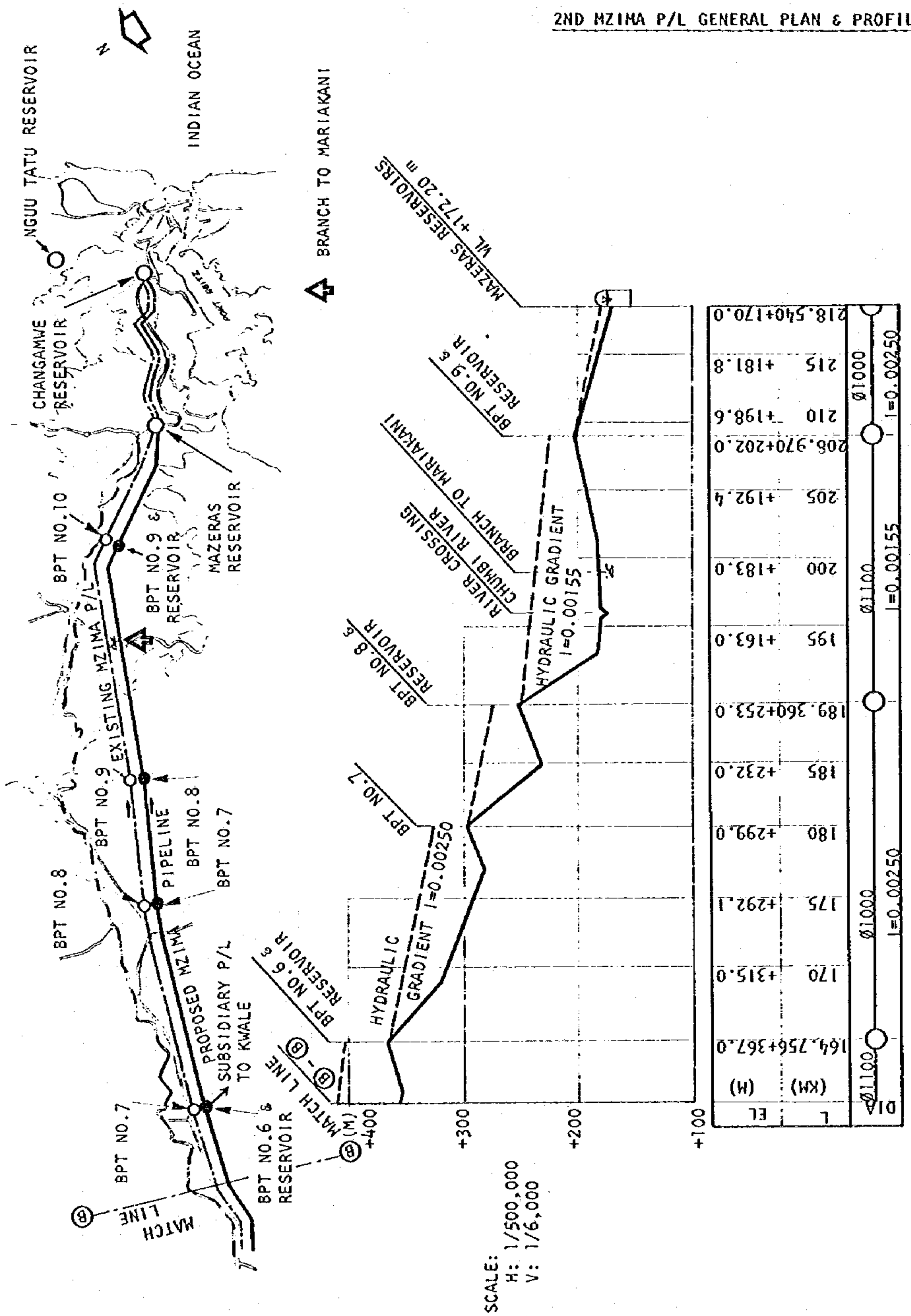
## 2ND MZIMA P/L GENERAL PLAN & PROFILE



## 2ND MZIMA P/L GENERAL PLAN & PROFILE



## 2ND MZIMA P/L GENERAL PLAN & PROFILE



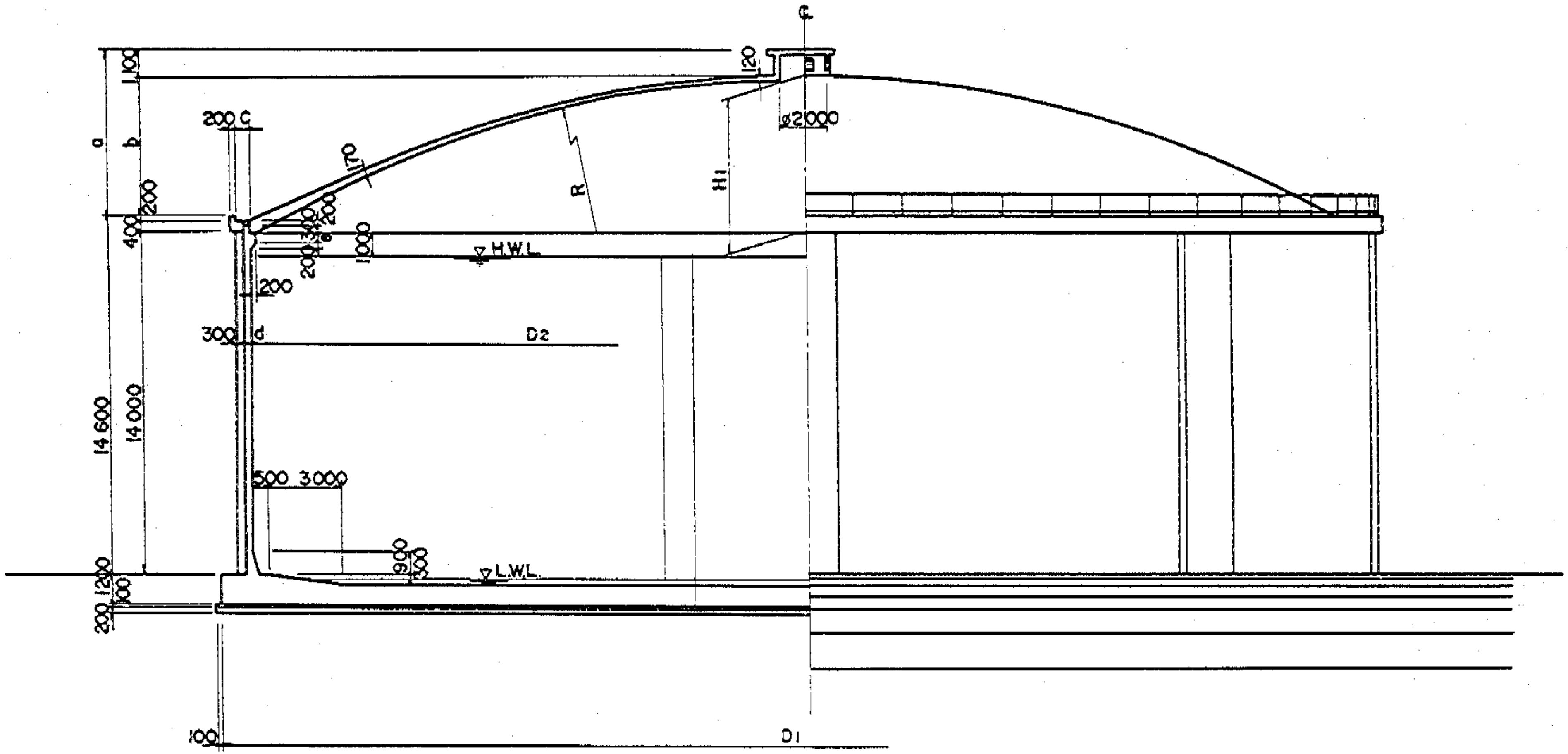
(2nd MZIMA P/L PLAN)

DISTRIBUTION RESERVOIR CONSTRUCTION SCHEDULE

| | Location | System | Provision in 1986 $m^3$ | Provision in 1995 $m^3$ | Total |
|---|---|---|---|---|---|
| 1. | Voi | 2nd Mzima P/L | 20,000 | - | 20,000 |
| 2. | Taru | " | 20,000 | - | 20,000 |
| 3. | Maliakani | " | 20,000 | - | 20,000 |
| 4. | Nguee Tatu | Sabaki P/L | 20,000 | 20,000 | 40,000 |
| 5. | Kaya Bambo | Marere P/L | 30,000 | 30,000 | 60,000 |
| 6. | Changamwe | Sabaki P/L | 13,600 1/ | - | 13,600 |
| 7. | Balancing | 2nd Mzima P/L | 30,000 | 30,000 | 60,000 |
| | Total | | 153,600 | 80,000 | 233,600 $m^3$ |

Note: 1/ Shall be provided in the Sabaki P/L system in 1984.

Standard @20,000 x 5 = 100,000 $m^3$
" @30,000 x 4 = 120,000 $m^3$
Total 220,000 $m^3$



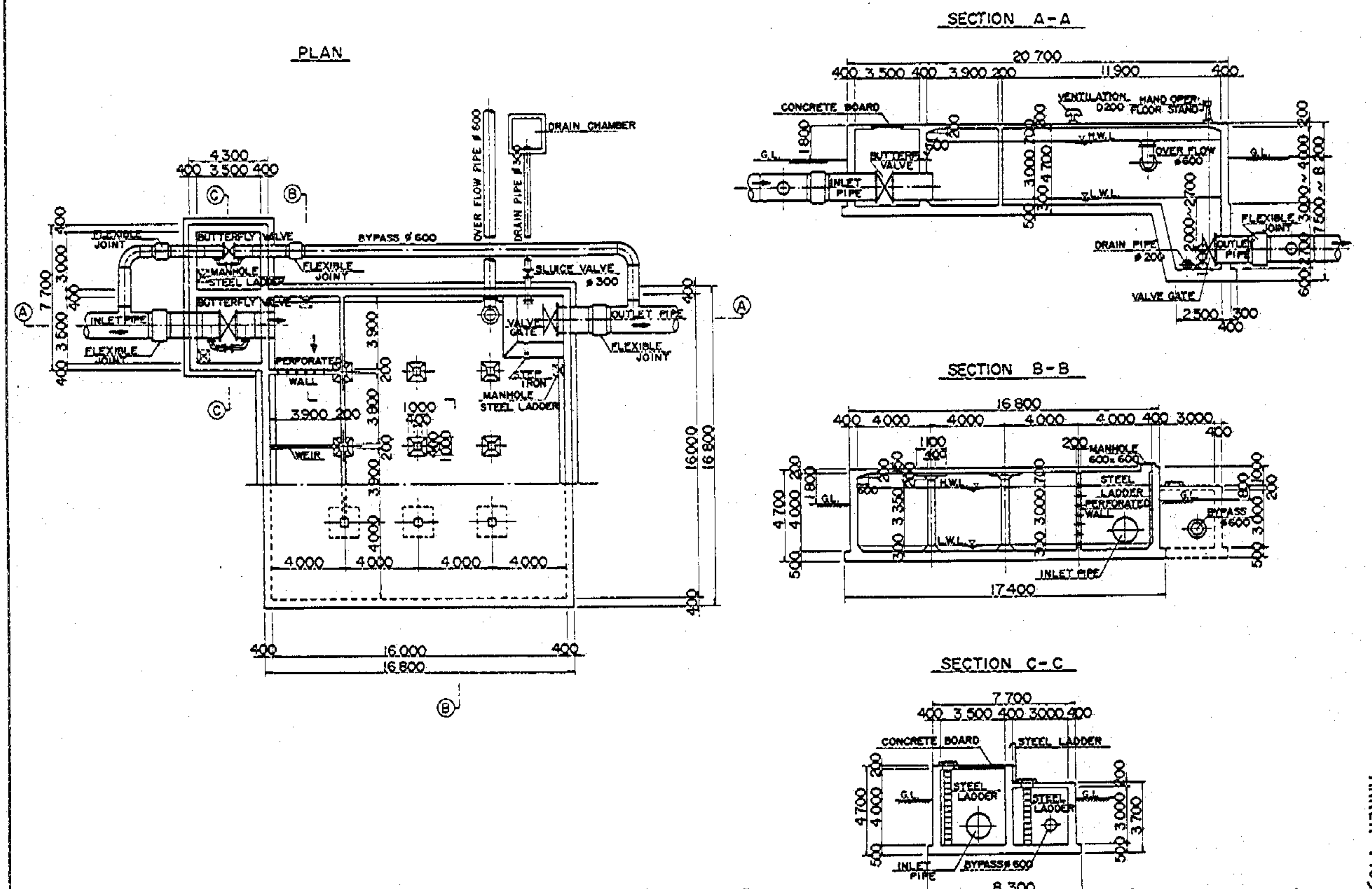

DIMENSIONS

(mm)

| CAPACITY | D1 | D2 | H1 | R | a | b | c | d | e |
|---|---|---|---|---|---|---|---|---|---|
| 20 000 cum | ø47,600 | ø45,000 | 6,030 | 45,000 | 6,430 | 5,330 | 600 | 300 | 400 |
| 30 000 cum | ø57,700 | ø55,000 | 7,370 | 55,000 | 7,870 | 6,770 | 650 | 350 | 500 |

**DISTRIBUTION RESERVOIR STANDARD MODEL**

( NOT TO SCALE )

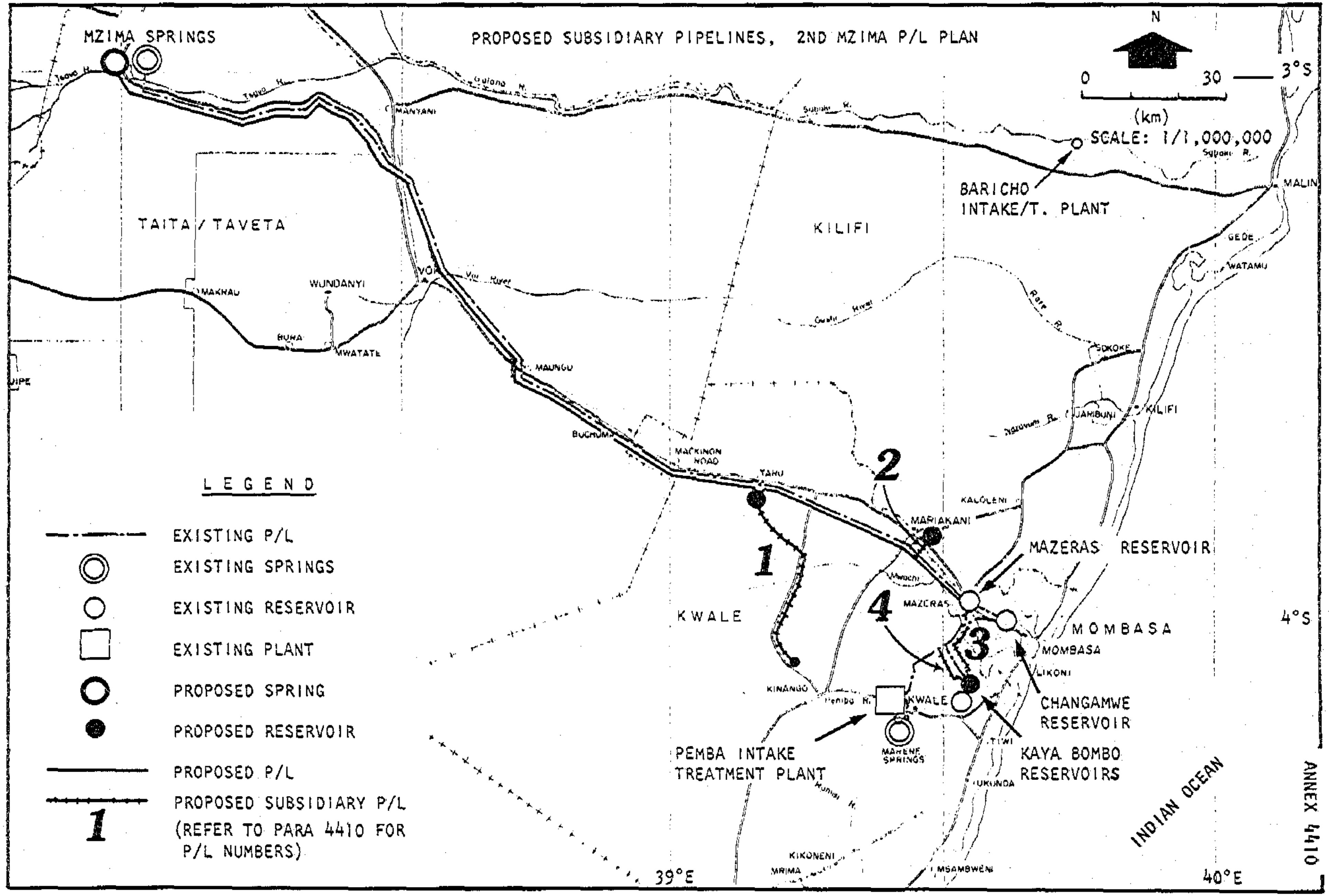



BREAK PRESSURE TANK STANDERD STRUCTURE

( NOT TO SCALE )

ANNEX 4410

PROPOSED SUBSIDIARY PIPELINES, 2ND MZIMA P/L PLAN



## Second Muzima P/L with Tsavo Reservoir Plan
## Sizes and Capacities of Major Components

| Plan Element | Description |
|---|---|
| Spring Intake | - Total 2 km long sheet piling and infiltration trench installed with 1,000 mm to 500 mm dia. concrete pipes. A RC made intake chamber with flow control valve and a drain and excess water draining outlet of 600 mm sluice valve. |
| Main Transmission P/L | - Pipes 1,350 mm dia; 86,000 m, 1,100 mm dia; 43,310 m, 1m000 mm dia, 88,230 m. Suitable for maximum working pressure of 12.5 kg/cm$^2$ including surge surplus. Peak capacity of flow would be 1.2 m$^3$/sec and flow control would be done at intake chamber.<br>- Line valves and operating points at about 2 km intervals<br>- Air valves and washouts as required by profile with approx. 10 per 9 km. |
| Break Pressure Tanks | - Capacity 720 m$^3$ each, detention time 10 min at max. flow.<br>- Installed with 600 mm dia by-pass.<br>- Six BPTs in total would be constructed. |
| Storage Reservoirs | - Voi Reservoir at 20,000 m$^3$.<br>- Taru Reservoir at 20,000 m$^3$.<br>- Mariakani Reservoir at 20,000 m$^3$.<br>- Balancing Reservoir near existing BPT No. 10 at 60,000 m$^3$.<br>- Kaya Bombo Reservoirs at 60,000 m$^3$.<br>- All reservoirs are designed to be circular prestressed concrete construction. See standard Annex 4480-2. |

| | |
|---|---|
| Subsidiary P/L | - 500 mm dia, 28,000 m |
| | - 400 mm dia, 17,000 m |
| | - 350 mm dia, 3,000 m |
| | - 300 mm dia, 40,000 m |
| | Materials suitable for maximum working pressure 12.5 $kg/cm^2$ including surge surplus. |

# MAIN FEATURES OF 2ND MZIMA P/L WITH TSAVO RESERVOIR PLAN

Development scale: 1.2 $m^3$/sec

## 1. Dam

| | |
|---|---|
| Catchment ($km^2$) | 4050 excluding the area of the Loolturesh River |
| Type | Rockfill |
| Height above river bed (m) | 34 |
| Reservoir, effective storage ($10^6m^3$) | 21 |
| Fill volume ($10^3m^3$) | 450 |
| Design flood ($m^3$/sec) | 1,550 |
| Annual mean discharge ($m^3$/sec) | 6.2 |

## 2. Water supply facilities

| | |
|---|---|
| Type of intake | Underground |
| Trunk main P/L, diameter (mm) and length (m) | 1,350mm - 86,000m<br>1,100mm - 43,310m<br>1,000mm - 88,230m |

COST ESTIMATES OF 2ND MZIMA P/L WITH TSAVO RESERVOIR

Unit: US$$10^3$
Development Scale: 1.2 $m^3$/sec

| | Economic Costs | | | Sales Taxes | Financial Costs | | |
|---|---|---|---|---|---|---|---|
| | L.C. | F.C. | Total | L.C. | L.C. | F.C. | Total |
| Capital Cost | | | | | | | |
| A Water Supply Facilities | | | | | | | |
| 1 Underground intake | 3,980,4 | 1,760.0 | 5,740.4 | 635.6 | 4,616.0 | 1,760.0 | 6,376.0 |
| 2 Transmission main P/L | 36,428.4 | 101,280.0 | 137,708.4 | 12,487.6 | 48,916.0 | 101,280.0 | 150,196.0 |
| 3 Pipes for B.P.T.'s and distribution reservoirs | 14,572.6 | 896.0 | 15,468.6 | 1,693.8 | 16,266.4 | 896.0 | 17,162.4 |
| 4 Communication equipments | 150.0 | 400.0 | 550.0 | 50 | 200.0 | 400.0 | 600.0 |
| 5 Subsidiary P/L | 3,965.0 | 7,420.0 | 11,385.0 | 1,058.9 | 5,023.9 | 7,420.0 | 12,443.9 |
| B Dam | | | | | | | |
| 6 General items | 2,279.2 | 1,584.1 | 3,863.3 | 335.9 | 2,615.1 | 1,584.1 | 4,199.2 |
| 7 Coffer dam and diversion tunnel | 8,298.7 | 5,913.4 | 14,212.1 | 1,235.8 | 9,534.5 | 5,913.4 | 15,447.9 |
| 8 Main dam | 5,168.5 | 7,018.0 | 12,186.5 | 1,059.7 | 6,228.2 | 7,018.0 | 13,246.2 |
| 9 Spillway | 9,290.9 | 2,746.1 | 12,037.0 | 1,046.7 | 10,337.6 | 2,746.1 | 13,083.7 |
| 10 River outlet facilities | 34.5 | 163.3 | 197.8 | 17.2 | 51.7 | 163.3 | 215.0 |
| C Engineering and Administration | 8,416.8 | 12,918.1 | 21,334.9 | 1,962.1 | 10,378.9 | 12,918.1 | 23,297.0 |
| Base Cost Total | 92,585.0 | 142,099.2 | 234,684.2 | 21,583.3 | 114,168.3 | 142,099.2 | 256,267.5 |
| D Physical Contingency | 13,887.8 | 21,315.0 | 35,203.7 | 3,237.5 | 17,125.3 | 21,315.0 | 38,440.3 |
| Capital Cost Total | 106,472.8 | 163,415.0 | 269,887.9 | 24,820.8 | 131,293.6 | 163,415.0 | 294,708.6 |
| E Price Contingency | - | - | - | - | 75,700 | 51,072 | 126,772 |
| F Financial Cost Total | - | - | - | - | 206,994 | 214,487 | 421,481 |

ECONOMIC COSTS ESTIMATED FOR WATER FACILITIES AND CIVIL WORKS ON 2ND MZIMA P/L WITH TSAVO RESERVOIR

Development Scale: 1.2 $m^3$/sec.

| Items | Unit | Quantity | L. C. | | F. C. | |
|---|---|---|---|---|---|---|
| | | | Unit Price (US$) | Amount (US$10³) | Unit Price (US$) | Amount (US$10³) |
| A. Water Supply Facilities | | | | | | |
| 1. Underground intake | L.S. | | | 3,980.4 | | 1,760.0 |
| 2. Transmission main P/L | | | | | | |
| ø 1350 | m | 87,000 | 215.90 | 18,780.0 | 600.00 | 52,200.0 |
| ø 1100 | m | 43,310 | 149.90 | 6,490.7 | 416.90 | 18,056.0 |
| ø 1000 | m | 88,230 | 126.50 | 11,156.9 | 351.60 | 31,024.0 |
| Sub-total | | | | 36,428.4 | | 101,280.0 |
| 3. Break pressure tanks and reservoirs | | | | | | |
| Break pressure tanks | No. | 6 | 85x10³ | 510.0 | 65x10³ | 390.0 |
| 30,000 m³ reservoirs | No. | 4 | 1,600x10³ | 6,400.0 | 52x10³ | 208.0 |
| 20,000 m³ reservoirs | No. | 5 | 1,400x10³ | 7,000.0 | 51x10³ | 255.0 |
| Miscellaneous | L.S. | | | 662.6 | | 43.0 |
| Sub-total | | | | 14,572.6 | | 896.0 |
| 4. Communication system | L.S. | | | 150.0 | | 400.0 |
| 5. Subsidiary P/L | | | | | | |
| ø 500 | m | 28,000 | 64.5 | 1,805.6 | 120.3 | 3,368.4 |
| ø 400 | m | 17,000 | 45.7 | 776.9 | 85.2 | 1,448.4 |
| ø 350 | m | 3,000 | 37.3 | 111.8 | 69.6 | 208.8 |
| ø 300 | m | 40,000 | 31.8 | 1,270.7 | 59.9 | 2,394.4 |
| Sub-total | | | | 3,965.0 | | 7,420.0 |
| B. Dam | | | | | | |
| 6. General items | L.S. | | | 2,279.2 | | 1,584.1 |
| 7. Coffer dam and diversion tunnel | | | | | | |
| Excavation in oepn cut | m³ | 153,300 | 6 | 919.8 | 3 | 459.9 |
| Excavation in tunnel | m³ | 40,200 | 45 | 1,809.0 | 75 | 3,015.0 |
| Embankment | m³ | 273,300 | 5 | 1,366.5 | 5 | 1,366.5 |
| Concrete | m³ | 23,400 | 100 | 2,340.0 | 30 | 702.0 |
| Reinforcement bars | ton | 1,000 | 900 | 900.0 | 80 | 80.0 |
| Miscellaneous | L.S | | | 963.4 | | 290.0 |
| Sub-total | | | | 8,298.7 | | 5,913.4 |

| Items | Unit | Quantity | L. C. Unit Price (US$) | L. C. Amount (US$10³) | F. C. Unit Price (US$) | F. C. Amount (US$10³) |
|---|---|---|---|---|---|---|
| 8. Main dam | | | | | | |
| Excavation | $m^3$ | 162,400 | 6 | 974.4 | 3 | 487.2 |
| Embankment | $m^3$ | 452.700 | 5 | 2,263.5 | 5 | 2,263.5 |
| Asphalt concrete facing | $m^2$ | 29,600 | 15 | 444.0 | 100 | 2,960.0 |
| Concrete in cut-off wall | $m^3$ | 2,500 | 100 | 250.0 | 20 | 50.0 |
| Curtain grouting | m | 6,000 | 25 | 150.0 | 100 | 600.0 |
| Miscellaneous | L.S. | | | 1,086.6 | | 657.3 |
| Sub-Total | | | | 5,168.5 | | 7,018.0 |
| 9. Spillway | | | | | | |
| Excavation | $m^3$ | 502,500 | 6 | 3,015.0 | 3 | 1,507.5 |
| Backfill | $m^3$ | 10,000 | 1 | 10.0 | 0.50 | 5.0 |
| Concrete | $m^3$ | 49,300 | 100 | 4,930.0 | 20 | 986.0 |
| Reinforcement bars | ton | 1,000 | 900 | 900.0 | 80 | 80.0 |
| Steel anchor bars | ton | 100 | 1,300 | 130.0 | 700 | 70.0 |
| Miscellaneous | L.S. | | | 305.9 | | 97.6 |
| Sub-Total | | | | 9,290.9 | | 2,746.1 |
| 10. River outlet facilities | L.S. | | | 34.5 | | 163.3 |
| Grand Total | | | | 84,168.2 | | 129,180.9 |

# ECONOMIC LIFE OF EQUIPMENT AND MATERIALS

**Second Mzima P/L with Tsavo Reservoir**

| Items | Economic Life (Years) |
|---|---|
| 1. Intake Facilities | |
| Valves | 30 |
| R.C. | 40 |
| 2. Transmission Main | |
| Pipes | 40 |
| Valves | 30 |
| R.C. | 30 |
| 3. BPTs & Reservoir | |
| Valves | 30 |
| Pipes | 40 |
| R.C. | 30 |
| 4. Communication | |
| Equipment | 15 |
| R.C. | 30 |

**Rare P/L with Rare Reservoir**

| Items | Economic Life (Years) |
|---|---|
| 1. Intake & Transmission Pumping Facilities | |
| - Pumps & Elec. | 10 |
| - Pipe & Valves | 30 |
| - Structure | 50 |
| 2. Raw Water Main | |
| - Pipes | 40 |
| - Valves | 30 |
| - Ancillary works | 30 |
| 3. Treatment Plant | |
| - Equipment | 15 |
| - Pipes & Valves | 30 |
| - Structure | 50 |
| 4. Transmission Main | |
| - Pipes | 40 |
| - Valves | 30 |
| - Ancillary works | 30 |
| 5. Distribution Reservoir | 30 |
| 6. Communication Equip. | 15 |

Remarks: R.C. stands for "Reinforced Concrete".

## BREAKDOWN OF O&M COST ON SECOND MZIMA P/L

Unit: US$$10^3$

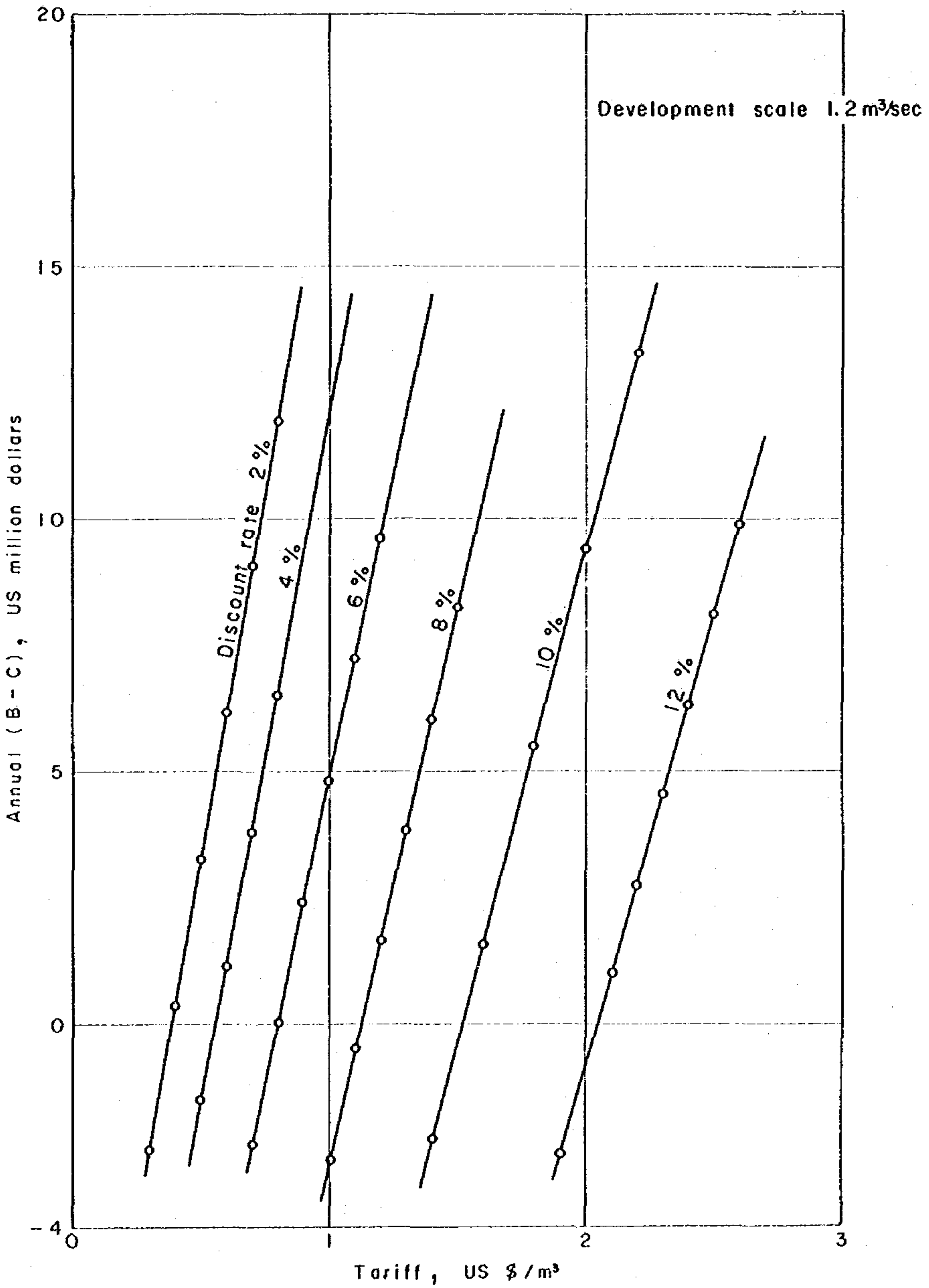
| Year | Proposed System Supply, $m^3/d$ | Staff Salary | Chemical | Repair | Total |
|---|---|---|---|---|---|
| 1986 | 1,990 | 32.17 | 0.54 | 16.2 | 48.91 |
| 1987 | 5,510 | ⋮ | 1.51 | ⋮ | 49.88 |
| 1988 | 8,480 | ⋮ | 2.29 | ⋮ | 50.66 |
| 1989 | 12,000 | ⋮ | 3.26 | ⋮ | 51.63 |
| 1990 | 18,400 | 56.44 | 5.01 | ⋮ | 77.65 |
| 1991 | 28,000 | ⋮ | 7.64 | ⋮ | 80.28 |
| 1992 | 39,890 | ⋮ | 10.88 | ⋮ | 83.52 |
| 1993 | 52,000 | ⋮ | 14.16 | ⋮ | 86.80 |
| 1994 | 63,990 | ⋮ | 17.42 | ⋮ | 90.06 |
| 1995 | 75,990 | ⋮ | 20.73 | ⋮ | 93.37 |
| 1996 | 89,760 | ⋮ | 24.55 | ⋮ | 97.19 |
| 1997 | 102,810 | ⋮ | 28.03 | ⋮ | 100.67 |
| 1998 | 104,000 | ⋮ | 28.32 | ⋮ | 100.96 |
| 1999 | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| 2000 | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| 2035 | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |

## SECOND MZIMA P/L WITH TSAVO RESERVOIR PLAN

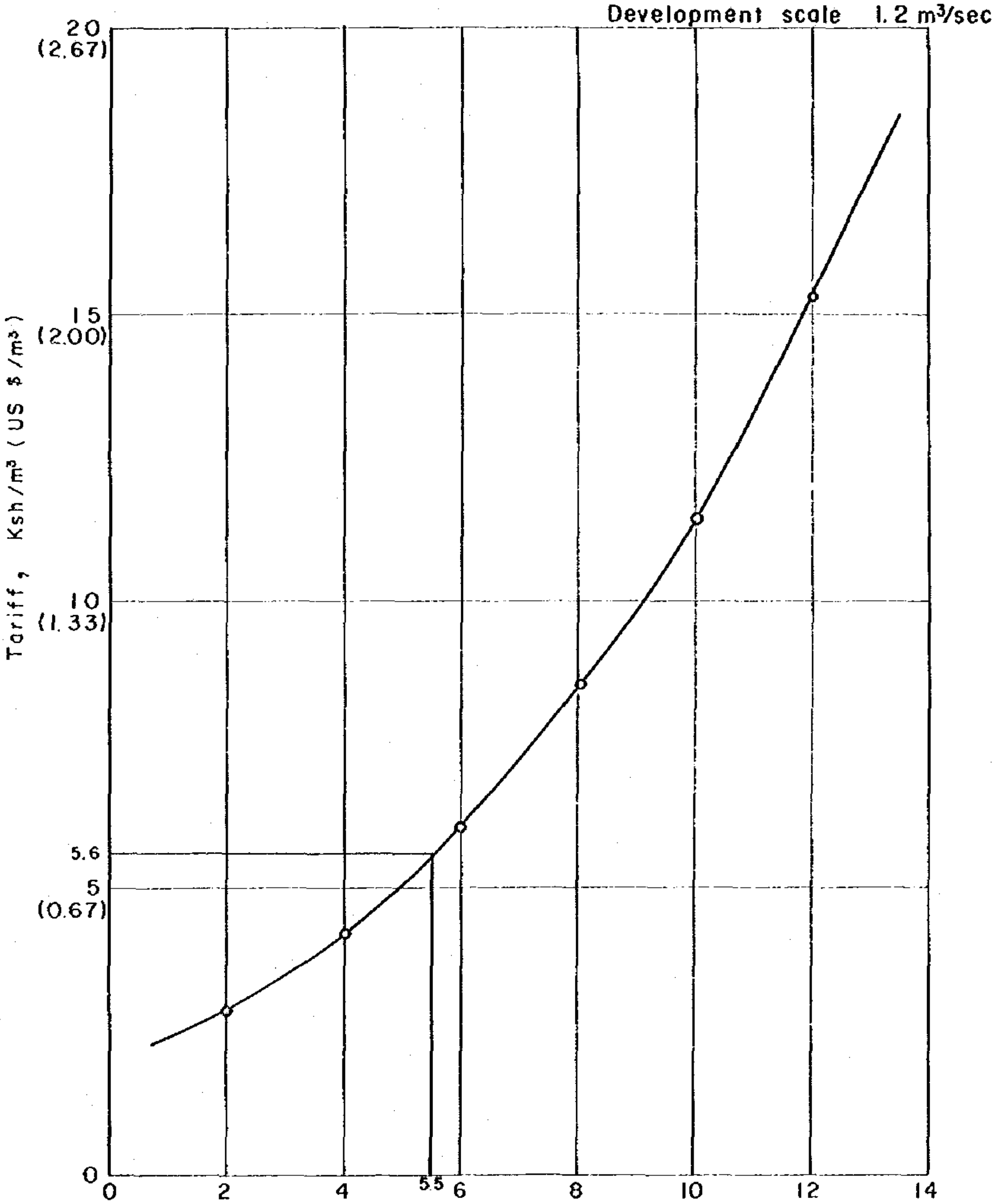
## COST AND WATER VOLUME STREAMS

Unit: US$ $10^6$
Development scale: 1.2 $m^3$/sec

| End of fiscal year | No. | Water volume $10^6 m^3$ | Capital cost | O & M cost |
|---|---|---|---|---|
| 1983 | -3 | - | 40.5 | - |
| 84 | -2 | - | 161.9 | - |
| 85 | -1 | - | 67.5 | - |
| 86 | 1 | 0.73 | - | 0.05 |
| 87 | 2 | 2.01 | - | 0.05 |
| 88 | 3 | 3.10 | - | 0.05 |
| 89 | 4 | 4.38 | - | 0.08 |
| 1990 | 5 | 6.57 | - | 0.08 |
| 91 | 6 | 10.22 | - | 0.08 |
| 92 | 7 | 14.60 | - | 0.09 |
| 93 | 8 | 18.98 | - | 0.09 |
| 94 | 9 | 23.36 | - | 0.09 |
| 95 | 10 | 27.74 | - | 0.10 |
| 96 | 11 | 32.85 | - | 0.10 |
| 97 | 12 | 37.53 | - | 0.10 |
| 98 | 13 | 37.96 | - | 0.10 |
| 99 | 14 | : | - | : |
| 2000 | 15 | : | 0.5 | : |
| 2000-'14 | 16-29 | : | - | : |
| 2015 | 30 | : | 31.9 | : |
| 2016-'24 | 31-39 | : | - | : |
| 2025 | 40 | : | 125.9 | : |
| 2026-'29 | 41-44 | : | - | : |
| 2030 | 45 | : | 0.5 | : |
| 2031-'35 | 46-50 | 37.96 | - | 0.10 |

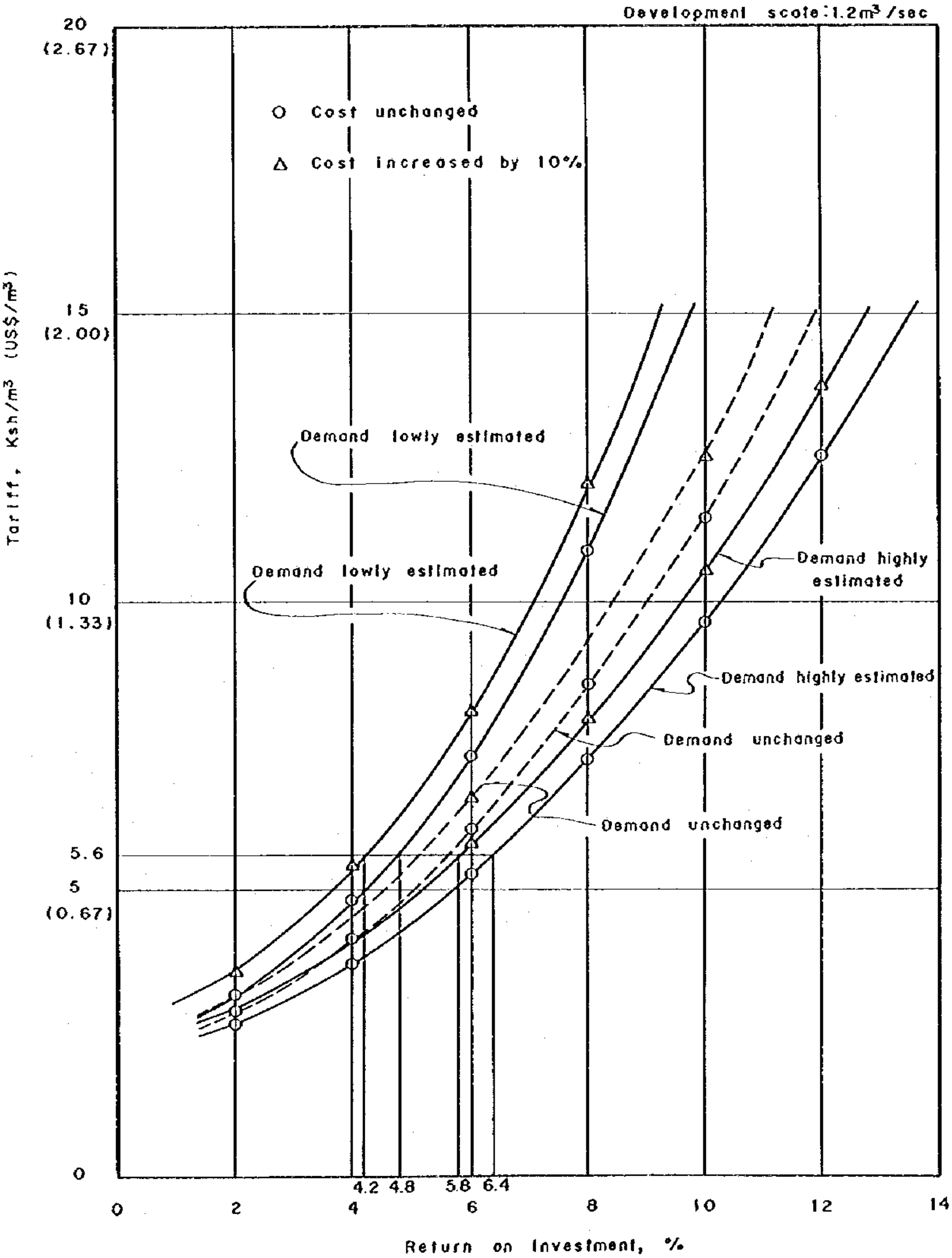



Variation of Annual ( B - C ) by Changing Tariff on the 2nd Mzima Plan




Return on Investment on the Development

(Mzima Plan) Scale of 1.2 $m^3$/sec




Sensitivity Tests for the Second Mzima Plan

# ROI AND WATER RATES (AT CURRENT PRICES) BY VARIOUS ANNUAL INCREASE RATES OF WATER RATE

| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|
| at Current Price | | | at 1980 Price | | | |
| Annual Increase for 1980 - 1986 | Water Rate /1 (KSh/$m^3$) 1980 | 1986 | Water Rate /1 (KSh/$m^3$) 1980 | 1986 | R O I 2nd Mzima | Rare |
| 13 % | 5.88 | 12.24 ($1.63/$m^3$) | 5.60 | 6.58 | 6.5 % | 9.4 % |
| 15 % | 5.88 | 13.60 ($1.81/$m^3$) | 5.60 | 7.31 | 7.1 % | 10.1 % |
| 17 % | 5.88 | 15.08 ($2.01/$m^3$) | 5.60 | 8.11 | 7.7 % | 10.8 % |
| 20 % | 5.88 | 17.56 ($2.34/$m^3$) | 5.60 | 9.44 | 8.7 % | 11.8 % |

| | (8) |
|---|---|
| | at Current Price |
| Annual Increase for 1980 - 1986 | Consumer's Water Tariff in 1986 /2 (KSh/$m^3$) |
| 13 % | 17.49 ($2.33/$m^3$) |
| 15 % | 19.43 ($2.59/$m^3$) |
| 17 % | 21.54 ($2.87/$m^3$) |
| 20 % | 25.09 ($3.35/$m^3$) |

/1 Evaluated at the outlet of distribution reservoir.

/2 (8) = (3)/0.7 Assuming the cost of distribution system constitutes 30% of the consumer's water tariff.

# SECOND MZIMA P/L WITH TSAVO RESERVOIR PLAN

## FIRR CALCULATION

Unit: US$$10^3$

| No. | Fiscal Year | Capital Cost & Replacement F.C. | Capital Cost & Replacement L.C. | O&M Cost | Gross Revenue | Net Benefit |
|---|---|---|---|---|---|---|
| 1 | 1983 | 29,292 | 25,555 | - | | -54,847 |
| 2 | 1984 | 124,139 | 112,390 | - | | -236,529 |
| 3 | 1985 | 54,828 | 51,522 | | | -106,350 |
| 4 | 1986 | - | - | 91 | 1,251 | 1,160 |
| 5 | 1987 | - | - | 93 | 3,463 | 3,370 |
| 6 | 1988 | - | - | 94 | 5,348 | 5,254 |
| 7 | 1989 | - | - | 96 | 7,542 | 7,446 |
| 8 | 1990 | 6,228 | 17,527 | 144 | 11,313 | -12,586 |
| 9 | 1991 | - | - | 149 | 17,604 | 17,455 |
| 10 | 1992 | - | - | 155 | 25,146 | 24,991 |
| 11 | 1993 | - | - | 161 | 32,688 | 32,527 |
| 12 | 1994 | - | - | 168 | 40,230 | 40,062 |
| 13 | 1995 | - | - | 174 | 47,773 | 47,599 |
| 14 | 1996 | - | - | 181 | 56,584 | 56,403 |
| 15 | 1997 | - | - | 187 | 64,633 | 64,446 |
| 16 | 1998 | - | - | 188 | 65,377 | 65,189 |
| 17 | 1999 | - | - | ⋮ | ⋮ | 65,189 |
| 18 | 2000 | (R) 584 | 186 | ⋮ | ⋮ | 64,419 |
| 19 | 2001 | - | - | ⋮ | ⋮ | 65,189 |
| 20 | 2002 | - | - | ⋮ | ⋮ | 65,189 |

| Discount Rate | Net Benefit |
|---|---|
| 0% | +215,576 |
| 3% | +16,588 |
| 4% | -28,690 |

FIRR = 3.4%

(R): Replacement Cost

PROJECTED INCOME STATEMENTS FOR SECOND MZIMA P/L WITH TSAVO RESERVOIR PLAN

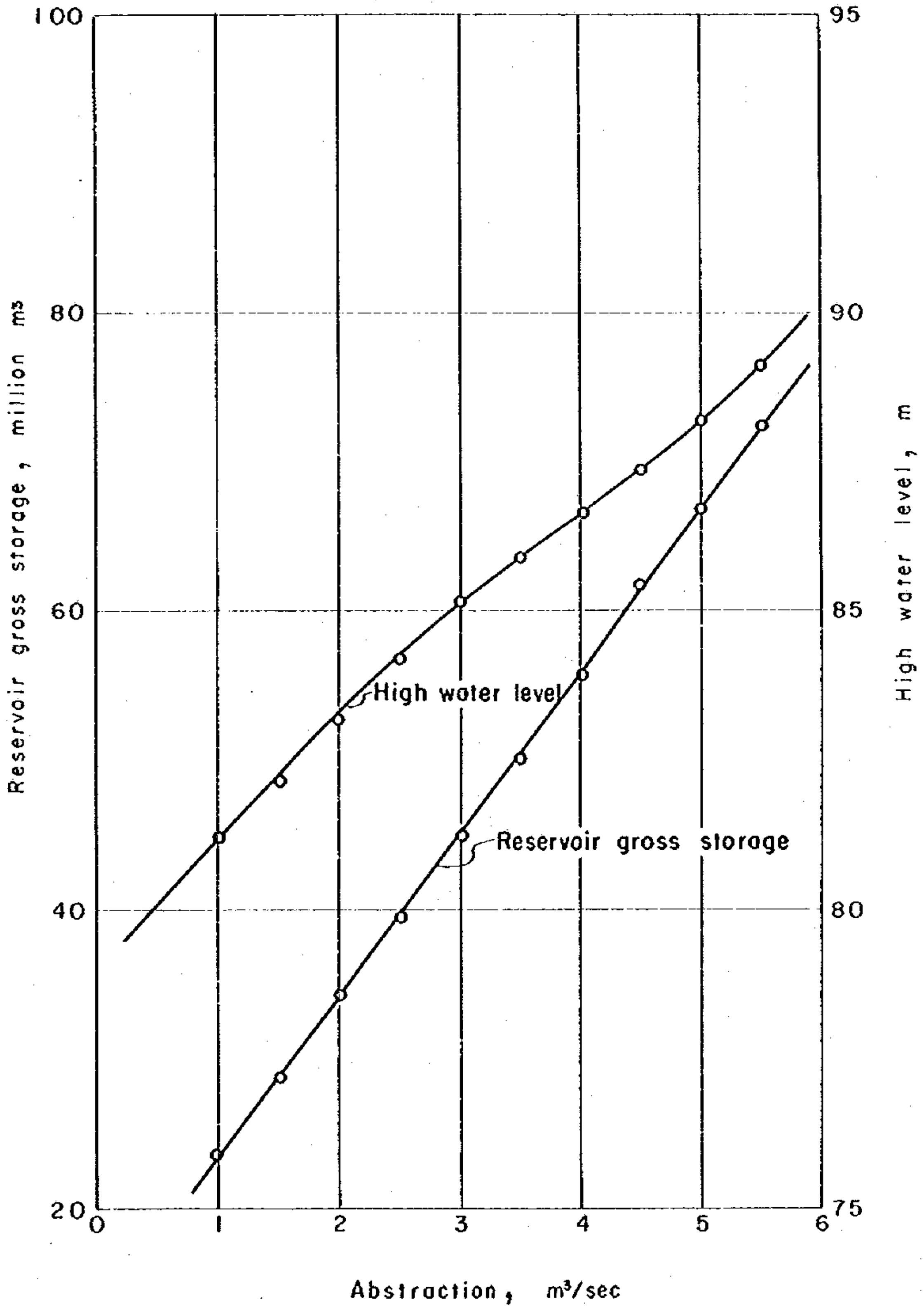
Unit: US$$10^3$

| No. | Year | Water Sold ($10^3$ $m^3$) | Average Water Rate (Ksh/$m^3$) | Operating Revenue | Operating Expense | | Income Before Interest | Interest Payment | Net Income |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Water Sales | O & M Cost | Depreciation | | | |
| 1 | 1983 | - | - | - | - | - | - | - | - |
| 2 | 1984 | - | - | - | - | - | - | - | - |
| 3 | 1985 | - | - | - | - | - | - | - | - |
| 4 | 1986 | 690 | 13.6($1.813) | 1,251 | 91 | 13,357 | -12,197 | 17,152 | -29,349 |
| 5 | 1987 | 1,910 | : | 3,463 | 93 | : | - 9,987 | 16,617 | -26,604 |
| 6 | 1988 | 2,950 | : | 5,348 | 94 | : | - 8,103 | 16,057 | -24,160 |
| 7 | 1989 | 4,160 | : | 7,542 | 96 | : | - 5,911 | 15,425 | -21,336 |
| 8 | 1990 | 6,240 | : | 11,313 | 144 | : | - 2,188 | 14,768 | -16,956 |
| 9 | 1991 | 9,710 | : | 17,604 | 149 | : | 4,098 | 14,501 | -10,403 |
| 10 | 1992 | 13,870 | : | 25,146 | 155 | : | 11,634 | 13,710 | - 2,076 |
| 11 | 1993 | 18,030 | : | 32,688 | 161 | : | 19,170 | 12,892 | 6,278 |
| 12 | 1994 | 22,190 | : | 40,230 | 168 | : | 26,705 | 11,976 | 14,729 |
| 13 | 1995 | 26,350 | : | 47,773 | 174 | : | 34,242 | 11,010 | 23,232 |
| 14 | 1996 | 31,210 | : | 56,584 | 181 | : | 43,046 | 9,970 | 33,076 |
| 15 | 1997 | 35,650 | : | 64,633 | 187 | : | 51,089 | 8,855 | 42,234 |
| 16 | 1998 | 36,060 | : | 65,377 | 188 | : | 51,832 | 7,667 | 44,165 |
| 17 | 1999 | : | : | : | : | : | : | 6,379 | 45,453 |
| 18 | 2000 | : | : | : | : | : | : | 4,992 | 46,840 |
| 19 | 2001 | : | : | : | : | : | : | 3,506 | 48,326 |
| 20 | 2002 | : | : | : | : | : | : | 1,897 | 49,935 |

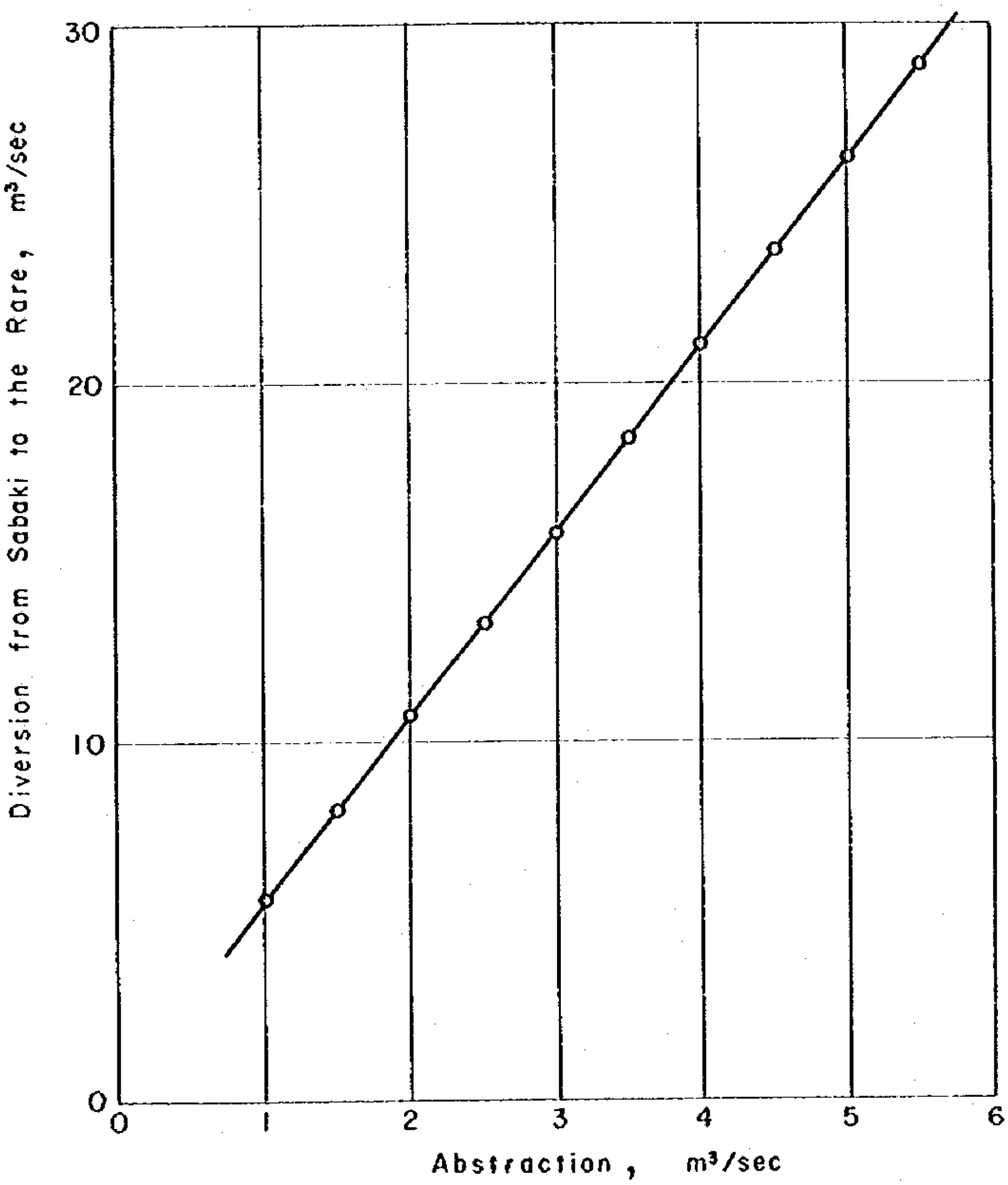
PROJECTED CASH FLOW FOR SECOND MZIMA P/L WITH TSAVO RESERVOIR PLAN

Unit: US$10^3

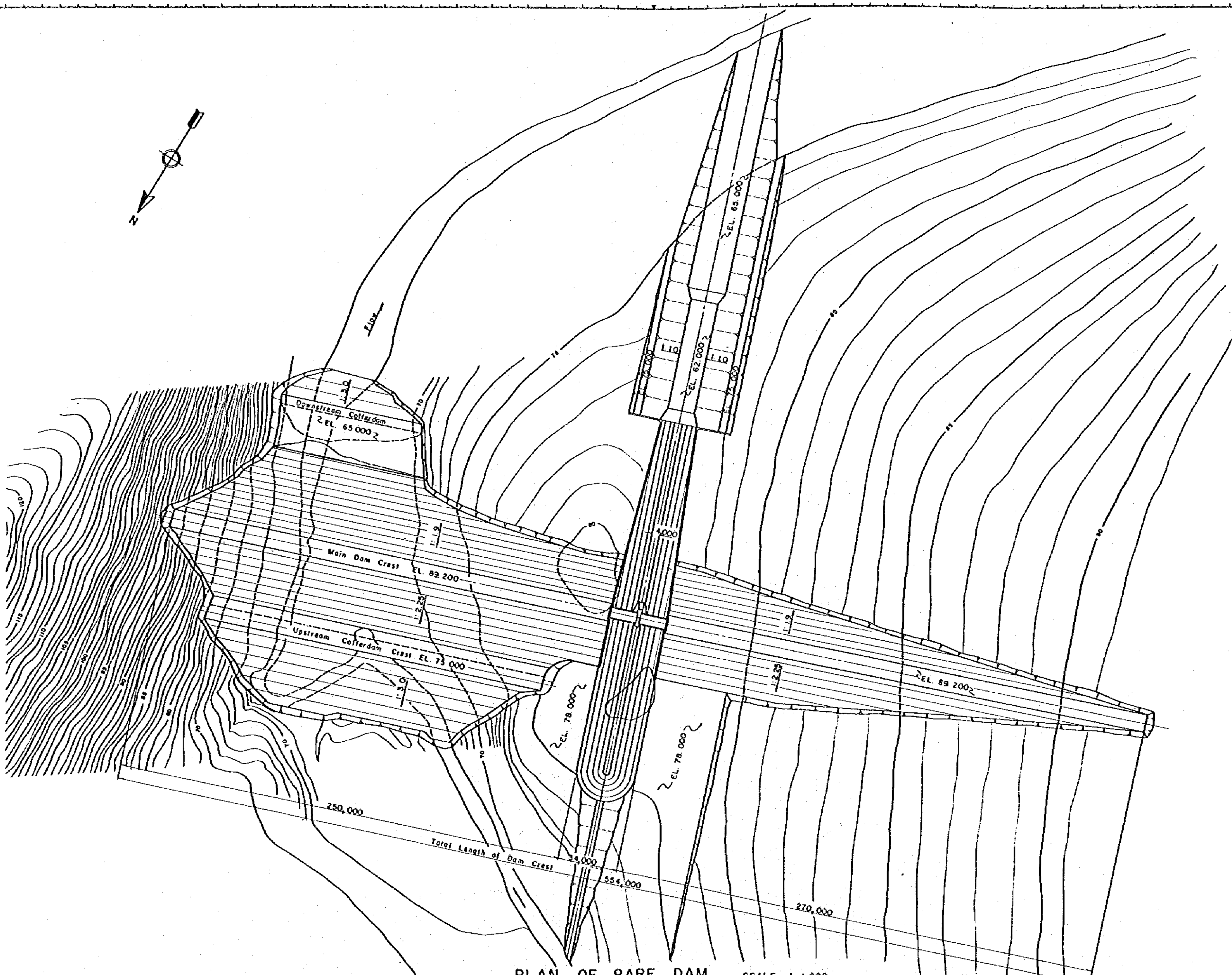
| No. | Year | Income Before Interest | Depreciation | Foreign Loan | Government Equity | Total Source | Capital Cost | | Debt Service | | Total Application | Increase in cash | Cash at End | Debt Service Coverage |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Foreign Currency | Local Currency | Interest | Principal | | | | |
| 1 | 1983 | - | - | 29,292 | 25,555 | 54,847 | 29,292 | 25,555 | - | - | 54,847 | 0 | 0 | - |
| 2 | 1984 | - | - | 124,139 | 112,390 | 236,529 | 124,139 | 112,390 | - | - | 236,529 | 0 | 0 | - |
| 3 | 1985 | - | - | 54,828 | 51,522 | 106,350 | 54,828 | 51,522 | - | - | 106,350 | 0 | 0 | - |
| 4 | 1986 | -12,197 | 13,357 | - | - | 1,160 | - | - | 17,152 | 7,177 | 24,329 | -23,169 | - 23,169 | 0.048 |
| 5 | 1987 | - 9,987 | ⋮ | - | - | 3,370 | - | - | 16,617 | 7,712 | 24,329 | -20,959 | - 44,128 | 0.139 |
| 6 | 1988 | - 8,103 | ⋮ | - | - | 5,254 | - | - | 16,057 | 8,272 | 24,329 | -19,075 | - 63,203 | 0.216 |
| 7 | 1989 | - 5,911 | ⋮ | - | - | 7,446 | - | - | 15,425 | 8,904 | 24,329 | -16,883 | - 80,086 | 0.306 |
| 8 | 1990 | - 2,188 | ⋮ | 6,228 | 17,527 | 34,924 | 6,228 | 17,527 | 14,768 | 9,561 | 48,084 | -13,160 | - 93,246 | 0.459 |
| 9 | 1991 | 4,096 | ⋮ | - | - | 17,455 | - | - | 14,501 | 10,451 | 24,952 | - 7,497 | -100,743 | 0.700 |
| 10 | 1992 | 11,634 | ⋮ | - | - | 24,991 | - | - | 13,710 | 11,242 | 24,952 | 39 | -100,704 | 1.002 |
| 11 | 1993 | 19,170 | ⋮ | - | - | 32,527 | - | - | 12,892 | 12,060 | 24,952 | 7,515 | - 93,129 | 1.304 |
| 12 | 1994 | 26,705 | ⋮ | - | - | 40,062 | - | - | 11,976 | 12,976 | 24,952 | 15,110 | - 78,019 | 1.606 |
| 13 | 1995 | 34,242 | ⋮ | - | - | 47,599 | - | - | 11,010 | 13,942 | 24,952 | 22,647 | - 55,372 | 1.908 |
| 14 | 1996 | 43,046 | ⋮ | - | - | 56,403 | - | - | 9,970 | 14,982 | 24,952 | 31,451 | - 23,921 | 2.260 |
| 15 | 1997 | 51,089 | ⋮ | - | - | 64,446 | - | - | 8,855 | 16,097 | 24,952 | 39,444 | 15,573 | 2.583 |
| 16 | 1998 | 51,832 | ⋮ | - | - | 65,189 | - | - | 7,667 | 17,285 | 24,952 | 40,237 | 55,810 | 2.613 |
| 17 | 1999 | ⋮ | ⋮ | - | - | ⋮ | - | - | 6,379 | 18,573 | 24,952 | ⋮ | 96,047 | ⋮ |
| 18 | 2000 | ⋮ | ⋮ | - | - | ⋮ | - | - | 4,992 | 19,960 | 24,952 | ⋮ | 136,284 | ⋮ |
| 19 | 2001 | ⋮ | ⋮ | - | - | ⋮ | - | - | 3,506 | 21,446 | 24,952 | ⋮ | 176,521 | ⋮ |
| 20 | 2002 | ⋮ | ⋮ | - | - | ⋮ | - | - | 1,897 | 23,055 | 24,952 | ⋮ | 216,758 | ⋮ |



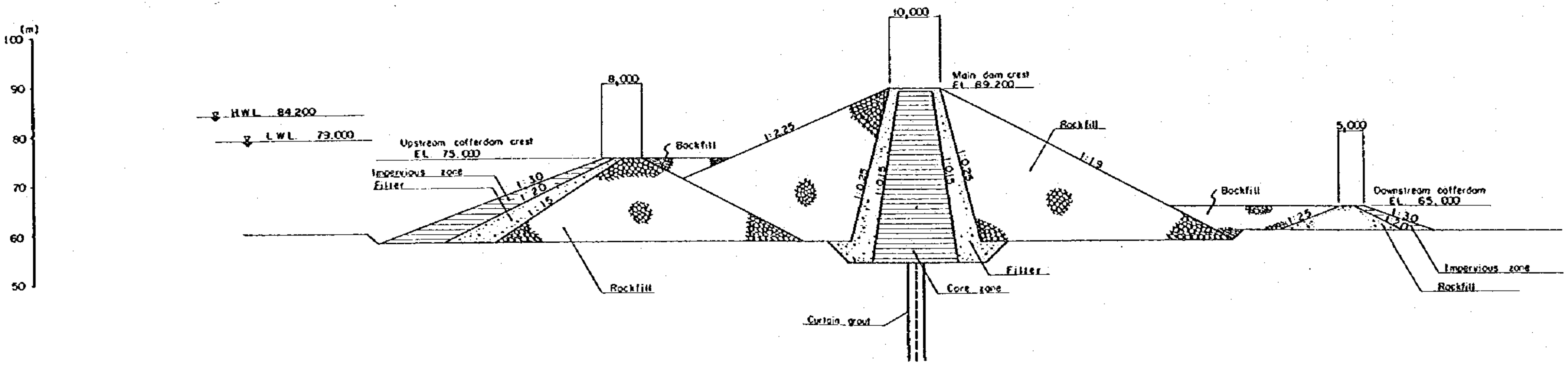

Reservoir Gross Storage and High Water Level of Rare Reservoir



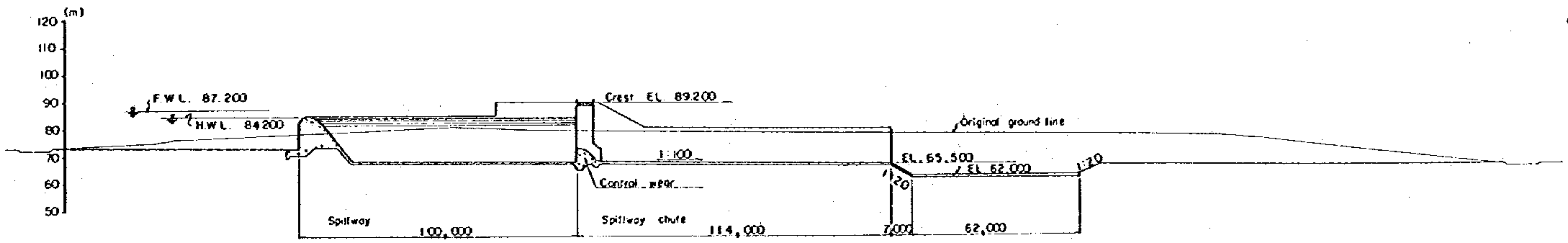

Flow Capacity of Diversion Canal from the Sabaki to the Rare



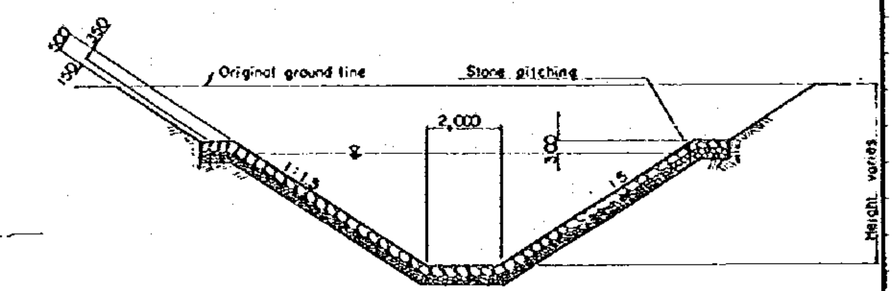

PLAN OF RARE DAM SCALE 1:1,000




CROSS SECTION OF RARE DAMS SCALE 1:500




PROFILE OF SPILLWAY SCALE 1:1000




CROSS SECTION OF DIVERSION CANAL FROM THE SABAKI TO THE RARE RESERVOIR (40 Km) SCALE 1:100

# FLOOD ESTIMATES AT RARE DAM SITE

## A. General

1. For the estimate of flood discharge at the dam site, it is desired to use discharge data at the existing gauging station (3LA2). However, discharge measurement on flood has never been made at the station. Moreover, there is no rainfall gauging station in the watershed except the area of the Voi River. As there is no available information for the prediction of flood in the basin, flood discharge is estimated from specific discharge of other basins.

## B. Specific Discharge

2. Specific discharge is defined as the value of peak discharge over the catchment. Flood discharge at the Tsavo dam site has been already discussed in ANNEX 4308. Design floods at the proposed Mwachi dam site have been estimated by the flood on May 14, 1972 and rainfall data at Maji ya Chumbi (93-39-23).

3. The specific discharges for design floods at the dam sites of Tsavo and Mwachi are summarized as below.

| | | Specific discharge, $m^3/sec/Km^2$ | | |
|---|---|---|---|---|
| | Catchment, $Km^2$ | Design flood for diversion | Design flood for spillway | PMF /1 |
| Tsavo | 4050 | 0.16 | 0.38 | 0.49 |
| Mwachi | 2090 | 0.34 | 0.87 | 1.27 |

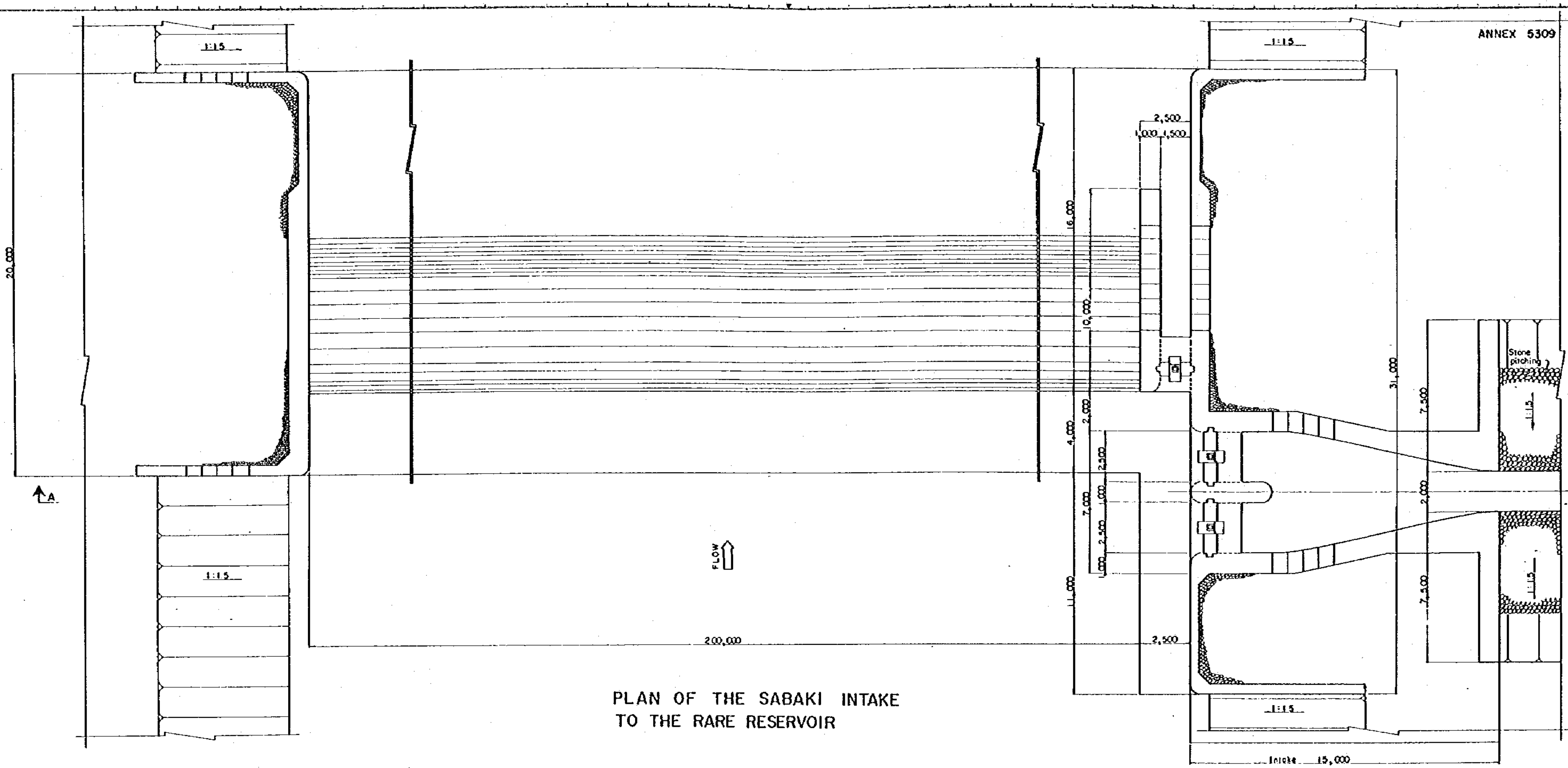
/1: Probable maximum flood.

4. The catchment of 2,090 $Km^2$ on the Mwachi dam site is measured by excluding the area belonging to the seasonal river. The catchment of the Rare dam is measured to be 1,500 $Km^2$ excluding the area of upper reaches as mentioned in para. 5201. For the estimate of discharge for the cofferdam and diversion channel, the catchment is made 580 $Km^2$ by providing another cofferdam at the point that El.400 ft contour runs across the Goshi River for the purpose of making the diversion facilities small.

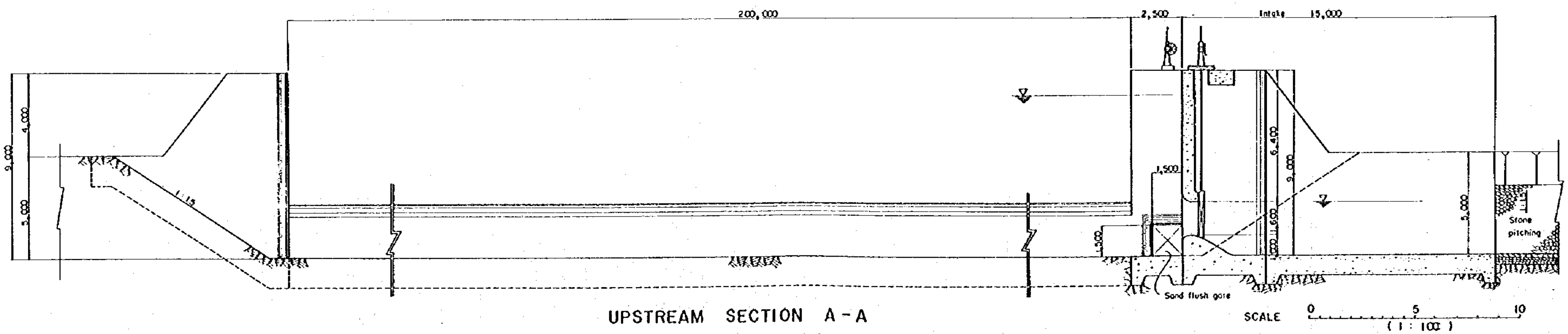
5. As the cofferdam near Goshi is only used for retarding the peak discharge of flood, it is allowed for the cofferdam to be over-topped without any diversion facilities. After the completion of the main dam, the cofferdam is removed.

6. It is said that the value of specific discharge exponentially decreases as catchment increases, that is, the specific discharge of the Rare is greater than that of the Mwachi. However, the specific discharge estimated for the Mwachi is applied to predict the flood discharges for the Rare dam, because the Rare River is located in the drier area than the Mwachi River. The peak discharges predicted for the Rare dam are as follows;

| | |
|---|---|
| Design flood for the diversion facilities; | 260 $m^3$/sec |
| Design flood for the spillway; | 1,305 $m^3$/sec |
| Probable maximum flood; | 1,905 $m^3$/sec |




PLAN OF THE SABAKI INTAKE TO THE RARE RESERVOIR

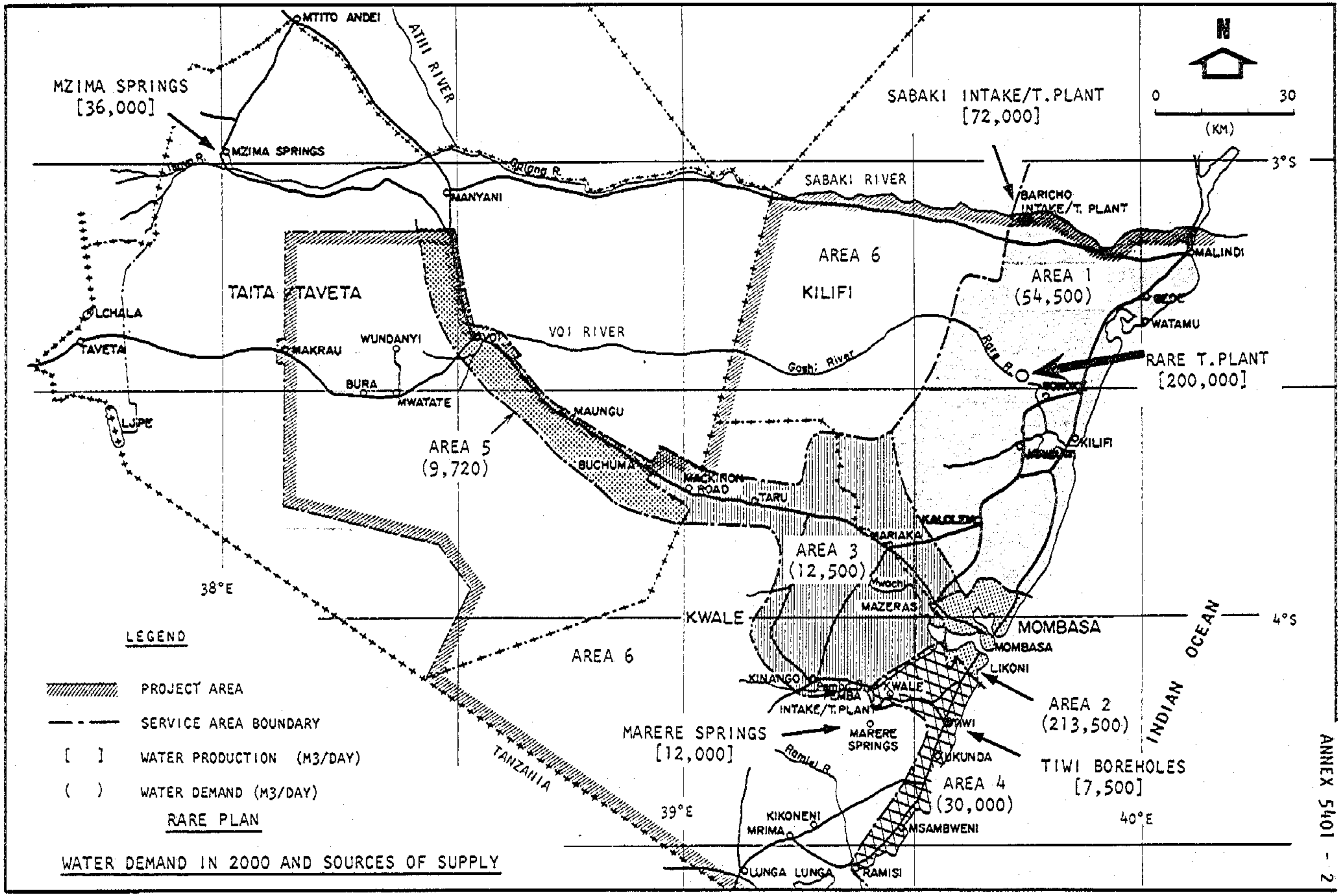



UPSTREAM SECTION A - A

(RARE PLAN)

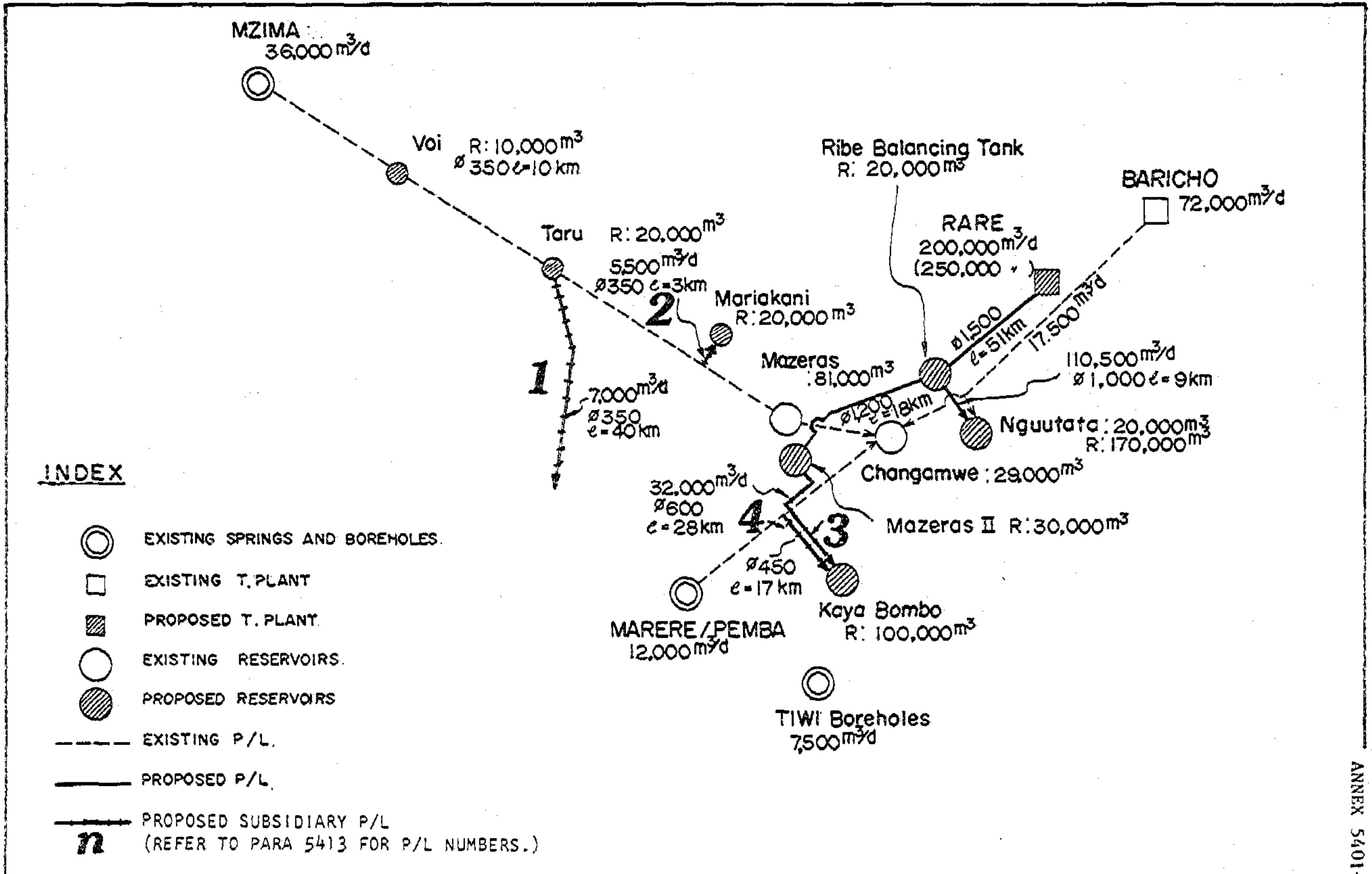
ESTIMATED 2000 DEMAND AND SOURCES OF SUPPLY

| AREA | Total Demand ($m^3/d$) | Mzima P/L ($m^3/d$) | SOURCES OF SUPPLY<br>Marere P/L Tiwi B.H. ($m^3/d$) | Rare P/L ($m^3/d$) | Sabaki P/L ($m^3/d$) |
|---|---|---|---|---|---|
| 1. Mombasa Is. | 75,000 | - | - | 75,000 | - |
| 2. West Mainland | 64,000 | 13,780 | - | 50,220 | - |
| 3. North Mainland | 53,000 | - | - | 35,500 | 17,500 |
| 4. South Mainland | 21,500 | - | - | 21,500 | - |
| 5. Kilifi District Coast | 54,500 | - | - | - | 54,500 |
| 6. Kilifi District South | 5,500 | 5,500 | - | - | - |
| 7. Kwal District North | 1,500 | 1,500 | - | - | - |
| 8. Kwal District Central | 5,500 | 5,500 | - | - | - |
| 9. Kwal District South | 30,000 | - | 19,500 | 10,500 | - |
| 10. Taita District | 9,720 | 9,720 | - | - | - |
| | 320,220 | 36,000 | 19,500 | 192,720 | 72,000 |

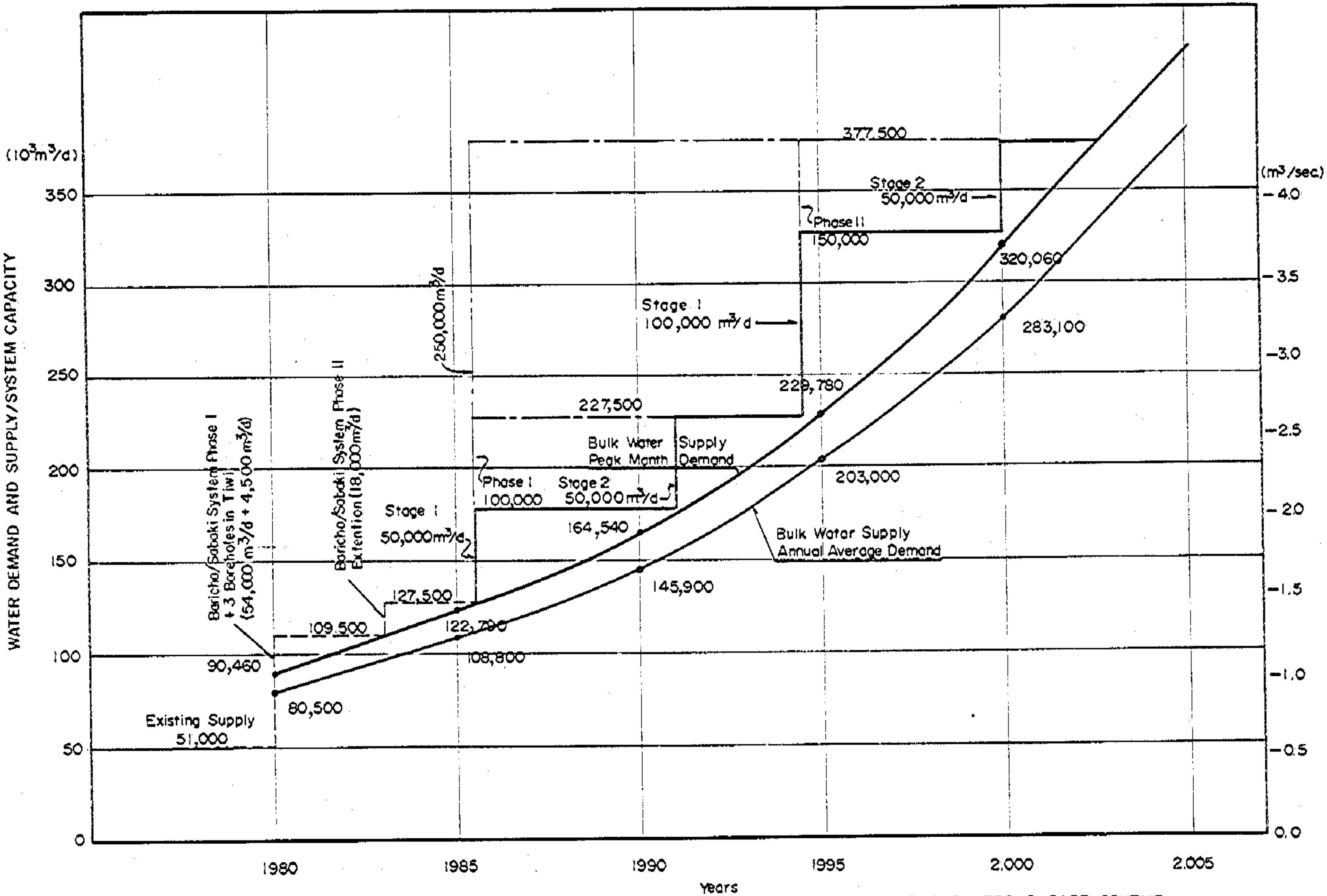



RARE PLAN

WATER DEMAND IN 2000 AND SOURCES OF SUPPLY




RARE PLAN SYSTEM



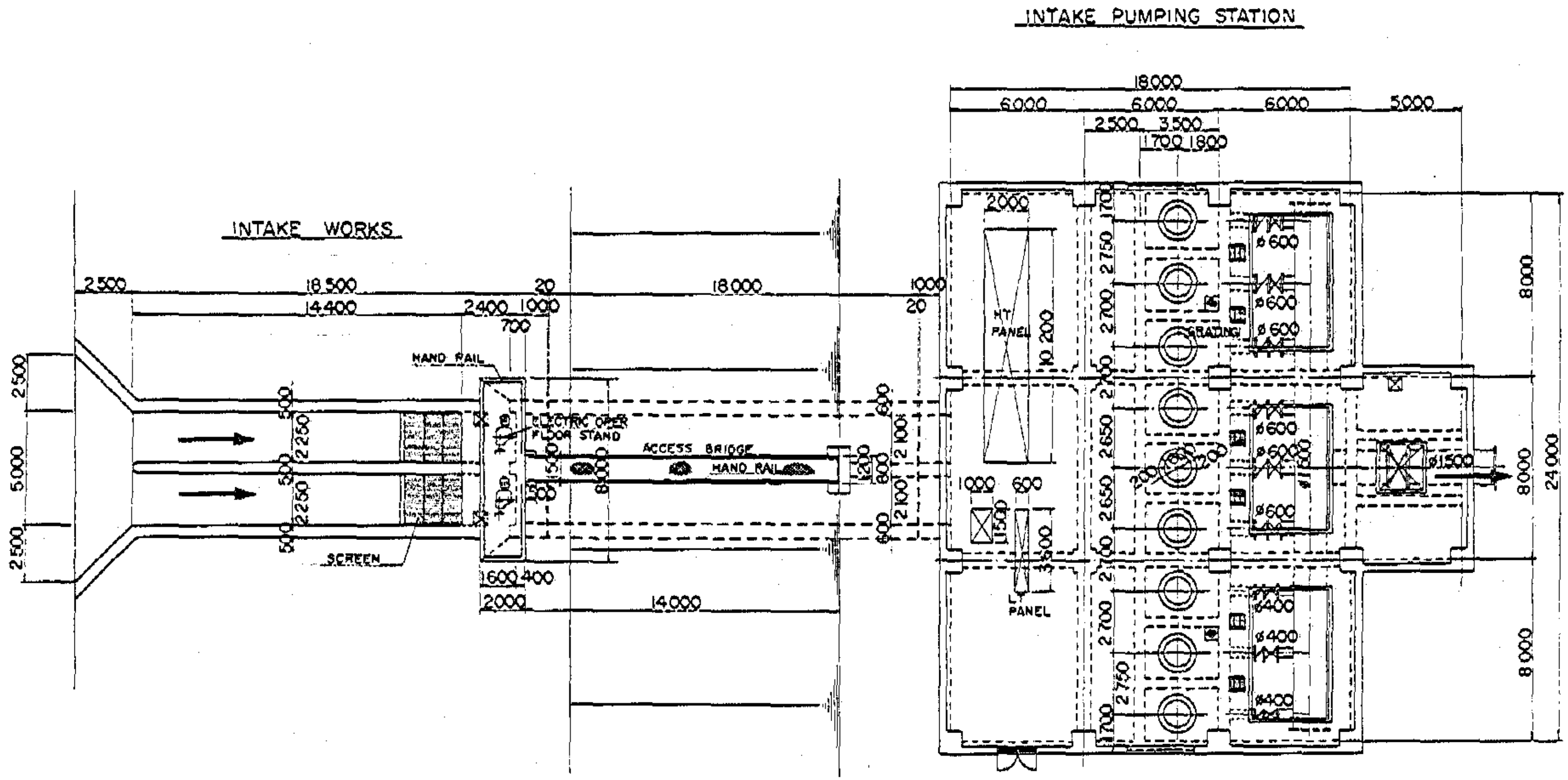

WATER DEMAND VERSUS RARE SCHEME
SYSTEM SUPPLY CAPACITY

## Rare P/L with Rare Reservoir Plan

Sizes and capacities of major components

| Plan Element | Description |
|---|---|
| Intake Facility and Pumping Station | - RC construction intake with two separate gates and intake conduits<br>- 9 vertical turbine pumps:<br>3 @19.1 $m^3$/min with 390 kw motors<br>6 @38.2 $m^3$/min with 750 kw motors |
| Raw Water Transmission Main | - 4.5 km long, 1,500 mm dia rising main from intake pumping station to treatment plant |
| Rare Water Treatment Plant | - Plant capacity for maximum output is 250,000 $m^3$/day, while in Phase I 100,000 $m^3$/day and 150,000 $m^3$/day in Phase II.<br>- Description of treatment plant elements are in the followings. |
| a) Receiving/Distributing Tank | - An RC circuler tank with 1 min ditention time for total influent of 250,000 $m^3$/day |
| b) Flocculation and Sedimentation Basins | - 6 rectangular tanks for the max capacity with one unit of stand-by<br>- Coagulation with aluminum sulphate with provisions for addition of sodium carbonate |
| c) Filters | - 30 rapid gravity filters with water back/surface washing and with total output capacity of 250,000 $m^3$/day |

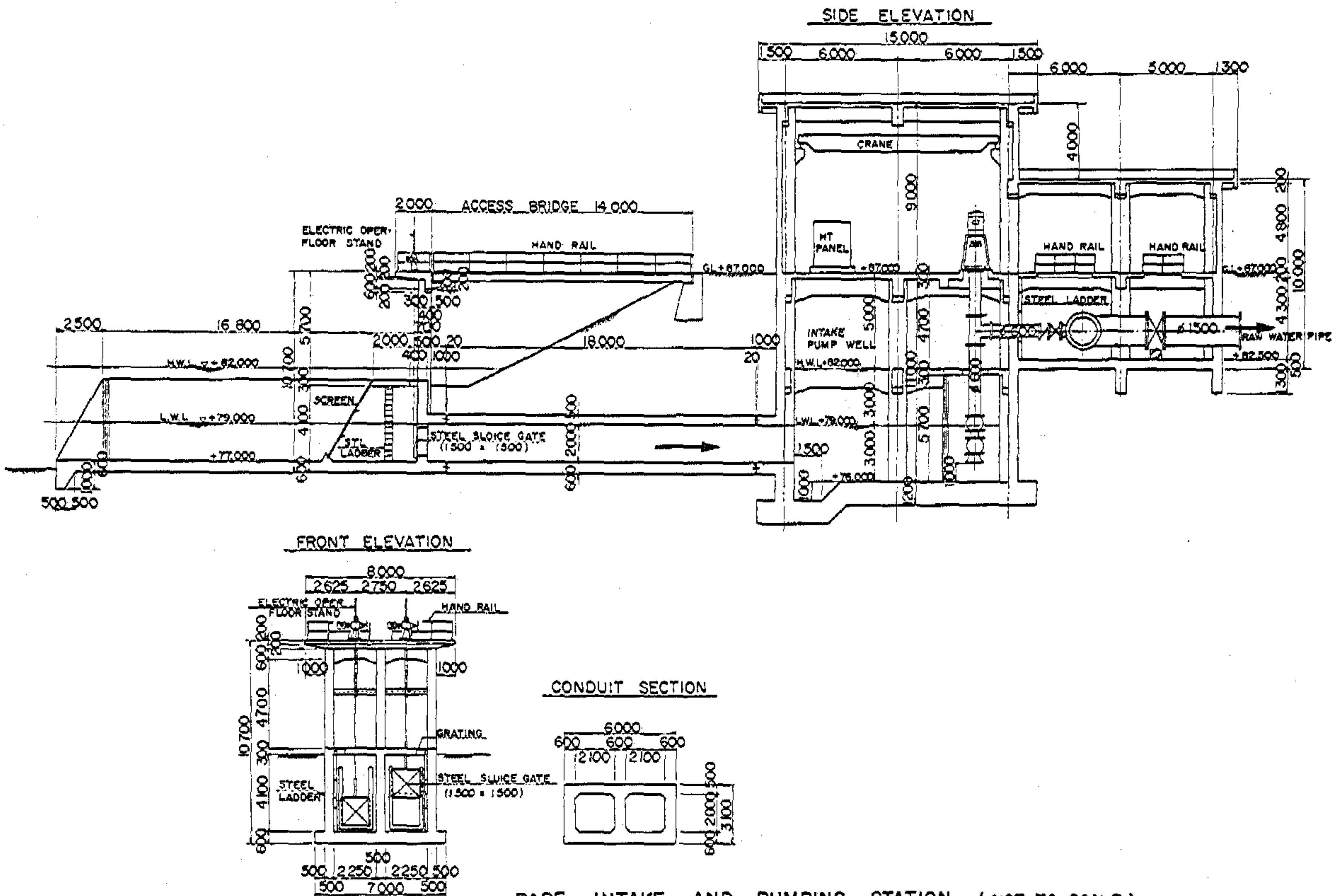
| | |
|---|---|
| d) Chemicals | - Plant would include facilities for storing, preparing, feeding alum, lime, sodium carbonate and chlorine |
| e) Administration and Operation Building | - Administration building with wash water tank on the top |
| Transmission Pumping Station | - An RC construction pumping station<br>- 9 horisontal turbine pumps:<br>3 @17.4 $m^3$/min with 570 kw motors<br>6 @34.8 $m^3$/min with 1,100 kw motors |
| Transmission Main | - 1,500, 1,200 and 1,000 mm dia pipes with total length about 78 km<br>- Line valves and controlling points at about 5 km intervals<br>- Air valves and washouts as required by profile with approx. 3 per 2 km |
| Break Pressure Tank and One-way Surge tanks | - 2 one-way surge tanks as required on the P/L<br>- Rabi balancing tank at 20,000 $m^3$ |
| Storage Reservoirs | - New Mazeras reservoirs at 30,000 $m^3$<br>- Nguu Tatu reservoirs at 170,000 $m^3$<br>- Kaya Bombo reservoirs at 100,000 $m^3$<br>- Voi reservoir at 20,000 $m^3$<br>- Taru reservoir at 20,000 $m^3$<br>- Mariakani reservoir at 20,000 $m^3$ |
| Subsidiary P/L | - 600 mm dia, 28,000 m<br>- 450 mm dia, 17,000 m<br>- 350 mm dia, 53,000 m<br>- Materials suitable for max. working pressure 12.5 kg/$cm^2$ including surge surplus |




INTAKE PUMPS

Ø600 x 38.2 M3/MIN x 32 M x 750 KW x 980 RPM x 6 UNITS
Ø400 x 19.1 M3/MIN x 32 M x 390 KW x1470 RPM x 3 UNITS

RARE INTAKE AND PUMPING STATION GENERAL PLAN (NOT TO SCALE)



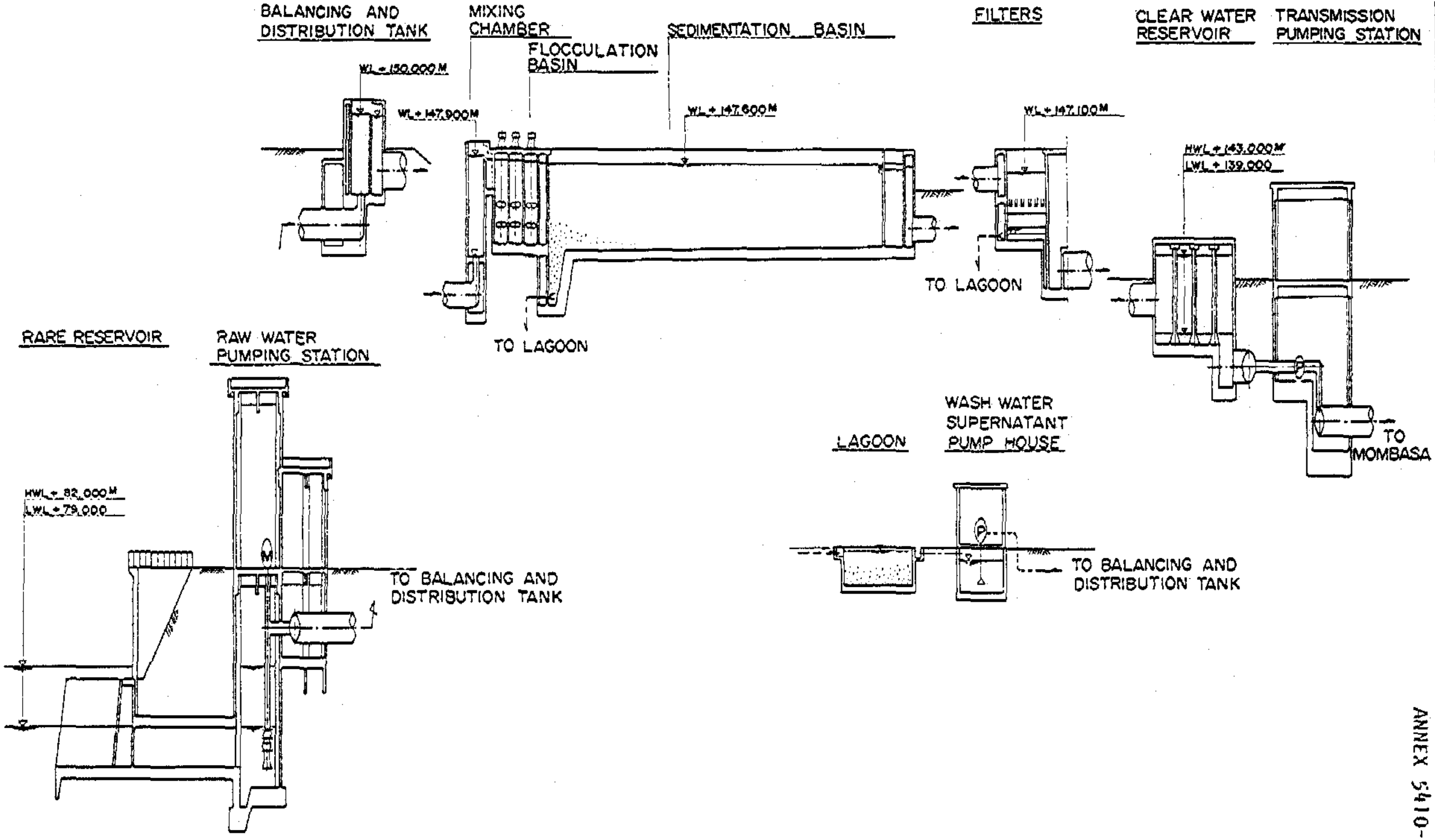

RARE INTAKE AND PUMPING STATION (NOT TO SCALE)

## Water Quality Standard

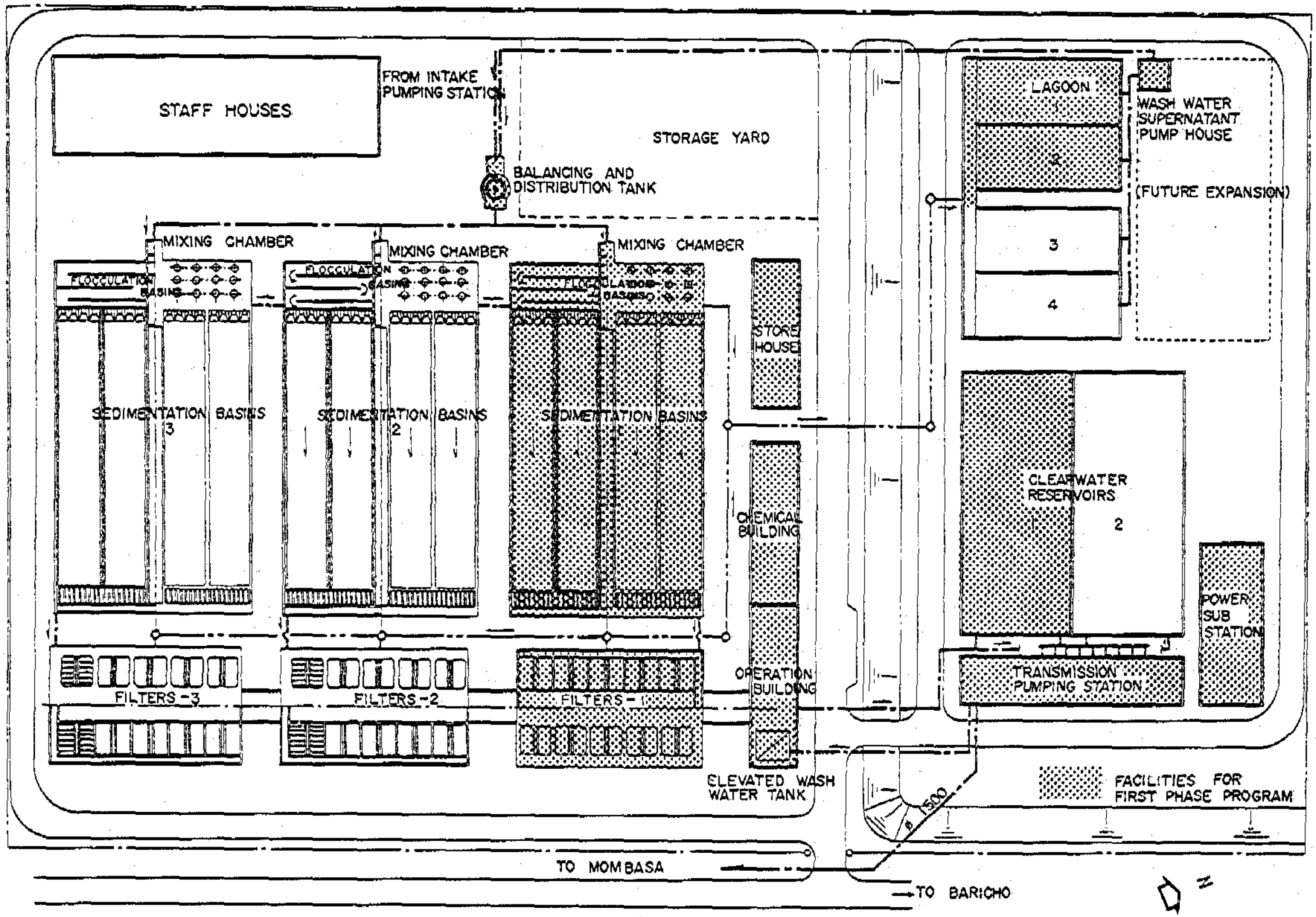
(WHO and Japanese Standards for Drinking Water)

| Substance or characteristic | | WHO Standards Highest Desireble Level | WHO Standards Maximum Permissible Level | Japanese Standards |
|---|---|---|---|---|
| Color as Pt.Co. | unit | 5 | 50 | Max. 5 |
| Turbidity | FTU | 5 | 25 | Max. 2 |
| Total Solids | mg/l | 500 | 1500 | Max. 500 |
| pH | | 7-8.5 | 6.5-9.2 | From max.8.6 to min.5.8 as pH value |
| Detergents | mg/l | 0.2 | 1.0 | - |
| Mineral Oil | mg/l | 0.01 | 0.3 | - |
| Phenol | mg/l | 0.001 | 0.002 | Max. 0.005 |
| Total Hardness (as $CaCO_3$) | mg/l | 100 | 500 | Max. 300 |
| Calcium as Ca | mg/l | 75 | 200 | - |
| Magnesium as Mg | mg/l | 30 | 150 | - |
| Chloride as $Cl_2$ | mg/l | 200 | 600 | Max. 200 |
| Copper as Cu | mg/l | 0.05 | 1.5 | Max. 1.0 |
| Total Iron as Fe | mg/l | 0.1 | 1.0 | Max. 0.3 |
| Manganese as Mn | mg/l | 0.05 | 0.5 | Max. 0.3 |
| Sulfates as $SO_4$ | mg/l | 200 | 400 | - |
| Zinc as Zn | mg/l | 5 | 15 | Max. 1.0 |
| Coliform Groups | /100 ml | - | - | Not to be detected |
| Total Bacteria | /1 ml | - | - | Max. 10 |

Note : The water quality is recommended to conform to criteria established by WHO. These criteria may be superseded by local standards.

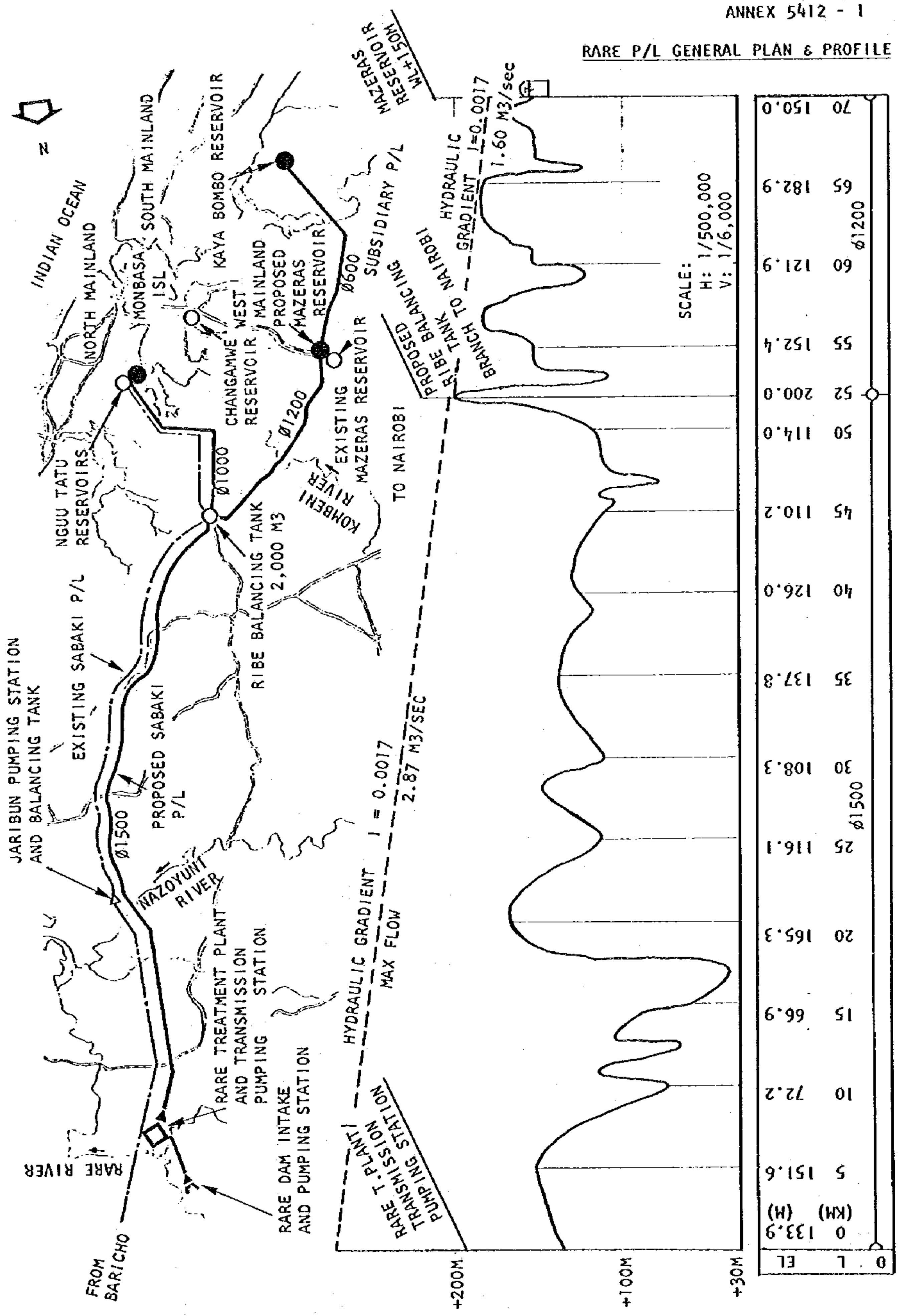



RARE TREATMENT PLANT FLOOR DIAGRAM (NOT TO SCALE)




RARE TREATMENT PLANT GENERAL SITE PLAN (NOT TO SCALE)

RARE P/L GENERAL PLAN & PROFILE



(RARE PLAN)

DISTRIBUTION RESERVOIR CONSTRUCTION SCHEDULE

| | Location | System Name | Existing $m^3$ | Provision in 2000 $m^3$ | Total $m^3$ |
|---|---|---|---|---|---|
| 1. | Mazeras | Mzima P/L | 81,000 | - | 81,000 |
| 2. | Changamwe | " | 29,600 | 13,600 1/ | 43,200 |
| 3. | Nguu Tatu | Sabaki P/L | 9,100 | 170,000 | 270,100 |
| | | Rare P/L | 18,000 | | |
| 4. | Voi | Mzima | 580 | 10,000 | 10,580 |
| 5. | Kaya Bombo | Marere P/L | 1,125 | 100,000 | 101,125 |
| | | Mwachi P/L | | | |
| 6. | Tiwi | Tiwi B.H. | 2,250 | - | 2,250 |
| 7. | Mazeras II | Mwachi P/L | - | 30,000 | 30,000 |
| 8. | Taru | Mzima P/L | - | 20,000 | 20,000 |
| 9. | Mariakani | " | - | 20,000 | 20,000 |
| 10. | Ribe Tank | Rare P/L | - | 20,000 | 20,000 |
| | Total | | 141,660 | 383,600 | 525,260 |

Note: 1/ Sabaki P/L project.

# MAIN FEATURES OF RARE RESERVOIR WITH P/L

| Item | Development Scale 1.5 $m^3$/sec | Development Scale 2.5 $m^3$/sec |
|---|---|---|
| **Dam** | | |
| Catchment($km^2$) | 1,500 | 1,500 |
| Type of dam | rockfill | rockfill |
| Height (m) | 31 | 33 |
| Reservoir effective storage ($10^6/m^3$) | 16.8 | 27.6 |
| Fill volume ($10^3m^3$) | 306 | 380 |
| Design flood ($m^3$/sec) | 1,305 | 1,305 |
| **Diversion canal** | | |
| Length (km) | 40 | 40 |
| Excavation ($10^3/m^3$) | 1,084 | 1,339 |
| Capacity ($m^3$/sec) | 8.0 | 13.3 |
| **Water supply facilities** | | |
| Pumping station (units) | 2 | 2 |
| Intake pumps (units) (@19.1 $m^3$/min) | 3 | 3 |
| (@38.2 $m^3$/min) | 3 | 6 |
| Transmission pumps (units) (@17.4 $m^3$/min) | 3 | 3 |
| (@34.8 $m^3$/min) | 3 | 6 |
| **Raw water main P/L** | | |
| Diameter (mm) and length (km) | 1,200mm-4.5km | 1,500mm-4.5km |
| Treatment plant (@55,000 $m^3$/d) (units) | 3 | 5 |
| Transmission main P/L | | |
| Diameter (mm) and length (km) | 1,200mm-51km | 1,500mm-51km |
| | 1,000mm-18km | 1,200mm-18km |
| | 800mm- 9km | 1,000mm- 9km |

# COST ESTIMATES OF RARE RESERVOIR WITH P/L

ECONOMIC COSTS

Unit: US$$10^3$

| | Development scale, $m^3$/sec | | | | | |
|---|---|---|---|---|---|---|
| | 1.5 | | | 2.5 | | |
| | L.C. | F.C. | Total | L.C. | F.C. | Total |
| Capital Cost | | | | | | |
| A. Water Supply Facilities | | | | | | |
| 1. Pumping equipments | 1,170 | 3,831 | 5,001 | 1,651 | 5,405 | 7,056 |
| 2. Raw water main P/L | 1,368 | 2,240 | 3,608 | 1,682 | 3,332 | 5,014 |
| 3. Treatment plants | 19,550 | 6,436 | 25,986 | 24,734 | 9,654 | 34,388 |
| 4. Transmission main P/L including trans. pumping st. and distribution res. | 31,278 | 32,533 | 63,811 | 49,147 | 52,056 | 101,203 |
| 5. Communication equip. | 300 | 800 | 1,100 | 300 | 800 | 1,100 |
| 6. Subsidiary P/L | 4,170 | 7,467 | 11,634 | 5,549 | 9,936 | 15,485 |
| B. Dam | | | | | | |
| 7. General items | 3,003 | 1,307 | 4,310 | 3,282 | 1,457 | 4,739 |
| 8. Sabaki intake and diversion canal | 17,530 | 7,195 | 24,725 | 19,661 | 8,175 | 27,836 |
| 9. Coffer dam and diversion channel | 4,501 | 1,444 | 5,945 | 4,501 | 1,444 | 5,945 |
| 10. Main dam | 3,418 | 3,130 | 6,548 | 4,076 | 3,649 | 7,725 |
| 11. Spillway | 4,543 | 1,142 | 5,685 | 4,543 | 1,142 | 5,685 |
| 12. River outlet facilities | 35 | 163 | 198 | 35 | 163 | 198 |
| C. Engineering and Adm. | 9,087 | 6,769 | 15,856 | 11,916 | 9,721 | 21,637 |
| Base Cost Total | 99,953 | 74,457 | 174,410 | 131,074 | 106,934 | 238,008 |
| D. Physical Contingency | 14,993 | 11,169 | 26,162 | 19,661 | 16,040 | 35,701 |
| Capital Cost Total | 114,946 | 85,626 | 200,572 | 150,735 | 122,974 | 273,709 |

ECONOMIC COSTS ESTIMATED FOR WATER FACILITIES AND CIVIL WORKS ON RARE RESERVOIR WITH P/L

Development Scale: 2.5 $m^3$/sec

| Items | Unit | Quantity | L. C. Unit Price (US$) | L. C. Amount (US$$10^3$) | F. C. Unit Price (US$) | F. C. Amount (US$$10^3$) |
|---|---|---|---|---|---|---|
| A. Water Supply Facilities | | | | | | |
| 1. Pumping Equipment (Intake/Transmission) | L.S. | | | 1,651.0 | | 5,405.0 |
| 2. Raw Water Main P/L ø 1500 | m | 4,500 | 373.8 | 1,682.0 | 740.5 | 3,332.0 |
| 3. Treatment Plant | L.S. | | | 24,734.0 | | 9,654.0 |
| 4. Transmission Main P/L | m | | | | | |
| ø 1500 | | 51,000 | 373.8 | 19,063.8 | 740.5 | 37,765.5 |
| ø 1200 | m | 18,000 | 157.6 | 2,836.8 | 498.1 | 8,964.9 |
| ø 1000 | m | 9,000 | 126.5 | 1,138.5 | 351.6 | 3,164.6 |
| Power Supply Facilities | L.S. | | | 3,112.3 | | 2,160.0 |
| Reservoirs 30,000 $m^3$ | units | 8 | 1600x$10^3$ | 12,800.0 | | |
| 20,000 $m^3$ | " | 6 | 1400x$10^3$ | 8,400.0 | | |
| 10,000 $m^3$ | " | 1 | 750x$10^3$ | 750.0 | | |
| Miscellaneous | L.S. | | | 1,045.6 | | |
| Sub-Total | | | | 49,147.0 | | 52,056.0 |
| 5. Communication Equipment | L.S. | | | 300.0 | | 800.0 |
| 6. Subsidiary P/L ø600 | m | 28,000 | 101.8 | 2,850.4 | 179.1 | 5,015.3 |
| ø450 | m | 17,000 | 64.4 | 1,094.7 | 113.4 | 1,927.9 |
| ø350 | m | 43,000 | 37.3 | 1,603.9 | 69.6 | 2,992.8 |
| Sub-Total | | | | 5,549.0 | | 9,936.0 |
| B. Dam | | | | | | |
| 7. General Item | L.S. | | | 3,282.0 | | 1,457.0 |
| 8. Sabaki intake and diversion channel | | | | | | |
| Excavation | $m^3$ | 1,338,500 | 6 | 8,031.0 | 3 | 4,015.5 |
| Stone pitching | $m^2$ | 722.600 | 2 | 1,445.2 | 1 | 722.6 |
| Sabaki intake | L.S. | | | 7,000.0 | | 2,500.0 |
| Miscellaneous | L.S. | | | 3,184.8 | | 936.9 |
| Sub-Total | | | | 19,661.0 | | 8,175.0 |

| Items | Unit | Quantity | L. C. Unit Price (US$) | L. C. Amount (US$$10^3$) | F. C. Unit Price (US$) | F. C. Amount (US$$10^3$) |
|---|---|---|---|---|---|---|
| 9. Cofferdam and diversion channel | | | | | | |
| Excavation | $m^3$ | 100,300 | 6 | 601.8 | 3 | 300.9 |
| Embankment | $m^3$ | 51,400 | 5 | 257.0 | 5 | 257.0 |
| Concrete | $m^3$ | 25,200 | 100 | 2,520.0 | 30 | 756.0 |
| Reinforcement bars | ton | 760 | 900 | 684.0 | 80 | 60.8 |
| Miscellaneous | L.S. | | | 438.2 | | 69.3 |
| Sub-Total | | | | 4,501.0 | | 1,444.0 |
| 10. Dam | | | | | | |
| Excavation | $m^3$ | 201,400 | 6 | 1,208.4 | 3 | 604.2 |
| Embankment | $m^3$ | 381,800 | 5 | 1,909.0 | 5 | 1,909.0 |
| Concrete, in cap for grouting | $m^3$ | 1,100 | 100 | 110.0 | 20 | 22.0 |
| Curtain and blanket grouting | m | 7,700 | 25 | 192.5 | 100 | 770.0 |
| Miscellaneous | L.S. | | | 656.1 | | 343.8 |
| Sub-Total | | | | 4,076.0 | | 3,649.0 |
| 11. Spillway | | | | | | |
| Excavation | $m^3$ | 94,000 | 6 | 564.0 | 3 | 282.0 |
| Backfill | $m^3$ | 2,600 | 1 | 2.6 | 0.50 | 1.3 |
| Concrete | $m^3$ | 30,700 | 100 | 3,070.0 | 20 | 614.0 |
| Reinforcement bars | ton | 620 | 900 | 58.0 | 80 | 49.0 |
| Steel anchor bars | ton | 210 | 1,300 | 273.0 | 700 | 147.0 |
| Miscellaneous | L.S. | | | 75.4 | | 48.1 |
| Sub-Total | | | | 4,543.0 | | 1,142.0 |
| 12. River outlet facilities | L.S. | | | 35.0 | | 163.0 |
| Grand Total | | | | 119,161 | | 97,213 |

# BREAKDOWN OF O&M COST ON RARE PLAN

Unit: US$$10^3$

Development Scale: 2.5 $m^3$/sec

| Year | Proposed System Supply, $m^3$/d | Staff Salary | Chemical | Repair | Electricity | Total |
|---|---|---|---|---|---|---|
| 1986 | 1,990 | 108.1 | 12.85 | 107.0 | 40.05 | 268.00 |
| 1987 | 5,510 | : | 35.62 | : | 110.91 | 361.63 |
| 1988 | 8,480 | : | 55.05 | : | 171.14 | 441.29 |
| 1989 | 12,000 | : | 77.67 | : | 241.53 | 534.30 |
| 1990 | 18,400 | : | 119.09 | : | 370.35 | 704.54 |
| 1991 | 28,000 | : | 193.65 | : | 602.19 | 1,010.94 |
| 1992 | 39,890 | : | 268.20 | : | 834.03 | 1,102.23 |
| 1993 | 52,000 | : | 342.76 | : | 1,065.86 | 1,623.72 |
| 1994 | 63,990 | : | 417.31 | : | 1,297.70 | 1,930.11 |
| 1995 | 75,990 | 210.7 | 491.87 | : | 1,529.54 | 2,339.11 |
| 1996 | 89,760 | : | 595.48 | : | 1,851.75 | 2,764.93 |
| 1997 | 106,010 | : | 699.09 | : | 2,173.95 | 3,190.74 |
| 1998 | 121,990 | : | 802.70 | : | 2,496.16 | 3,616.56 |
| 1999 | 138,000 | : | 906.31 | : | 2,818.36 | 4,042.37 |
| 2000 | 155,600 | : | 1,009.92 | : | 3,140.57 | 4,468.19 |
| 2001 | 170,490 | : | 1,087.56 | : | 3,382.01 | 4,787.27 |
| 2002 | 186,500 | : | 1,165.19 | : | 3,623.45 | 5,106.34 |
| 2003 | 202,480 | : | 1,242.83 | : | 3,864.90 | 5,425.43 |
| 2004 | 214,660 | : | 1,320.46 | : | 4,106.34 | 5,426.80 |
| 2005 | 216,000 | : | 1,398.10 | : | 4,347.78 | 6,063.58 |
| : | : | : | : | : | : | : |
| 2035 | : | : | : | : | : | : |

# FINANCIAL COST ESTIMATES OF RARE RESERVOIR WITH RARE P/L

Unit: US$$10^3$
Development Scale: 2.5 $m^3$/sec

| | Economic Costs | | | Sales Taxes | Financial Costs | | |
|---|---|---|---|---|---|---|---|
| | L.C. | F.C. | Total | L.C. | L.C. | F.C. | Total |
| Capital Cost | | | | | | | |
| A. Water Supply Facilities | | | | | | | |
| 1. Pumping equipments | 1,651 | 5,405 | 7,056 | 634 | 2,285 | 5,405 | 7,690 |
| 2. Raw water main P/L | 1,682 | 3,332 | 5,014 | 465 | 2,147 | 3,332 | 5,479 |
| 3. Treatment plants | 24,734 | 9,654 | 34,388 | 3,553 | 28,287 | 9,654 | 37,941 |
| 4. Transmission main P/L including trans. pumping st. and distribution res. | 49,147 | 52,056 | 101,203 | 9,859 | 59,006 | 52,056 | 111,062 |
| 5. Communication equip. | 300 | 800 | 1,100 | 100 | 400 | 800 | 1,200 |
| 6. Subsidiary P/L | 5,549 | 9,936 | 15,485 | 1,445 | 6,994 | 9,936 | 16,930 |
| B. Dam | | | | | | | |
| 7. General items | 3,282 | 1,457 | 4,739 | 412 | 3,694 | 1,457 | 5,151 |
| 8. Sabaki intake and diversion canal | 19,661 | 8,175 | 27,836 | 2,421 | 22,082 | 8,175 | 30,257 |
| 9. Coffer dam and diversion channel | 4,501 | 1,444 | 5,945 | 517 | 5,018 | 1,444 | 6,462 |
| 10. Main dam | 4,076 | 3,649 | 7,725 | 672 | 4,748 | 3,649 | 8,397 |
| 11. Spillway | 4,543 | 1,142 | 5,685 | 494 | 5,037 | 1,142 | 6,179 |
| 12. River outlet facilities | 35 | 163 | 198 | 17 | 52 | 163 | 215 |
| C. Engineering and Adm. | 11,916 | 9,721 | 21,637 | 2,059 | 13,975 | 9,721 | 23,696 |
| Base Cost Total | 131,074 | 106,934 | 238,008 | 22,648 | 153,722 | 106,934 | 260,656 |
| D. Physical Contingency | 19,661 | 16,040 | 35,701 | 3,397 | 23,058 | 16,040 | 39,098 |
| Capital Cost Total | 150,735 | 122,974 | 273,709 | 26,045 | 176,780 | 122,974 | 299,754 |
| E. Price Contingency | - | - | - | - | 111,487 | 40,758 | 152,245 |
| F. Financial Cost Total | - | - | - | - | 288,267 | 163,733 | 452,000 |

# RARE RESERVOIR WITH P/L PLAN

## COST AND WATER VOLUME STREAMS

Unit: US$ $10^6$
Development scale: 2.5 $m^3$/sec

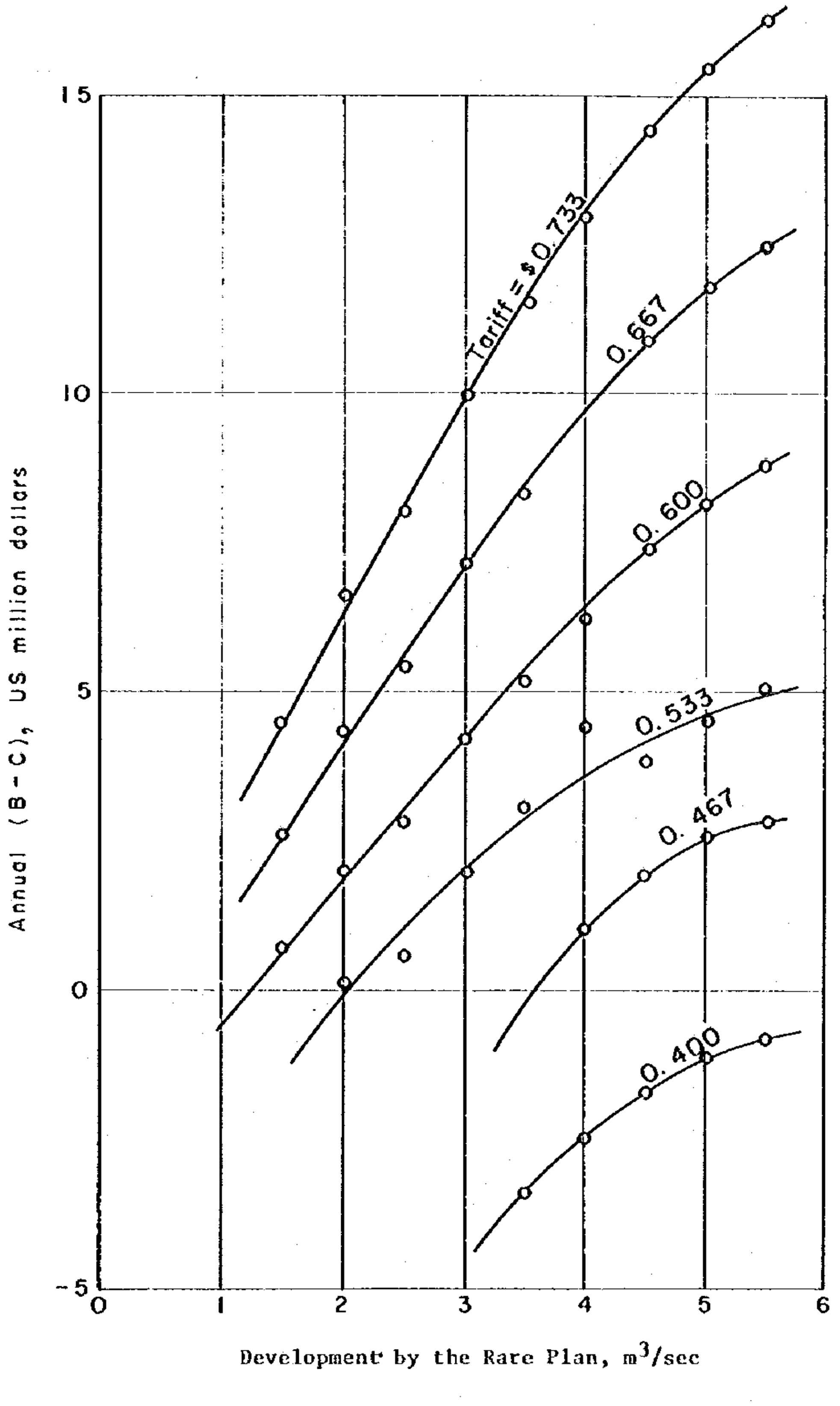
| End of fiscal year | No. | Water volume $10^6 m^3$ | Capital cost | O & M cost |
|---|---|---|---|---|
| 1983 | -3 | - | 34.3 | - |
| 84 | -2 | - | 137.1 | - |
| 85 | -1 | - | 57.1 | - |
| 86 | 1 | 0.73 | - | 0.3 |
| 87 | 2 | 2.01 | - | 0.4 |
| 88 | 3 | 3.01 | - | 0.4 |
| 89 | 4 | 4.38 | - | 0.5 |
| 1990 | 5 | 6.57 | 5.7 | 0.7 |
| 91 | 6 | 10.22 | 5.7 | 1.0 |
| 92 | 7 | 14.60 | - | 1.3 |
| 93 | 8 | 18.98 | 11.3 | 1.6 |
| 94 | 9 | 23.36 | 11.3 | 1.9 |
| 95 | 10 | 27.74 | - | 2.3 |
| 96 | 11 | 32.85 | 1.1 | 2.7 |
| 97 | 12 | 38.69 | - | 3.1 |
| 98 | 13 | 44.53 | 5.7 | 3.5 |
| 99 | 14 | 50.37 | 5.7 | 4.0 |
| 2000 | 15 | 56.21 | - | 4.5 |
| 01 | 16 | 62.23 | 4.3 | 4.8 |
| 02 | 17 | 68.07 | - | 5.1 |
| 03 | 18 | 73.91 | - | 5.4 |
| 04 | 19 | 78.57 | - | 5.7 |
| 05 | 20 | 78.84 | 2.1 | 6.1 |
| 06 | 21 | ⋮ | 3.1 | ⋮ |
| 07 | 22 | ⋮ | - | ⋮ |
| 08 | 23 | ⋮ | - | ⋮ |
| 09 | 24 | | - | |

- to be continued -

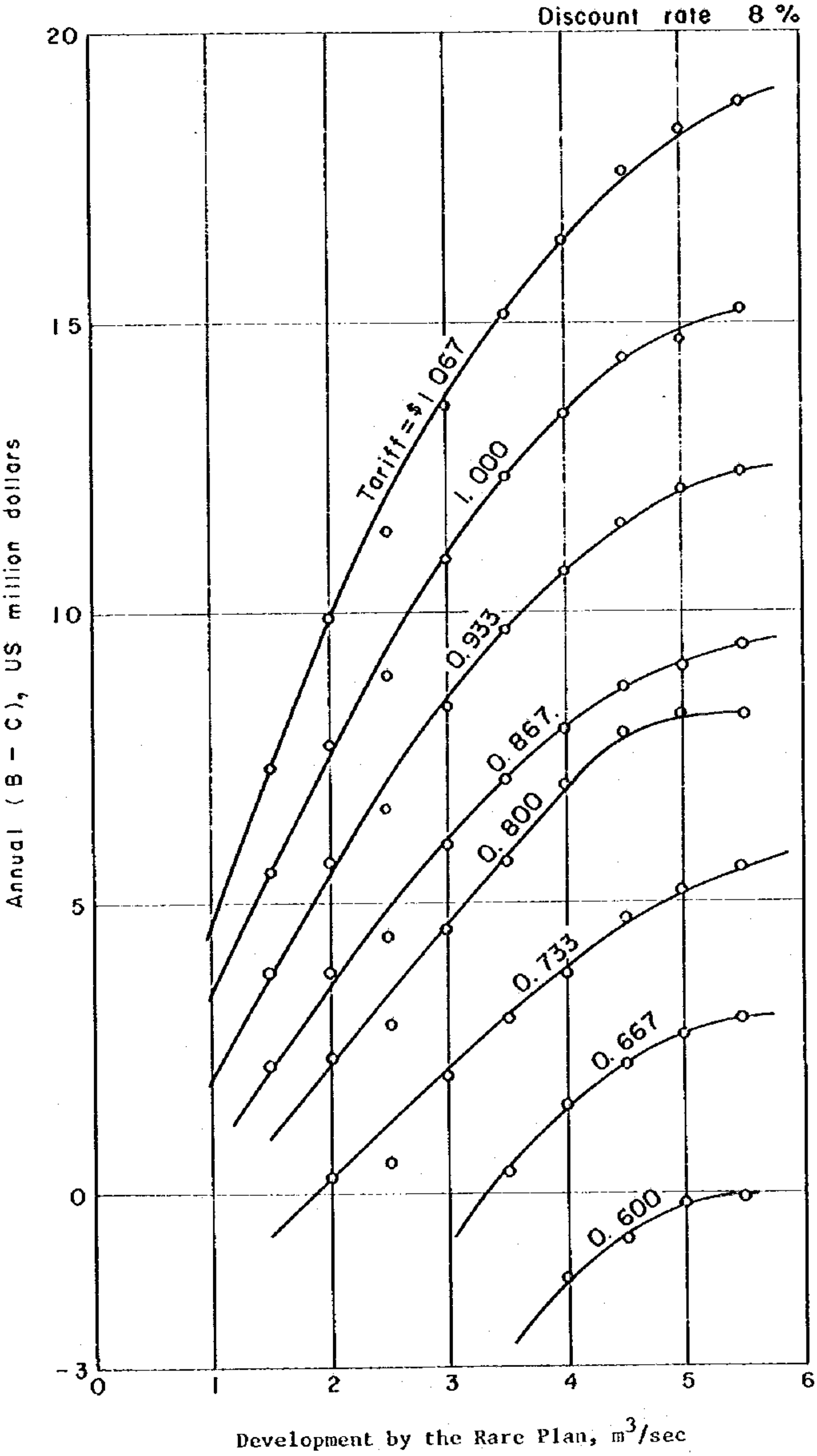
Unit: US$ $10^6$
Development scale: 2.5 $m^3$/sec

| End of fiscal year | No. | Water volume $10^6 m^3$ | Capital cost | O & M cost |
|---|---|---|---|---|
| 2010 | 25 | 78.84 | 5.2 | 6.1 |
| 11 | 26 | | 1.1 | |
| 12 | 27 | | - | |
| 13 | 28 | | - | |
| 14 | 29 | | - | |
| 15 | 30 | | 4.0 | |
| 16 | 31 | | 44.7 | |
| 17 | 32 | | - | |
| 18 | 33 | | - | |
| 19 | 34 | | - | |
| 2020 | 35 | | 1.1 | |
| 21 | 36 | | 3.9 | |
| 22 | 37 | | - | |
| 23 | 38 | | - | |
| 24 | 39 | | - | |
| 25 | 40 | | 7.8 | |
| 26 | 41 | | 69.5 | |
| 27 | 42 | | - | |
| 28 | 43 | | - | |
| 29 | 44 | | - | |
| 2030 | 45 | | 3.9 | |
| 31 | 46 | | - | |
| 32 | 47 | | - | |
| 33 | 48 | | - | |
| 34 | 49 | | - | |
| 2035 | 50 | 78.84 | - | 6.1 |

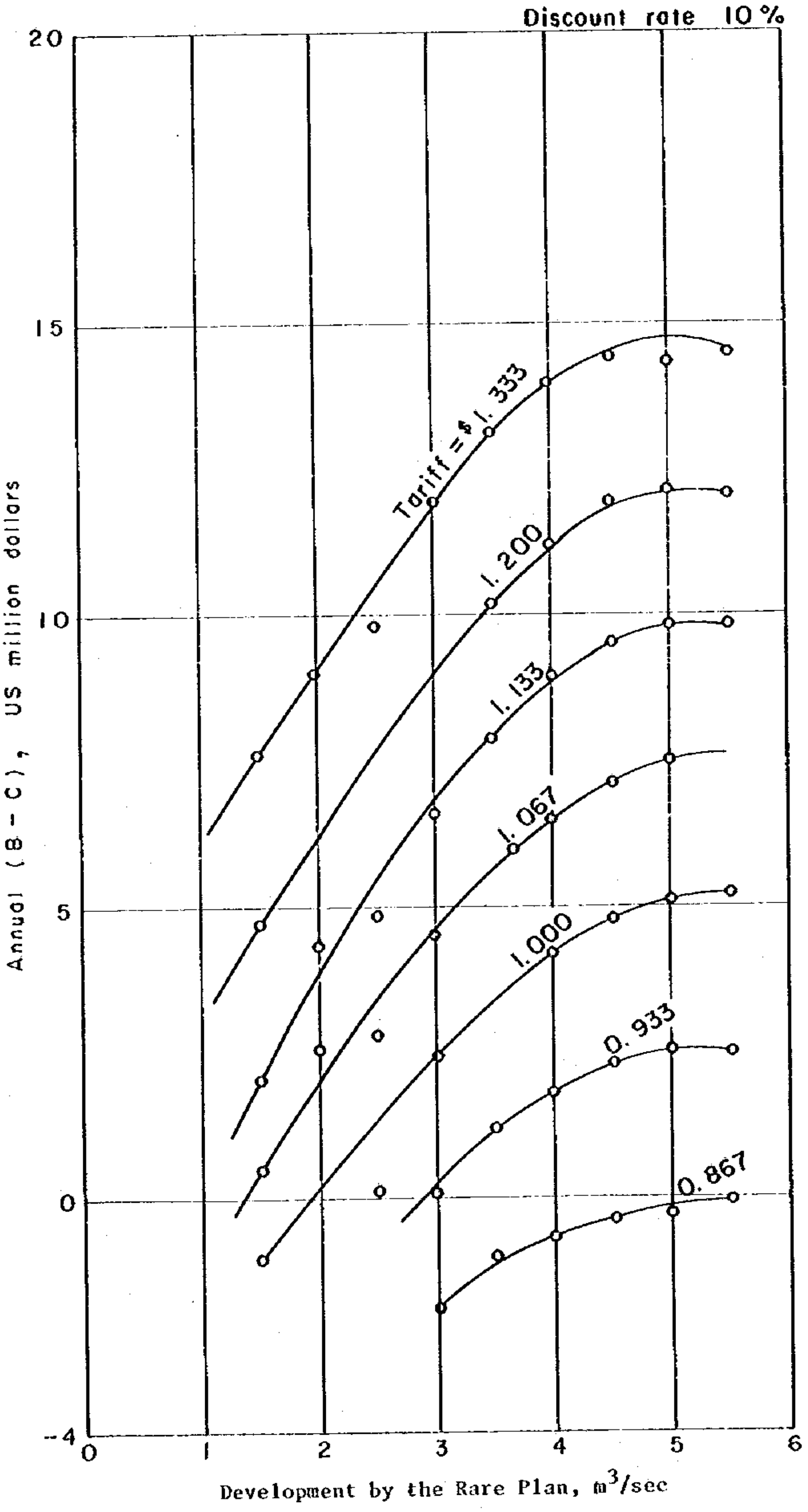
Discount rate 6 %



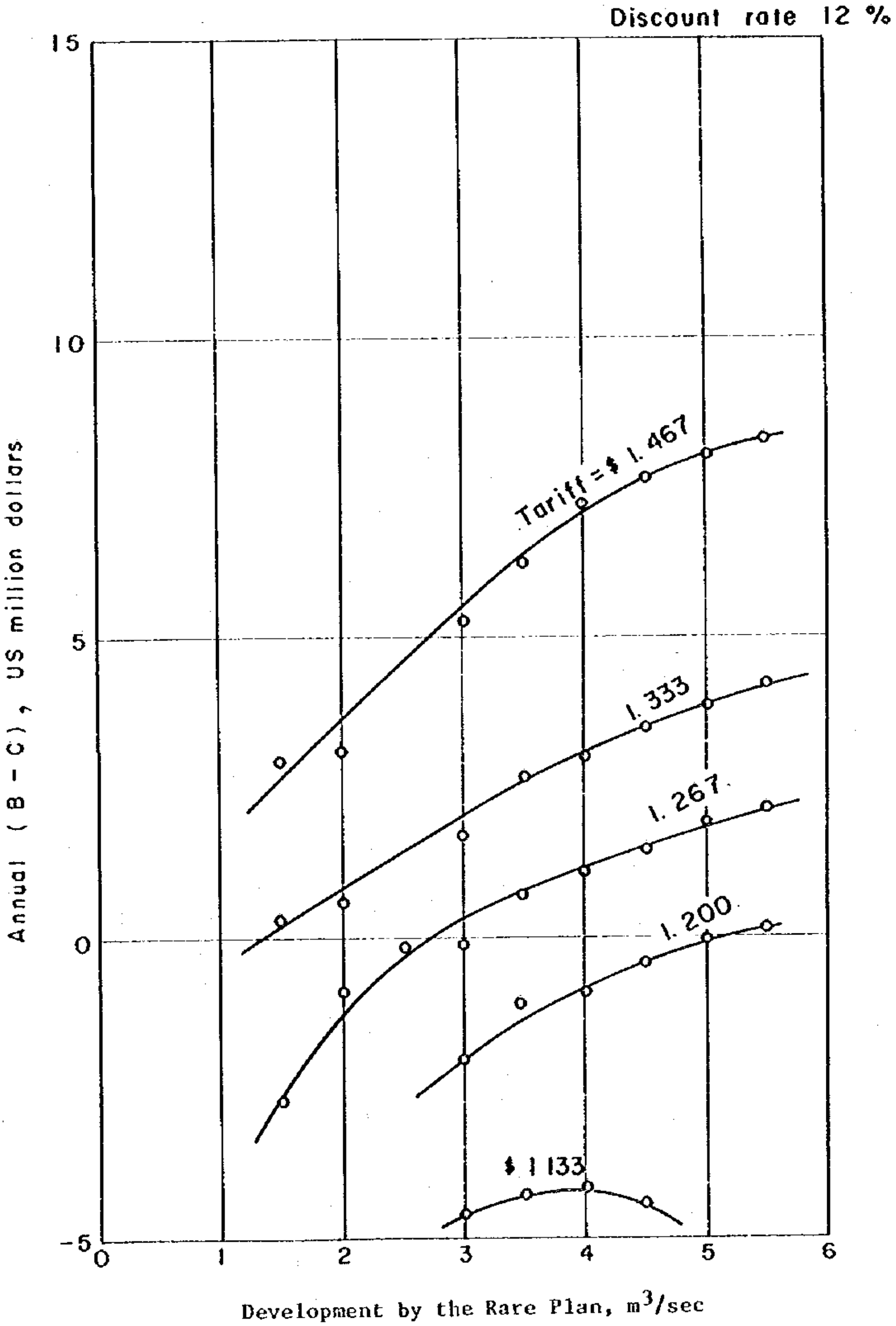

Movement of Optimal Development Scale by Changing Tariff



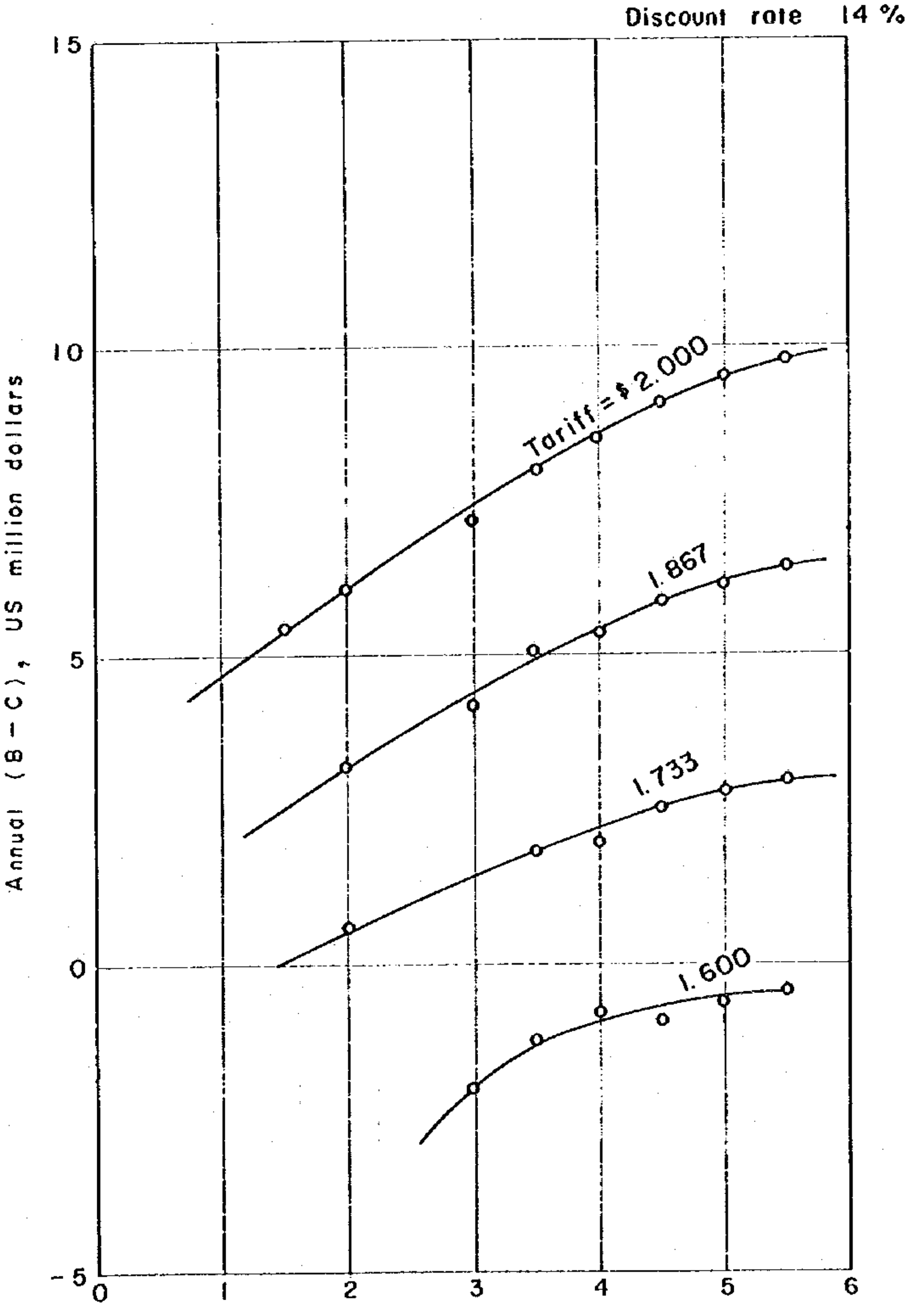

Movement of Optimal Development Scale by Changing Tariff




Movement of Optimal Development Scale by Changing Tariff

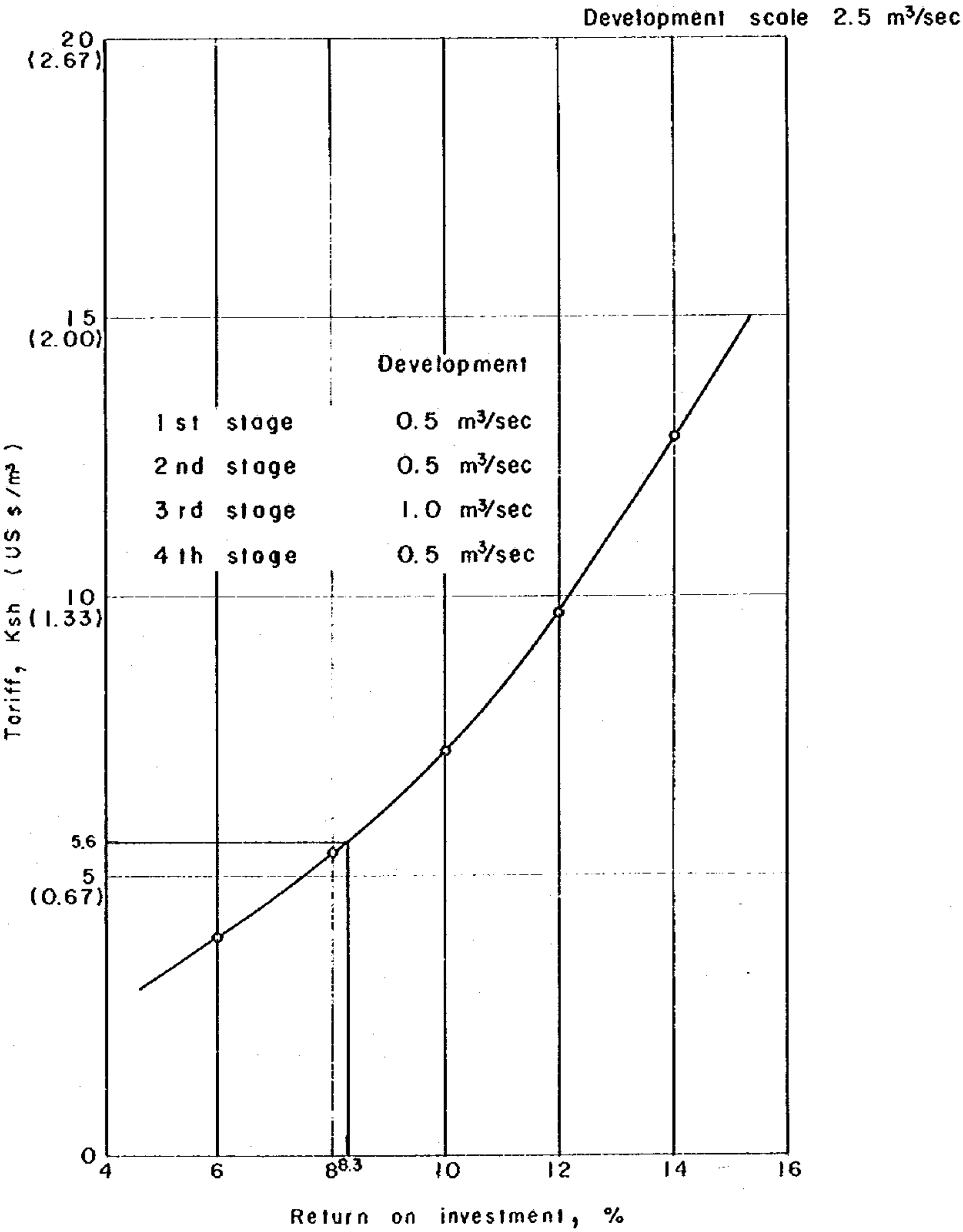



Movement of Optimal Development
Scale by Changing Tariff



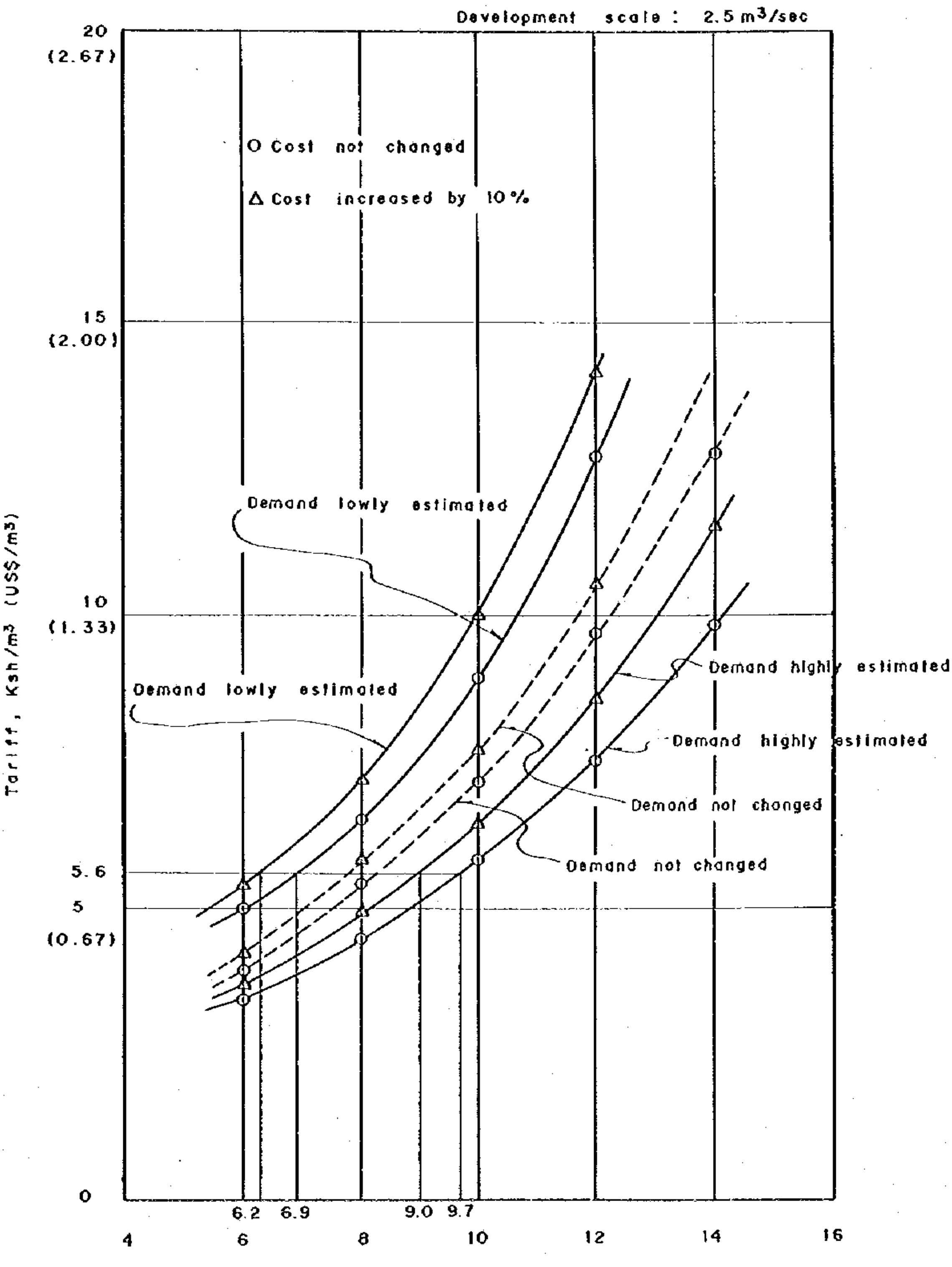

Development by the Rare Plan, $m^3$/sec

Movement of Optimal Development Scale by Changing Tariff




**Return on Investment on the Development Scale of 2.5 m³/sec**

(Rare Plan)




Sensitivity Tests for the Rare Plan

RARE P/L WITH RARE RESERVOIR PLAN
(FIRST PHASE DEVELOPMENT)

FINANCIAL INTERNAL RATE OF RETURN

Unit: US$$10^3$

| No. | Fiscal Year | Capital Cost F.C. | Capital Cost L.C. | O&M Cost | Gross Revenue | Net Benefit |
|---|---|---|---|---|---|---|
| 1 | 1983 | 19,236 | 27,844 | - | - | -47,080 |
| 2 | 1984 | 81,521 | 122,447 | - | - | -203,968 |
| 3 | 1985 | 36,004 | 56,132 | - | - | -92,136 |
| 4 | 1986 | - | - | 498 | 1,251 | 753 |
| 5 | 1987 | - | - | 673 | 3,463 | 2,790 |
| 6 | 1988 | - | - | 821 | 5,348 | 4,527 |
| 7 | 1989 | - | - | 994 | 7,542 | 6,548 |
| 8 | 1990 | 5,352 | 14,871 | 1,310 | 11,313 | -10,220 |
| 9 | 1991 | 5,352 | 14,871 | 1,666 | 17,604 | - 4,285 |
| 10 | 1992 | - | - | 2,118 | 25,146 | 23,028 |
| 11 | 1993 | - | - | 2,692 | 32,688 | 29,996 |
| 12 | 1994 | - | - | 3,422 | 40,230 | 36,808 |
| 13 | 1995 | - | - | 4,351 | 47,773 | 43,422 |
| 14 | 1996 | (R) 5,859 | 1,866 | 4,904 | 53,846 | 41,217 |
| 15 | 1997 | - | - | 4,937 | 54,209 | 49,272 |
| 16 | 1998 | - | - | : | : | : |
| 17 | 1999 | - | - | : | : | : |
| 18 | 2000 | - | - | : | : | 49,272 |
| 19 | 2001 | (R) 12,454 | 4,261 | : | : | 32,557 |
| 20 | 2002 | - | - | 4,937 | 54,209 | 49,272 |

| Discount Rate | Net Benefit |
|---|---|
| 0% | +110,317 |
| 2% | +6,154 |
| 3% | -33,195 |

FIRR = 2.2%

Remarks: (R) stands for Replacement Cost

PROJECTED INCOME STATEMENTS FOR RARE P/L WITH RARE RESERVOIR PLAN
(FIRST PHASE DEVELOPMENT)

Unit: US$$10^3$

| No. | Year | Water Sold (10 $m^3$) | Average Water Rate(Ksh/$m^3$) | Operating Revenue | Operating Expense | | Income Before Interest | Interest Payment | Net Income |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Water Sales | O&M Cost | Depreciation | | | |
| 1 | 1983 | - | - | - | - | - | - | - | - |
| 2 | 1984 | - | - | - | - | - | - | - | - |
| 3 | 1985 | - | - | - | - | - | - | - | - |
| 4 | 1986 | 690 | 13.6($1.813) | 1,251 | 498 | 25,351 | -24,598 | 11,264 | -35,862 |
| 5 | 1987 | 1,910 | ⋮ | 3,463 | 673 | ⋮ | -22,561 | 10,912 | -33,473 |
| 6 | 1988 | 2,950 | ⋮ | 5,348 | 821 | ⋮ | -20,824 | 10,545 | -31,369 |
| 7 | 1989 | 4,160 | ⋮ | 7,542 | 994 | ⋮ | -18,803 | 10,129 | -28,932 |
| 8 | 1990 | 6,240 | ⋮ | 11,313 | 1,310 | ⋮ | -15,348 | 9,698 | -25,046 |
| 9 | 1991 | 9,710 | ⋮ | 17,604 | 1,666 | ⋮ | - 9,413 | 9,235 | -18,648 |
| 10 | 1992 | 13,870 | ⋮ | 25,146 | 2,118 | ⋮ | - 2,323 | 9,581 | -11,904 |
| 11 | 1993 | 18,030 | ⋮ | 32,688 | 2,692 | ⋮ | 4,645 | 9,029 | - 4,384 |
| 12 | 1994 | 22,190 | ⋮ | 40,230 | 3,422 | ⋮ | 11,457 | 8,412 | 3,045 |
| 13 | 1995 | 26,350 | ⋮ | 47,773 | 4,351 | ⋮ | 18,071 | 7,762 | 10,309 |
| 14 | 1996 | 29,700 | ⋮ | 53,846 | 4,904 | ⋮ | 23,591 | 7,060 | 16,531 |
| 15 | 1997 | 29,900 | ⋮ | 54,209 | 4,937 | ⋮ | 23,921 | 6,734 | 17,187 |
| 16 | 1998 | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | 5,921 | 18,000 |
| 17 | 1999 | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | 5,039 | 18,882 |
| 18 | 2000 | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | 4,093 | 19,828 |
| 19 | 2001 | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | 3,076 | 20,845 |
| 20 | 2002 | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | 2,880 | 21,041 |

PROJECTED CASH FLOW FOR RARE P/L WITH RARE RESERVOIR PLAN (FIRST PHASE DEVELOPMENT)

Unit: US$$10^3$

| No. | Year | Income Before Interest | Depreciation | Foreign Loan | Government Equity | Total Source | Capital Cost | | Debt Service | | Total Application | Increase in Cash | Cash at End | Debt Service Coverage |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Foreign Currency | Local Currency | Interest | Principal | | | | |
| 1 | 1983 | - | - | 19,236 | 27,844 | 47,080 | 19,236 | 27,844 | - | - | 47,080 | 0 | 0 | - |
| 2 | 1984 | - | - | 81,521 | 122,447 | 203,968 | 81,521 | 122,447 | - | - | 203,968 | 0 | 0 | - |
| 3 | 1985 | - | - | 36,004 | 56,132 | 92,136 | 36,004 | 56,132 | - | - | 92,136 | 0 | 0 | - |
| 4 | 1986 | -24,598 | 25,351 | - | - | 753 | - | - | 11,264 | 4,713 | 15,977 | -15,224 | -15,224 | 0.047 |
| 5 | 1987 | -22,561 | : | - | - | 2,790 | - | - | 10,913 | 5,065 | 15,977 | -13,187 | -28,411 | 0.175 |
| 6 | 1988 | -20,824 | : | - | - | 4,527 | - | - | 10,545 | 5,432 | 15,977 | -11,450 | -39,861 | 0.283 |
| 7 | 1989 | -18,803 | : | - | - | 6,548 | - | - | 10,129 | 5,848 | 15,977 | - 9,429 | -49,290 | 0.410 |
| 8 | 1990 | -15,348 | : | 5,352 | 14,871 | 30,226 | 5,352 | 14,871 | 9,698 | 6,279 | 36,200 | - 5,974 | -55,264 | 0.626 |
| 9 | 1991 | - 9,413 | : | 5,352 | 14,871 | 36,161 | 5,352 | 14,871 | 9,235 | 6,742 | 36,200 | - 39 | -55,303 | 0.998 |
| 10 | 1992 | - 2,323 | : | - | - | 23,028 | - | - | 9,581 | 7,578 | 17,159 | 5,869 | -49,434 | 1.342 |
| 11 | 1993 | 4,645 | : | - | - | 29,996 | - | - | 9,029 | 8,130 | 17,159 | 12,837 | -36,597 | 1.748 |
| 12 | 1994 | 11,457 | : | - | - | 36,808 | - | - | 8,412 | 8,747 | 17,159 | 19,649 | -16,948 | 2.145 |
| 13 | 1995 | 18,071 | : | - | - | 43,422 | - | - | 7,762 | 9,397 | 17,159 | 26,263 | 9,315 | 2.531 |
| 14 | 1996 | 23,591 | : | - | - | 48,942 | - | - | 7,060 | 10,099 | 17,159 | 31,783 | 41,098 | 2,852 |
| 15 | 1997 | 23,921 | : | - | - | 49,272 | - | - | 6,734 | 11,011 | 17,745 | 31,527 | 72,625 | 2.777 |
| 16 | 1998 | : | : | - | - | : | - | - | 5,921 | 11,824 | 17,745 | : | 104,152 | : |
| 17 | 1999 | : | : | - | - | : | - | - | 5,039 | 12,706 | 17,745 | : | 135,679 | : |
| 18 | 2000 | : | : | - | - | : | - | - | 4,093 | 13,652 | 17,745 | : | 167,206 | : |
| 19 | 2001 | : | : | - | - | : | - | - | 3,076 | 14,669 | 17,745 | 31,527 | 198,733 | 2.777 |
| 20 | 2002 | : | : | - | - | : | - | - | 2,880 | 16,111 | 18,991 | 30,281 | 229,014 | 2.594 |

## RARE P/L WITH RARE RESERVOIR PLAN (FULL DEVELOPMENT)

## FIRR CALCULATION

| No. | Fiscal Year | Capital Cost F.C. | Capital Cost L.C. | O&M Cost | Gross Revenue | Net Benefit |
|---|---|---|---|---|---|---|
| 1 | 1983 | 19,236 | 27,844 | - | - | -47,080 |
| 2 | 1984 | 81,521 | 122,447 | - | - | -203,968 |
| 3 | 1985 | 36,004 | 56,132 | - | - | -92,136 |
| 4 | 1986 | - | - | 498 | 1,251 | 753 |
| 5 | 1987 | - | - | 673 | 3,463 | 2,790 |
| 6 | 1988 | - | - | 821 | 5,348 | 4,527 |
| 7 | 1989 | - | - | 994 | 7,542 | 6,548 |
| 8 | 1990 | 5,352 | 14,871 | 1,310 | 11,313 | -10,220 |
| 9 | 1991 | 5,352 | 14,871 | 1,666 | 17,604 | - 4,285 |
| 10 | 1992 | - | - | 2,118 | 25,146 | 23,028 |
| 11 | 1993 | 4,067 | 17,417 | 2,692 | 32,688 | 8,512 |
| 12 | 1994 | 4,067 | 17,417 | 3,422 | 40,230 | 15,324 |
| 13 | 1995 | - | - | 4,351 | 47,773 | 43,422 |
| 14 | 1996 | (R) 5,859 | 1,866 | 4,952 | 56,584 | 43,907 |
| 15 | 1997 | - | - | 5,636 | 66,646 | 61,010 |
| 16 | 1998 | 4,067 | 8,632 | 6,415 | 76,690 | 57,576 |
| 17 | 1999 | 4,067 | 8,632 | 7,302 | 86,752 | 66,751 |
| 18 | 2000 | - | - | 8,311 | 96,814 | 88,503 |
| 19 | 2001 | (R) 12,454 | 4,261 | 8,834 | 107,185 | 81,636 |
| 20 | 2002 | - | - | 9,390 | 117,247 | 107,857 |

| Discount Rate | Net Benefit |
|---|---|
| 0% | +254,455 |
| 3% | +39,432 |
| 4% | -2,225 |

FIRR 3.95%

Remarks: (R) stands for Replacement Cost

# PROJECTED INCOME STATEMENTS FOR RARE P/L WITH RARE RESERVOIR PLAN (FULL DEVELOPMENT)

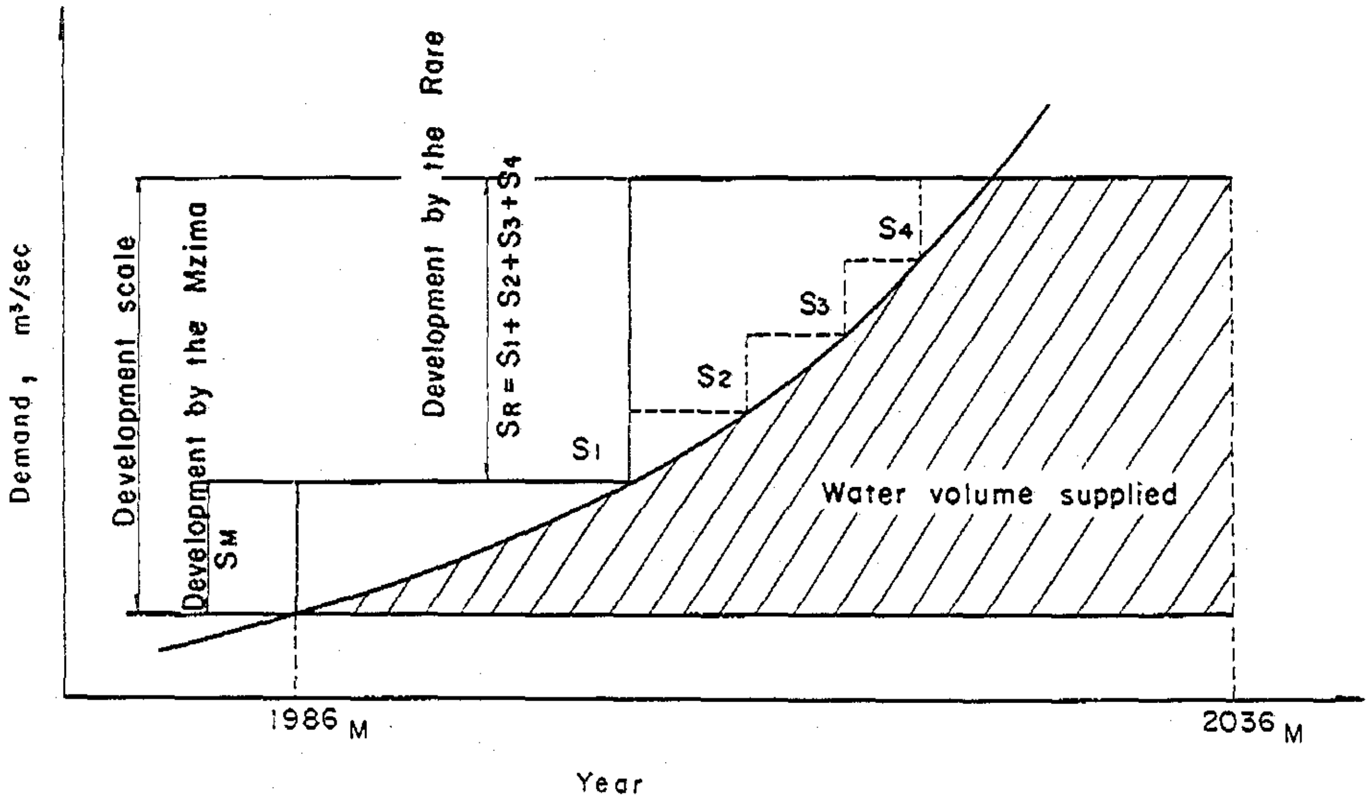
Unit: US$$10^3$

| No. | Year | Water Sold ($10 m^3$) | Average Water Rate ($Ksh/m^3$) | Operating Revenue | Operating Expense | | Income Before Interest | Interest Payment | Net Income |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Water Sales | O&M Cost | Depreciation | | | |
| 1 | 1983 | - | - | - | - | - | - | - | - |
| 2 | 1984 | - | - | - | - | - | - | - | - |
| 3 | 1985 | - | - | - | - | - | - | - | - |
| 4 | 1986 | 690 | 13.6($1.813) | 1,251 | 498 | 29,100 | -28,347 | 11,264 | -39,611 |
| 5 | 1987 | 1,910 | : | 3,463 | 673 | : | -26,310 | 10,912 | -37,222 |
| 6 | 1988 | 2,950 | : | 5,348 | 821 | : | -24,573 | 10,545 | -35,118 |
| 7 | 1989 | 4,160 | : | 7,542 | 994 | : | -22,552 | 10,129 | -32,681 |
| 8 | 1990 | 6,240 | : | 11,313 | 1,310 | : | -19,097 | 9,698 | -28,795 |
| 9 | 1991 | 9,710 | : | 17,604 | 1,666 | : | -13,162 | 9,235 | -22,397 |
| 10 | 1992 | 13,870 | : | 25,146 | 2,118 | : | - 6,072 | 9,581 | -15,653 |
| 11 | 1993 | 18,030 | : | 32,688 | 2,692 | : | 896 | 9,029 | - 8,133 |
| 12 | 1994 | 22,190 | : | 40,230 | 3,422 | : | 7,708 | 8,412 | - 704 |
| 13 | 1995 | 26,350 | : | 47,773 | 4,351 | : | 14,322 | 8,414 | 5,908 |
| 14 | 1996 | 31,210 | : | 56,584 | 4,952 | : | 22,532 | 7,693 | 14,839 |
| 15 | 1997 | 36,760 | : | 66,646 | 5,636 | : | 31,910 | 7,347 | 24,563 |
| 16 | 1998 | 42,300 | : | 76,690 | 6,415 | : | 41,175 | 6,514 | 34,661 |
| 17 | 1999 | 47,850 | : | 86,752 | 7,302 | : | 50,350 | 5,608 | 44,742 |
| 18 | 2000 | 53,400 | : | 96,814 | 8,311 | : | 59,403 | 5,290 | 54,113 |
| 19 | 2001 | 59,120 | : | 107,185 | 8,834 | : | 69,251 | 4,228 | 65,023 |
| 20 | 2002 | 64,670 | : | 117,247 | 9,390 | : | 78,757 | 3,983 | 74,774 |

PROJECTED CASH FLOW FOR RARE P/L WITH RARE RESERVOIR PLAN (FULL DEVELOPMENT)

Unit: US$10^3

| No. | Year | Income Before Interest | Depreciation | Foreign Loan | Government Equity | Total Source | Capital Cost | | Debt Service | | Total Application | Increase in Cash | Cash at End | Debt Service Coverage |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Foreign Currency | Local Currency | Interest | Principal | | | | |
| 1 | 1983 | - | - | 19,236 | 27,844 | 47,080 | 19,236 | 27,844 | - | - | 47,080 | 0 | 0 | - |
| 2 | 1984 | - | - | 81,521 | 122,447 | 203,968 | 81,521 | 122,447 | - | - | 203,968 | 0 | 0 | - |
| 3 | 1985 | - | - | 36,004 | 56,132 | 92,136 | 36,004 | 56,132 | - | - | 92,136 | 0 | 0 | - |
| 4 | 1986 | -28,347 | 29,100 | - | - | 753 | - | - | 11,264 | 4,713 | 15,977 | -15,224 | -15,224 | 0.047 |
| 5 | 1987 | -26,310 | | - | - | 2,790 | - | - | 10,912 | 5,065 | 15,977 | -13,187 | -28,411 | 0.175 |
| 6 | 1988 | -24,573 | | - | - | 4,527 | - | - | 10,545 | 5,432 | 15,977 | -11,450 | -39,861 | 0.283 |
| 7 | 1989 | -22,552 | | - | - | 6,548 | - | - | 10,129 | 5,848 | 15,977 | - 9,429 | -49,290 | 0.410 |
| 8 | 1990 | -19,097 | | 5,352 | 14,871 | 30,226 | 5,352 | 14,871 | 9,698 | 6,279 | 36,200 | - 5,974 | -55,264 | 0.626 |
| 9 | 1991 | -13,162 | | 5,352 | 14,871 | 36,161 | 5,352 | 14,871 | 9,235 | 6,742 | 36,200 | - 39 | -55,303 | 0.998 |
| 10 | 1992 | - 6,072 | | - | - | 23,028 | - | - | 9,581 | 7,578 | 17,159 | 5,869 | -49,434 | 1.342 |
| 11 | 1993 | 896 | | 4,067 | 17,417 | 51,480 | 4,067 | 17,417 | 9,029 | 8,130 | 38,643 | 12,837 | -36,597 | 1.748 |
| 12 | 1994 | 7,708 | | 4,067 | 17,417 | 58,292 | 4,067 | 17,417 | 8,412 | 8,747 | 38,643 | 19,649 | -16,948 | 2.145 |
| 13 | 1995 | 14,322 | | - | - | 43,422 | - | - | 8,414 | 9,643 | 18,057 | 25,365 | 8,417 | 2.405 |
| 14 | 1996 | 22,532 | | - | - | 51,632 | - | - | 7,693 | 10,364 | 18,057 | 33,575 | 41,992 | 2.859 |
| 15 | 1997 | 31,910 | | - | - | 61,010 | - | - | 7,347 | 11,296 | 18,643 | 42,367 | 84,359 | 3.273 |
| 16 | 1998 | 41,175 | | 4,067 | 8,632 | 82,974 | 4,067 | 8,632 | 6,514 | 12,129 | 31,342 | 51,632 | 135,991 | 3.770 |
| 17 | 1999 | 50,350 | | 4,067 | 6,632 | 92,149 | 4,067 | 8,632 | 5,608 | 13,035 | 31,342 | 60,807 | 196,798 | 4.262 |
| 18 | 2000 | 59,403 | | - | - | 88,503 | - | - | 5,290 | 14,251 | 19,541 | 68,962 | 265,760 | 4.529 |
| 19 | 2001 | 69,251 | | - | - | 98,351 | - | - | 4,228 | 15,313 | 19,541 | 78,810 | 344,570 | 5.033 |
| 20 | 2002 | 78,757 | | - | - | 107,857 | - | - | 3,983 | 16,804 | 20,787 | 87,070 | 431,640 | 5.189 |




Development Order and Scale of the Plans

WATER SUPPLY AUGMENTATION PROJECT OF MOMBASA-COASTAL AREA-HINTERLAND

DISCOUNT RATE IN PERCENT 10

TARIFF,KSH (US DOLLAR) 6.50 (0.87)

STAGE DEVELOPMENT

| DEVELOP-MENT SCALE IN CMS | MZIMA PLAN | | | | BARE PLAN | | | | ANNUAL NET BENEFIT MIL. DOL. |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | |
| 3.0 | 0. | 0. | 0. | 0. | 0.5 | 0.3 | 1.2 | 1.0 | -1.9 |
| 3.5 | 0. | 0. | 0. | 0. | 0.5 | 0.4 | 1.7 | 0.9 | -1.1 |
| 4.0 | 0. | 0. | 0. | 0. | 0.5 | 1.8 | 1.3 | 0.4 | -0.8 |
| 4.5 | 0. | 0. | 0. | 0. | 0.5 | 1.5 | 1.8 | 0.4 | -0.4 |
| 5.0 | 0. | 0. | 0. | 0. | 0.5 | 1.8 | 2.5 | 0.4 | -0.3 |
| 5.5 | 0. | 0. | 0. | 0. | 0.5 | 1.8 | 2.4 | 0.8 | -0.1 |

WATER SUPPLY AUGMENTATION PROJECT OF MOMBASA-COASTAL AREA-HINTERLAND

DISCOUNT RATE IN PERCENT 10

TARIFF,KSH (US DOLLAR) 7.00 (0.93)

| DEVELOP-MENT SCALE IN CMS | STAGE DEVELOPMENT MZIMA PLAN 1 | 2 | 3 | 4 | RARE PLAN 1 | 2 | 3 | 4 | ANNUAL NET BENEFIT MIL. DOL. |
|---|---|---|---|---|---|---|---|---|---|
| 3.0 | 0. | 0. | 0. | 0. | 0.5 | 0.4 | 1.2 | 0.9 | 0.3 |
| 3.5 | 0. | 0. | 0. | 0. | 0.5 | 0.4 | 1.7 | 0.9 | 1.2 |
| 4.0 | 0. | 0. | 0. | 0. | 0.5 | 1.6 | 0.9 | 1.0 | 1.8 |
| 4.5 | 0. | 0. | 0. | 0. | 0.5 | 1.6 | 1.4 | 1.0 | 2.3 |
| 5.0 | 0. | 0. | 0. | 0. | 0.5 | 1.6 | 1.9 | 1.0 | 2.5 |
| 5.5 | 0. | 0. | 0. | 0. | 0.5 | 1.6 | 2.4 | 1.0 | 2.5 |

WATER SUPPLY AUGMENTATION PROJECT OF MOMBASA-COASTAL AREA-HINTERLAND

DISCOUNT RATE IN PERCENT 10

TARIFF,KSH (US DOLLAR) 7.50 (1.00)

STAGE DEVELOPMENT

| DEVELOP-MENT SCALE IN CMS | MZIMA PLAN 1 | 2 | 3 | 4 | RARE PLAN 1 | 2 | 3 | 4 | ANNUAL NET BENEFIT MIL. DOL. |
|---|---|---|---|---|---|---|---|---|---|
| 1.5 | 0. | 0. | 0. | 0. | 0.5 | 0.1 | 0. | 0.9 | -1.1 |
| 2.0 | 0. | 0. | 0. | 0. | 0.5 | 0.4 | 1.1 | 0. | 0.7 |
| 2.5 | 0. | 0. | 0. | 0. | 0.5 | 0.4 | 1.0 | 0.6 | 0.8 |
| 3.0 | 0. | 0. | 0. | 0. | 0.5 | 0.4 | 1.7 | 0.9 | 2.4 |
| 3.5 | 0. | 0. | 0. | 0. | 0.5 | 0.4 | 1.7 | 0.9 | 3.4 |
| 4.0 | 0. | 0. | 0. | 0. | 0.5 | 1.4 | 0.9 | 1.2 | 4.2 |
| 4.5 | 0. | 0. | 0. | 0. | 0.5 | 1.4 | 1.2 | 1.4 | 4.8 |
| 5.0 | 0. | 0. | 0. | 0. | 0.5 | 1.4 | 1.6 | 1.5 | 5.1 |
| 5.5 | 0. | 0. | 0. | 0. | 0.5 | 1.4 | 2.1 | 1.5 | 5.2 |

WATER SUPPLY AUGMENTATION PROJECT OF MOMBASA-COASTAL AREA-HINTERLAND

DISCOUNT RATE IN PERCENT 10

TARIFF,KSH (US DOLLAR) 8.00 (1.07)

STAGE DEVELOPMENT

| DEVELOP-MENT SCALE IN CMS | MZIMA PLAN 1 | MZIMA PLAN 2 | MZIMA PLAN 3 | MZIMA PLAN 4 | BARE PLAN 1 | BARE PLAN 2 | BARE PLAN 3 | BARE PLAN 4 | ANNUAL NET BENEFIT MIL. DOL. |
|---|---|---|---|---|---|---|---|---|---|
| 1.5 | 0. | 0. | 0. | 0. | 0.5 | 0.1 | 0.1 | 0.8 | 0.5 |
| 2.0 | 0. | 0. | 0. | 0. | 0.5 | 0.4 | 0.7 | 0.4 | 2.6 |
| 2.5 | 0. | 0. | 0. | 0. | 0.5 | 0.4 | 1.0 | 0.6 | 2.8 |
| 3.0 | 0. | 0. | 0. | 0. | 0.5 | 0.4 | 1.7 | 0.9 | 4.5 |
| 3.5 | 0. | 0. | 0. | 0. | 0.5 | 0.4 | 1.7 | 0.9 | 5.6 |
| 4.0 | 0. | 0. | 0. | 0. | 0.7 | 1.2 | 0.9 | 1.2 | 6.5 |
| 4.5 | 0. | 0. | 0. | 0. | 0.7 | 1.2 | 1.7 | 1.4 | 7.1 |
| 5.0 | 0. | 0. | 0. | 0. | 0.7 | 1.2 | 1.6 | 1.5 | 7.5 |
| 5.5 | 0. | 0. | 0. | 0. | 0.7 | 1.2 | 1.7 | 1.9 | 7.7 |

WATER SUPPLY AUGMENTATION PROJECT OF MOMBASA-COASTAL AREA-HINTERLAND

DISCOUNT RATE IN PERCENT 10

TARIFF,KSH (US DOLLAR) 8.50 (1.13)

STAGE DEVELOPMENT

| DEVELOP-MENT SCALE IN CMS | MZIMA PLAN 1 | 2 | 3 | 4 | RARE PLAN 1 | 2 | 3 | 4 | ANNUAL NET BENEFIT MIL. DOL. |
|---|---|---|---|---|---|---|---|---|---|
| 1.5 | 0. | 0. | 0. | 0. | 0.5 | 0.1 | 0.2 | 0.7 | 2.0 |
| 2.0 | 0. | 0. | 0. | 0. | 0.5 | 0.4 | 0.5 | 0.6 | 4.3 |
| 2.5 | 0. | 0. | 0. | 0. | 0.5 | 0.4 | 1.0 | 0.6 | 4.7 |
| 3.0 | 0. | 0. | 0. | 0. | 0.5 | 0.4 | 1.0 | 1.1 | 6.6 |
| 3.5 | 0. | 0. | 0. | 0. | 0.5 | 0.4 | 1.3 | 1.5 | 7.9 |
| 4.0 | 0. | 0. | 0. | 0. | 0.5 | 0.4 | 1.6 | 1.5 | 8.9 |
| 4.5 | 0. | 0. | 0. | 0. | 0.5 | 0.4 | 1.6 | 2.0 | 9.5 |
| 5.0 | 0. | 0. | 0. | 0. | 0.5 | 0.4 | 1.8 | 2.3 | 9.8 |
| 5.5 | 0. | 0. | 0. | 0. | 0.5 | 0.4 | 2.3 | 2.5 | 9.8 |

WATER SUPPLY AUGMENTATION PROJECT OF MOMBASA-COASTAL AREA-HINTERLAND

DISCOUNT RATE IN PERCENT 10

TARIFF/KSH (US DOLLAR) 9.00 (1.20)

STAGE DEVELOPMENT

| DEVELOP-MENT SCALE IN CMS | MZIMA PLAN | | | | BARE PLAN | | | | ANNUAL NET BENEFIT MIL. DOL. |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | |
| 1.5 | 0. | 0. | 0. | 0. | 0.5 | 0.4 | 0.7 | 0.4 | 4.6 |
| 2.0 | 0. | 0. | 0. | 0. | 0.5 | 0.4 | 0.5 | 0.6 | 6.1 |
| 2.5 | 0. | 0. | 0. | 0. | 0.5 | 0.4 | 1.0 | 0.6 | 6.6 |
| 3.0 | 0. | 0. | 0. | 0. | 0.5 | 0.4 | 1.0 | 1.1 | 8.7 |
| 3.5 | 0. | 0. | 0. | 0. | 0.5 | 0.4 | 1.3 | 1.3 | 10.2 |
| 4.0 | 0. | 0. | 0. | 0. | 0.5 | 0.4 | 1.6 | 1.5 | 11.2 |
| 4.5 | 0. | 0. | 0. | 0. | 0.5 | 0.4 | 1.6 | 2.0 | 11.9 |
| 5.0 | 0. | 0. | 0. | 0. | 0.5 | 0.4 | 2.1 | 2.0 | 12.1 |
| 5.5 | 0. | 0. | 0. | 0. | 0.5 | 0.4 | 2.5 | 2.1 | 12.1 |

WATER SUPPLY AUGMENTATION PROJECT OF MOMBASA-COASTAL AREA-HINTERLAND

DISCOUNT RATE IN PERCENT 10

TARIFF,KSH (US DOLLAR) 10.00 (1.33)

STAGE DEVELOPMENT

| DEVELOP-MENT SCALE IN CMS | MZIMA PLAN 1 | MZIMA PLAN 2 | MZIMA PLAN 3 | MZIMA PLAN 4 | RARE PLAN 1 | RARE PLAN 2 | RARE PLAN 3 | RARE PLAN 4 | ANNUAL NET BENEFIT MIL. DOL. |
|---|---|---|---|---|---|---|---|---|---|
| 1.5 | 0. | 0. | 0. | 0. | 0.5 | 0.4 | 0.3 | 0.3 | 7.6 |
| 2.0 | 0. | 0. | 0. | 0. | 0.5 | 1.5 | 0. | 0. | 9.0 |
| 2.5 | 0. | 0. | 0. | 0. | 0.9 | 1.0 | 0.6 | 0. | 9.8 |
| 3.0 | 0. | 0. | 0. | 0. | 0.9 | 1.7 | 0.4 | 0. | 11.9 |
| 3.5 | 0. | 0. | 0. | 0. | 0.9 | 2.2 | 0.4 | 0. | 13.1 |
| 4.0 | 0. | 0. | 0. | 0. | 0.9 | 2.6 | 0.5 | 0. | 14.0 |
| 4.5 | 0. | 0. | 0. | 0. | 0.9 | 3.0 | 0.6 | 0. | 14.4 |
| 5.0 | 0. | 0. | 0. | 0. | 0.9 | 5.5 | 0.3 | 0.3 | 14.3 |
| 5.5 | 0. | 0. | 0. | 0. | 1.9 | 2.5 | 1.5 | 0. | 14.8 |

# OBJECTIVE FUNCTION AND DYNAMIC PROGRAMMING /1

1. The problem whether the limited resources available are allocated in efficient ways is arisen in many fields. Though the problem given is quite simple, there are many difficulties encountered in treating this apparently simple and straightforward problem.

2. For tackling the problem mentioned above, it is necessary to express the problem in the precise mathematical form. The problem is expressed as follows;

(1) $R(x_1, x_2, \ldots, x_n) = g_1(x_1) + g_2(x_2) + \ldots + g_n(x_n)$

subject to

(2) (a) $x_1 + x_2 + \ldots + x_n = x$ ,

(b) $x_i \geq 0$

where $x_i$ denotes the quantity of resources assigned to the i th activity, $g_i(x_i)$ is the return function from the i th activity and $R(\cdot)$ is the objective function. The problem is to maximize Eq.(1) under the constraints of Eq.(2).

3. It can be considered that the above problem is solved by calculus using a Lagrange multiplier or by linear programming. However, in calculus the return function must be expressed in the functional form. Even though the return function can be expressed in the functional form, the problems that are arisen in applications are usually less amenable to route techniques. In linear programming, the objective function and constraints of Eq.(1) and (2) must be expressed in a linear function. As the technique called dynamic programming developed by R.E. Bellman is applicable to the problems which are not solved by calculus or linear programming, dynamic programming is applied to the optimization study.

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/1 R.E. Bellman, Applied Dynamic Programming, Princeton University Press, Princeton, New Jersey, 1962.

4. Dynamic programming is explained by the classifical stagecoach problem. A coward salesman must travel the teritory of unfriendly Indian 100 years ago. Though his starting point and destination is fixed, he can travel by some combination of the routes available as shown page 4 of 5 of the ANNEX. He likes to travel the Indian teritory by the safest route.

5. The figure written between the numbered blocks is the cost to buy the life insurance policies offered to stagecoach passengers. The safest route is defined as the cheapest route to buy life insurance policy.

6. It is possible to find the chepest route by evaluating all the possible routes. However, if the problem is large and complex, it takes much time, even though it not impossible to find the cheapest route by evaluating all the possible routes. For saving the computation time, the problem is solved by dynamic programming.

7. The procedures to find the cheapest route by dynamic programming are as follows. First, the numbered blocks are defined as "state" and there are five stage from the starting point to the destination. The cheapest route from the first stage to each state of the second stage is fixed like 1 - 2, 1 - 3 and 1 - 4. The cost to buy the life insurance policy is shown in the block with parenthesis. The cheapest route from the second stage to "state 5" of the third stage is obtained by comparing the sum of the current cost from each state of the second stage to the state 5 and the cheapest cost upto each state of the second stage, so that the cheapest route to come "state 5" is 1 - 2 - 5 and the cost is 5.

8. By the procedure mentioned above, the cheapest route on each state of each stage is obtained. There is only one way to come "state 10" from the forth stage, so that the cheapest route from "state 1" to "state 10" is exclusively determined and the route is traced back by the arrows of the reverse direction.

9. The objective function to maximize the difference between benefits yielded from the projects and costs charged to the project is mathematically expressed as follows;

$$\max \sum_{j} \sum_{i} (Bij - Cij)$$

subject to

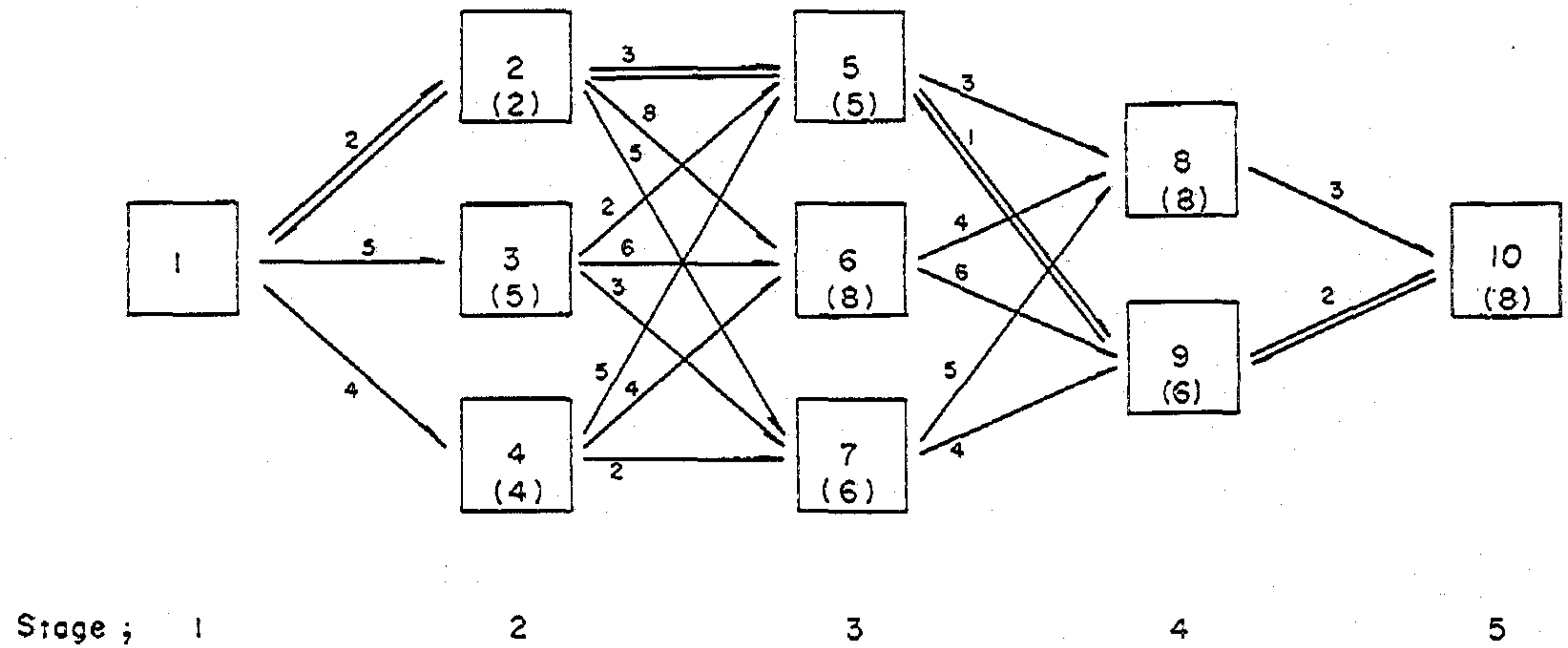
$$\sum_{i} Xij \leq Xj,$$

$$\sum_{j} \sum_{i} Xij \leq Y, \text{ and}$$

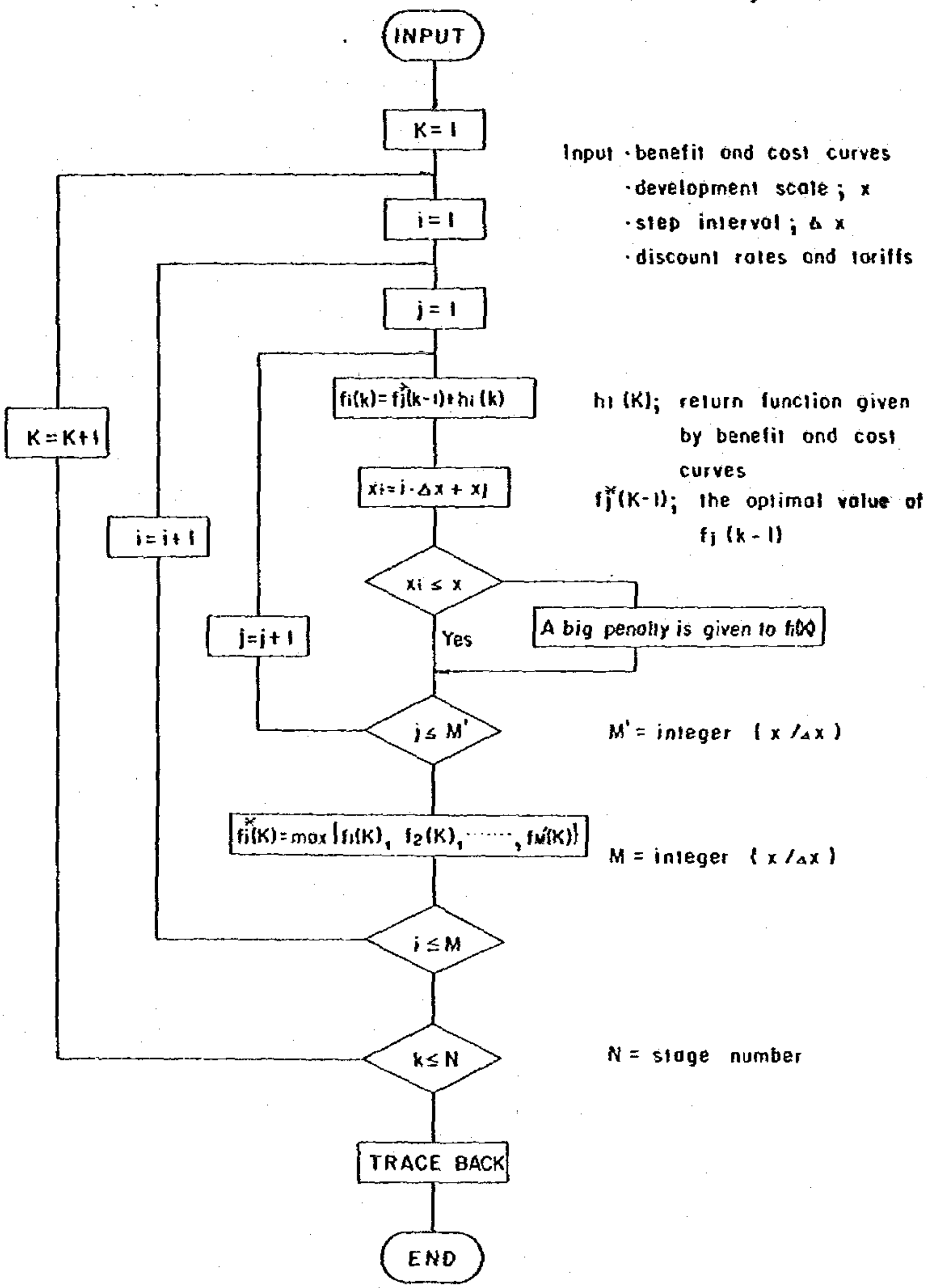
$$Xij \geq 0$$

where Xij is the development scale of i stage on the j plan and Xj is the physical limit of the j plan. For the development scale selected arbitrarily Y, the maximum net benefit is searched. It is quite hard to find the maximum value of the above equation, because the numerical combinations can be conceivable. To overcome this situation, applied is dynamic programming.

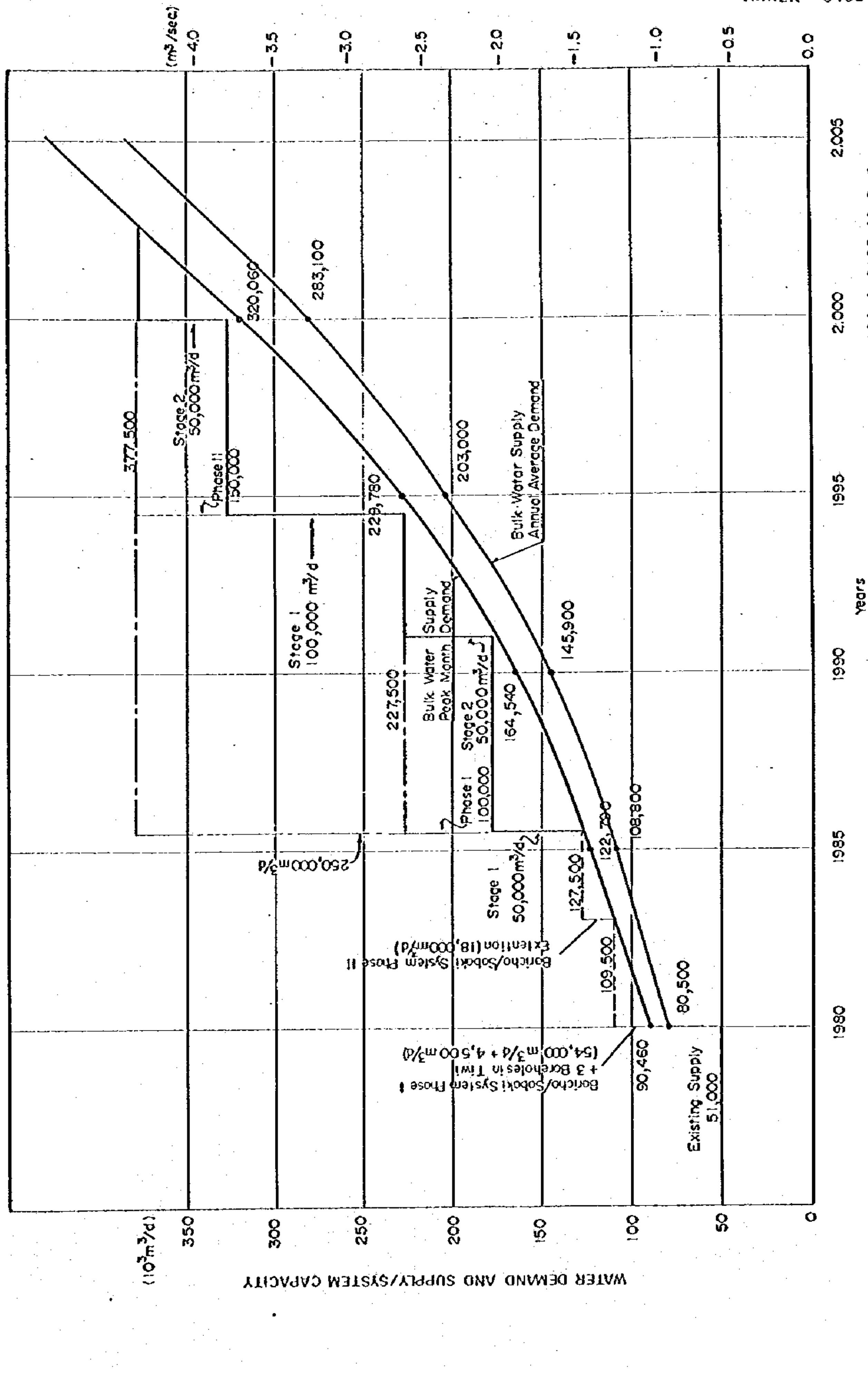
10. A computer program of the optimization study is made by dynamic programming. The flow chart of it is shown in page 5 of 5 of the ANNEX.




Transportation Routes of Stagecoach

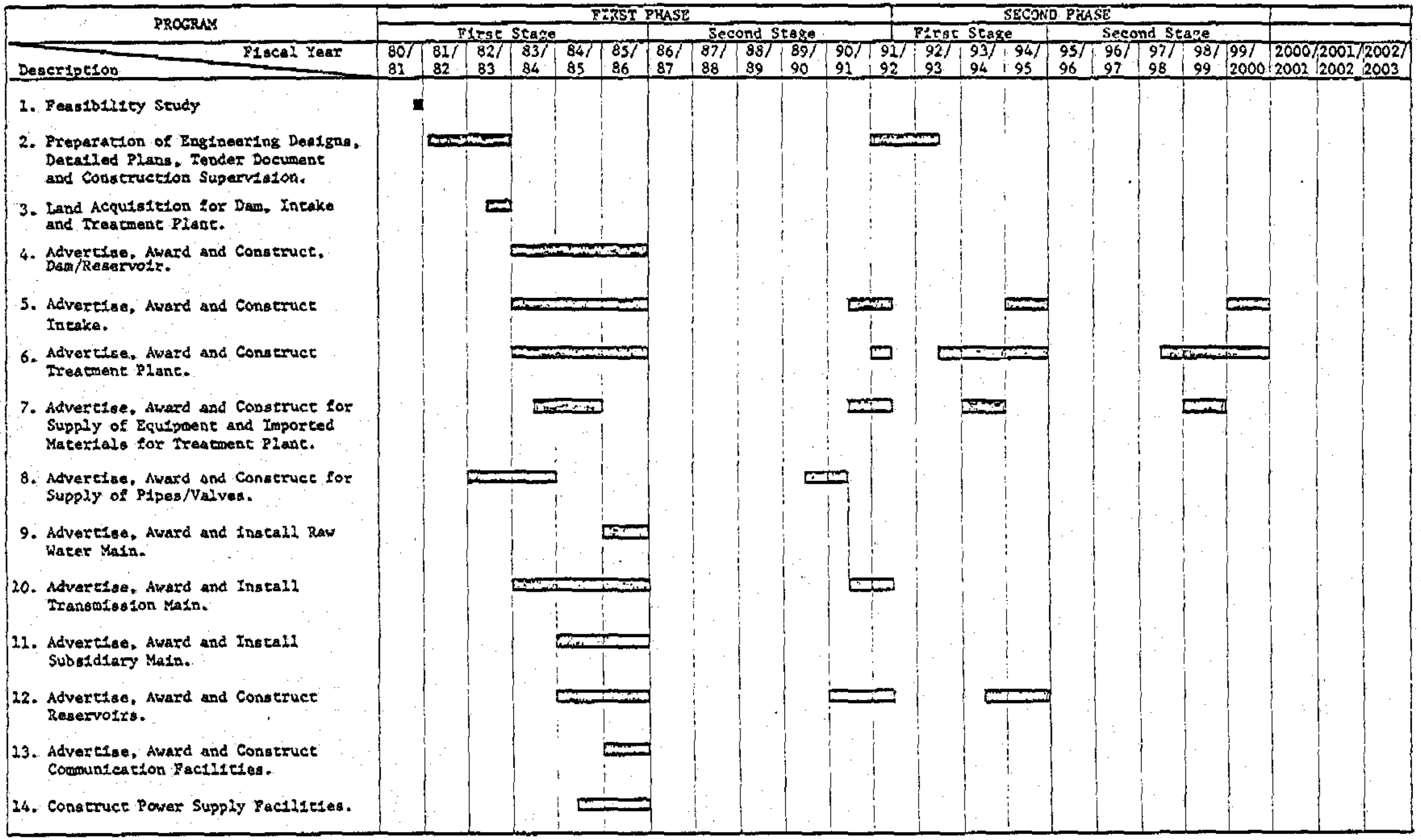



Flow Chart of Dynamic Programing

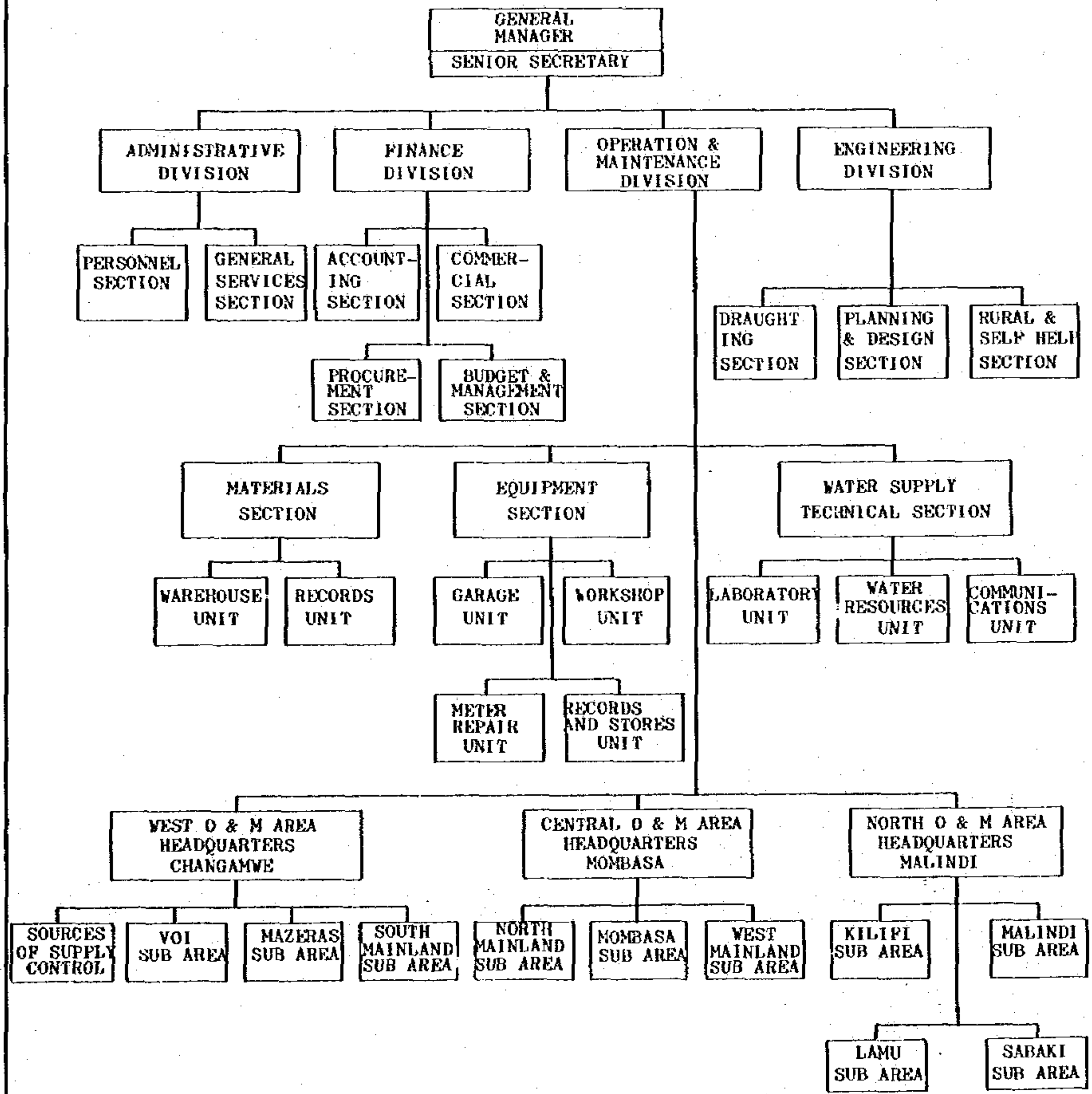



WATER DEMAND VERSUS RARE SCHEME
SYSTEM SUPPLY CAPACITY

DEVELOPMENT SCHEDULE OF RARE PLAN



## COAST PROVINCE WATER BRANCH ORGANIZATION



## MINISTRIES AND AGENCIES INVOLVED IN COMMUNITY WATER SUPPLIES

a. The Nairobi City Council is responsible for the water supply and sewage systems of Nairobi.

b. Five municipalities and two county councils operate their urban water supply systems under the direction of the Ministry of Local Government.

c. Several hundred small rural water supply schemes are operated by county councils.

d. The Kenya Railways operates about 100 water schemes supplying staff houses and adjacent villages.

e. The President's Office plans and budgets water supplies for new settlement areas, usually with the Water Engineering Department of MOWD as the executing agency.

f. The Ministry of Cooperative Development administers government grants to all self-help schemes in rural areas.

g. The Ministry of Health is responsible for potable water supply quality surveillance from the community-health point of view.

## MAIN FEATURES OF THE SECOND MZIMA PLAN AND THE RARE PLAN

| | Items | Second Mzima Plan | Rare Plan |
|---|---|---|---|
| I. | Development Scale ($m^3/s$) | 1.2 | 2.5 |
| II. | Dam and Reservoir | | |
| | Catchment Area ($km^2$) | 4,050 | 1,500 |
| | Type of Dam | Rockfill | Rockfill |
| | Height of Dam (m) | 34 | 33 |
| | Reservoir Effective Storage ($10^6m^3$) | 21 | 27.6 |
| | Fill Volume ($10^3m^3$) | 450 | 380 |
| | Design Flood ($m^3/s$) | 1,550 | 1,305 |
| III. | Diversion Canal | | |
| | Length (km) | - | 40 |
| | Excavation ($10^3m^3$) | - | 1,339 |
| | Capacity ($m^3/s$) | - | 13.3 |
| IV. | Water Supply Facilities | | |
| | Raw Water Main P/L | | |
| | Diameter (mm) & Length (km) | - | 1,500mm - 4.5km |
| | Transmission Main P/L | | |
| | Diameter (mm) & Length (km) | 1,350mm - 86km<br>1,100mm - 43km<br>1,000mm - 88km | 1,500mm - 51km<br>1,200mm - 18km<br>1,000mm - 9km |
| | Pumping Station (unit) | - | 2 |
| | Treatment Plant (@55,000$m^3$/d)(unit) | - | 5 |
| V. | Costs/1 | | |
| | Economic Cost (US$ million) | 270 | 274 |
| | Foreign Currency Portion | 163 | 123 |
| | Local Currency Portion | 107 | 151 |

| Items | Second Mzima Plan | Rare Plan |
|---|---|---|
| Financial Cost /2 (US$ million) | 421 | 452 |
| Foreign Currency Portion | 214 | 164 |
| Local Currency Portion | 207 | 288 |
| O&M Cost /3 (Economic)(US$$10^3$) | 101 | 6,064 |
| VI. Evaluation | | |
| Return on Investment /4 (%) | 5.5 | 8.3 |
| FIRR /5 (%) | 3.4 | 4.0 |

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/1 Excluding replacement cost.

/2 Excluding replacement cost and interest during construction.

/3 Under full supply conditions.

/4 When the estimated water rate of 5.6 KSh/$m^3$ is applied to evaluate the water at the outlet of distribution reservoir.

/5 When the water rate of 13.6 KSh/$m^3$ is applied under the same conditions as mentioned in /4.