United Republic of Tanzania
Ministry of Water, Energy
and Minerals

Kingdom of the Netherlands
Ministry of Foreign Affairs
DGIS

Morogoro Domestic Water Supply Plan

Volume I

Main Report

Final Report

August 1980

DHV

DHV Consulting Engineers

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1. INTRODUCTION

1.1. General

At the beginning of 1977, following the "Administrative Arrangement" between the Governments of Tanzania and The Netherlands, the International Technical Assistance Department of the Ministry of Foreign Affairs of the Netherlands charged DHV Consulting Engineers with the execution of the Morogoro Domestic Water Supply Plan (MDWSP). The Tanzanian Government appointed the Ministry of Water, Energy and Minerals as executive authority for the implementation of the project.

The aim of the MDWSP is to study the possibilities for improvement of the rural water supply in the northern part of the Morogoro Region. Carrying out a Domestic Water Supply Plan, instead of a Water Master Plan, implies that the study has to be focused on the supply of drinking water for the villagers only. During the discussion with the Tanzanian and Netherlands Governments on the determination of the Terms of Reference, the need was felt to incorporate an implementation component in the study. Based on information derived from earlier studies in the Morogoro Region it was decided to incorporate a drilling programme for exploration and exploitation of deep ground water in the survey.

In the "Note concerning Morogoro Domestic Water Supply Plan" of February 1977 an outline was presented of the survey and the studies.

The studies started in June 1977 with a geographical survey to identify the conditions and problems of rural water supply in the northern part of the Region. The results of the geographical survey were presented in the first report "Identification of the present conditions and problems of rural water supply in the northern part of Morogoro Region", issued December 1977.

During the first months of 1978, an interpretation of satellite photos of the Morogoro Region was carried out in the Netherlands in order to get a rough impression of the geological and hydrogeological conditions in the project area.

The hydrological and hydrogeological survey started at the end of May 1978, after some delay due to housing and cholera problems.

In September 1978 a Progress Report was issued, dealing with the surveys and studies carried out during the period end May- end August 1978 and presenting the plan of operations of the team for the following months.

Mid September 1978 the deep well drilling programme started. The survey for the locations of shallow well sites was intensified in co-operation with the Morogoro Wells Construction Project team. The regular measurements programme, covering monthly observations of streams and existing shallow wells in the survey area, was finished at the start of the rainy season in November 1978. The water supply survey commenced in October 1978.
The fieldwork of the different surveys was finalized in May 1979.

The domestic water supply plan is presented in this final report. The report consists of six volumes:

Volume 1	Main Report
Volume 2	Water Supply Conditions
Volume 3	Hydrology
Volume 4	Hydrogeology
Volume 5	Water Supply Development
Volume 6	Village Data Handbook

1.2. Survey area

The Morogoro Region is situated in the eastern part of Tanzania - roughly between 36°30' and 38°30' east of Greenwich and between 5°45' and 8°00' south of the Equator (see fig. 1.2-1).
The Morogoro and Kilosa Districts, the survey area dealt with in this report, cover the northern part of the Morogoro Region and comprise around 45% of the Region's 73,000 sq.km. The area is composed of the wide alluvial flood plains of the Mkata and Wami Rivers which are flanked at the northern and western sides by respectively the Nguru and Rubeho Mountains.
In the southern and eastern directions these plains are bordered by the Uluguru Mountains, rising abruptly out of the flood plains with only a steep and narrow piedmont as a transition between mountains and plain. To the south of the Uluguru Mountains there is no such abrupt transition but a rather extensive zone of foothills, known as the Broken Hilly Mountains. A similar foothill area of smaller size is found along the Rubeho Mountains, whereas along the Nguru Mountains again a narrow and steep piedmont is observable. The south-eastern part of the survey area consists of the flood plains of the Ruvu and Mgeta Rivers.
Consequently, one may distinguish three types of geomorphological zones, i.e. the mountainous areas, the transitional zone of foothills and steep piedmonts, and the flood plains.
Rainfall generally increases with altitude. Therefore, the annual rainfall in the plains remains lower than that of the transitional zones, and these in their turn receive less than the mountainous areas.
Yet these geomorphological zones do not exactly coincide with clear-cut zones of precipitation, since the exposure in relation to the prevailing humid, south-easterly wind is another important factor influencing the annual rainfall distribution.
The rural population of the area under study is mainly found in the transitional zone (53%). The other half of the population is almost equally distributed over the mountainous areas (26%) and the flood plains (21%).
The main urban centre in the survey area is Morogoro Town (estimated at about 75,000 inh.), the regional capital and an important centre for interregional communication.

MOROGORO REGION ĀND THE SURVEY AREA

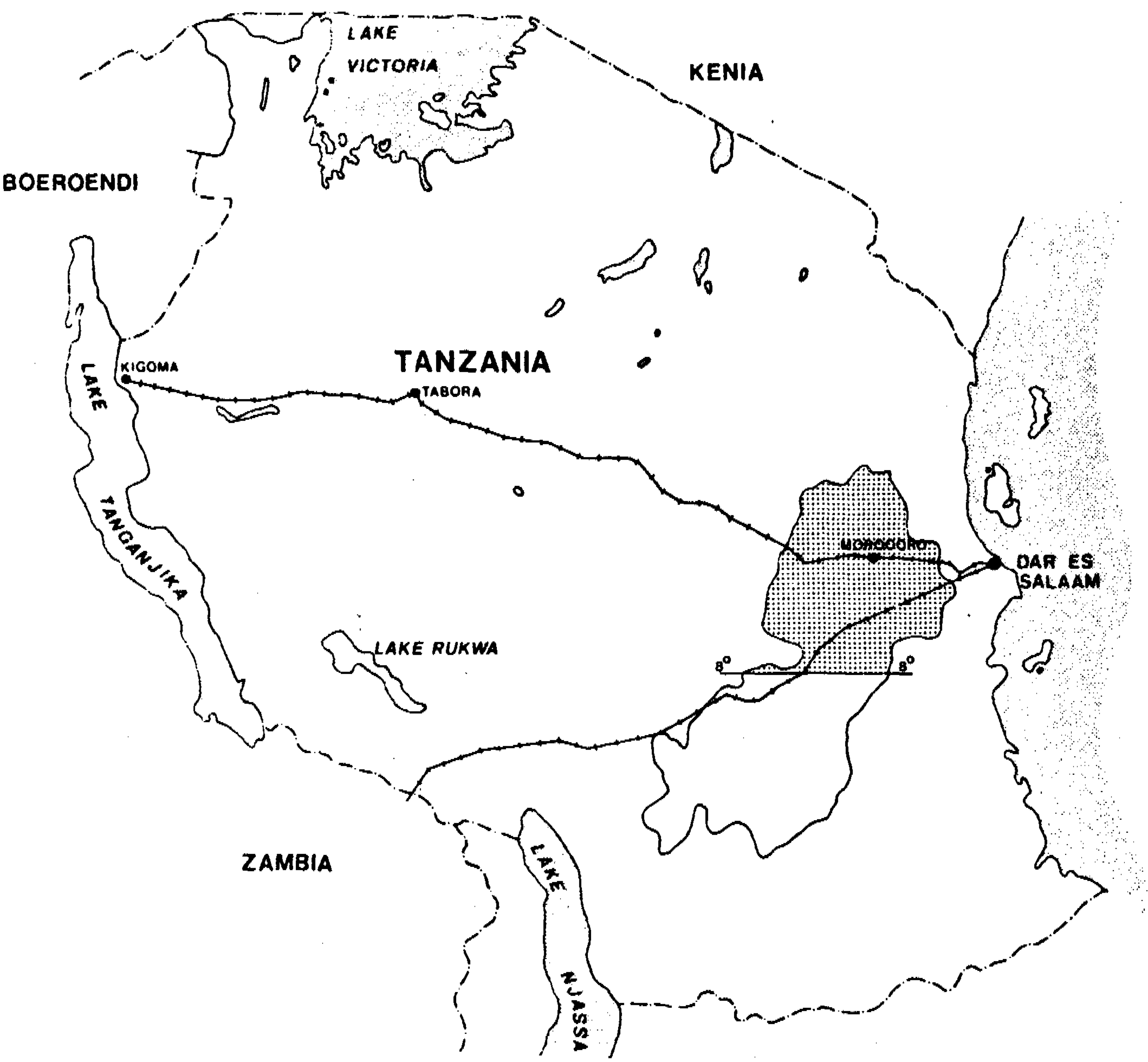

Fig. 1.2-1 Morogoro Region and the survey area

1.3. Scope and implementation of the study

1.3.1. Scope of the study

In the absence of Terms of Reference the information and recommendations contained in the Regional Integrated Development Plan for Morogoro Region (1975) have served as a guideline in establishing the scope of work and priorities as to which areas and villages are to be investigated.
The main purpose of the study is to collect and analyse all necessary geographical, demographical, hydrological, hydrometeorological, hydrogeological, geophysical, financial and other data, in the northern and most populated part of the Morogoro Region in order to prepare a Domestic Water Supply Plan which has to provide recommendations to releave the immediate need for water supply of less favoured areas and villages. This requires detailed surveys of selected areas and villages with respect to water demand and water resources. Besides this an inventory of technically feasible solutions has to be carried out.

1.3.2. Study phases

As explained before, the drawing-up of the Morogoro Domestic Water Supply Plan requires the investigation and study of different items. However, the execution of the study is roughly divided into three main phases:
- analysis of water demand
- analysis of water potential
- establishment of water exploitation

a. Water demand

As the studies focus on the water supply for the villagers, the water demand is related to the location of the villages, the number of their inhabitants, the problems concerning and the condition of their existing supplies.
Since considerable resettlement of population has taken place in the last few years the presently available topographical maps and aerial photographs do not provide sufficient and accurate details of the village pattern within the Region. This necessitated a geographical survey and an inventory of the survey area with reference to the existing water supply.
The assessment of the water demand is based on the results of the geographical survey and the water supply survey.
In the geographical survey the location of the villages was mapped, the number of inhabitants was determined and the actual sources of water supply were established. During this first survey the quantity and quality aspects have been based on the subjective information by the village population in terms of salt versus fresh water and water problems during the wet and dry season.

Priority areas have been established on the basis of the information gathered after discussion with the relevant authorities. In a further stage of the study the number of inhabitants of the villages was adjusted to the output of the population census of August 1978.
In the water supply survey the quantity and quality aspects of the existing supplies were detailed by chemical and bacteriological analyses of water samples. To this end a measurements programme was undertaken covering the villages of the survey area. If necessary the data of the geographical survey and consequently the results were rectified.
No survey was carried out for establishing the consumption, per capita, as already many investigators paid attention to this item. To establish the daily consumption per capita earlier studies and publications and existing data were evaluated.

The results of the geographical and water supply surveys, mentioned as "water demand", are presented in Part B of this report. The approach, the execution and the data output of the geographical and water supply survey are outlined in the Parts A and B respectively.

b. Water potential

In the second phase, partly coinciding with the first phase, a hydrological and hydrogeological survey and relevant studies have been carried out to establish the potential of water sources available for domestic water supply.
In general in the case of hydrological and hydrogeological surveys of an area like the Morogoro Region, a choice has to be made between two alternative methods:

- a detailed survey of small selected areas (e.g. the priority areas)
- a regional study aimed at providing a basic outline of the hydrological and hydrogeological situation throughout the Region

Within the scope of the MDWSP the first alternative seems to be more attractive and logical. However, to establish the long-term water policy, insight into the hydrological and hydrogeological situation in the whole Region is required.
Therefore the decision was made to consider the northern part of the Region only and to focus the detailed investigations on the priority areas as indicated in the report on the geographical survey (Part A).

The resources and potential of surface water, shallow and deep ground water for rural water supply have been considered in the hydrological and hydrogeological survey. This is done by overall and detailed surveys of sub-areas, in which measurements are carried out, on the basis of the preliminary information, to quantify the water resources and potential.

The measurements include geophysical investigations, a regular measurement programme of streams, existing shallow wells and hand dug holes, a hand drilling programme and a deep well drilling programme. The deep well drilling programme aims to create deep wells for the water supply and at the same time permits a more detailed interpretation of the geophysical measurements.
The hydrological and geohydrological studies include the following items:

- hydrogeological explanation for the present salt water problems in the Region
- studies of small catchments
- study of recharge of aquifers

In the study much attention was paid to the collection and evaluation of existing data with regard to the hydrological and hydrogeological conditions of the survey area.

The results of the hydrological and hydrogeological investigations and studies, mentioned as "water potential" are presented in Parts C and D of this report. A division has been made between the potential of surface water and ground water.

In parts C and D no decision is made about the use and exploitation of the potential for the domestic water supply, it just deals with the water availability. How the results of the potential of surface and ground water were derived is explained in the Parts C and D respectively.

c. Water exploitation

After establishing the water demand and the water potential, a water exploitation programme had to be drawn up.
The basis for the water exploitation programme are the 1981 and 1991 targets to rural water supply as defined by the Tanzanian Government.
This phase will result in recommendations for the short-term and long-term water policy with reference to domestic water supply. The financial and organizational repercussions and consequences will be outlined.

To this end the cost on one side and the long-term and short-term quantity and quality aspects of the water resources on the other side have to be optimized. The construction of new schemes as well as the renovation and upgrading of existing systems will be considered. This requires the establishment of the construction and renovation costs and the operation and maintenance costs of the different alternative supply methods with respect to their reliability. The reliability refers to the quantity and quality prospects and to the mechanical conception. The experience gained during water supply projects in and outside the Morogoro Region is a valuable contribution to the know-how available on this point.

As the scope of the MDWSP includes the objective to releave the need for the priority villages as soon as possible, the construction of a limited number of priority schemes will be worked out more in detail.

The implementation of the study results has already started during the survey. The boreholes of the deep well drilling programme which were found suitable for water supply have been completed with casings and screens and developed as production wells. Pending the supply and assembling of the supply system the wells have been equipped with a hand pump. On July 1st., 1978 the Morogoro Wells Construction Project started its activities in the Morogoro Region. Guided by the tentative results of the MDWSP survey a start was made with the construction of shallow wells.

1.4. Personnel

1.4.1. Expatriates

Until end May 1979 the following expatriate personnel was present in Morogoro:

		From	-	To
R.G. Campen	Project Manager	01-06-1977	-	19-06-1977
		03-10-1977	-	13-10-1977
		05-03-1979	-	16-03-1978
		02-05-1978	-	10-11-1978
		25-11-1978	-	22-05-1979
I.J.J. Beerens	Geographer	01-06-1977	-	30-11-1977
T.J. Kliest	Geographer	01-06-1977	-	30-11-1977
		05-03-1978	-	29-03-1978
		02-05-1978	-	26-05-1978

		From	-	To
J. Hinderink	Geograph. Advisor	21-10-1977	-	10-11-1977
J.J. Sterkenburg	Geograph. Advisor	21-10-1977	-	10-11-1977
R.V. v. Lissa	Hydrogeologist	07-05-1978	-	15-05-1979
C.M. de Wijs	Hydrologist	21-05-1978	-	18-10-1978
		10-01-1978	-	12-05-1979
T. Stavenga	Geophysicist	21-05-1978	-	01-05-1979
M. van Krimpen	Hydrogeological Ass.	21-05-1978	-	01-12-1978
E.J. Wedman	Sen. Hydrogeologist	04-06-1978	-	23-06-1978
		07-02-1979	-	16-02-1979
C.M. Engelsman	Hydrologist	30-07-1978	-	08-05-1979
A.J.M. Kuylen	Drill. Engineer	10-08-1978	-	01-02-1979
J. Louwe Kooijmans	Sen. Wat. Suppl. E.	13-09-1978	-	27-09-1978
		17-10-1978	-	25-10-1978
P. v. Dongen	Sen. Geophysicist	15-09-1978	-	29-09-1978
J. Oomen	Water Supply Eng.	01-10-1978	-	31-05-1979
P. Ruytenberg	Geophysical Ass.	02-01-1979	-	01-04-1979

1.4.2. Local personnel

The Regional Water Engineer made the following local personnel available to the team of expatriate experts for this period:

A. Yateria	Geophysical Ass.
T. Bernard	Driver
M.M. Mkilalu	Hydrological Ass.
M. Juma	Geophysical Ass.
O. Paul	Geophysical Ass.
S. Nassoro	Geophysical Ass.
A. Mlelwa	Hydrogeological Techn.
A. Chambuso	Hydrological Ass.
J. Ilyasa	Laboratory Techn.

Contrary to the Administrative Arrangement, the night-out allowances according to Governmental Standards were paid by the Netherlands Government, due to the shortage of funds available to the Regional Water Engineer's office in Morogoro.

Maji made available the crew for the execution of the drilling programme with Schrammrig 42, starting September 1978. This crew consisted of one foreman, E. Sadihid, one driver and five labourers. If needed, additional personnel was employed at the drilling site on a daily paid basis.

As the Regional Water Engineer was not able to supply personnel for the complete period of the survey, with as a consequence the loss of several working days, the decision was made that the team itself should recruit and employ local personnel at those places where their input is most essential for the study. This arrangement applies to the following employees:

P.W. Kwaikombe Geophysical Ass.

J. Ramathani	Driver
S. Katondo	Secretary/Typist
C.A. Lihanjale	Hydrological Ass.
A. Athanas	Driver
G. Andrew	Driver
L. Ndaghala	Gauge Reader
E. Mwakyoma	Field Assistant
J. Selousi	Field Assistant

1.5. Acknowledgements

Several meetings and discussions have been held with the Tanzanian Authorities during the stay of the team in Morogoro.

An outline of studies was presented to Mr. Mashuda, Regional Planning Officer and Mr. Chohollo, Regional Water Engineer.

During the study contacts were maintained frequently with:

Mrs. Anna Abdellah	Regional Commisioner of Morogoro Region
Mr. L. Lupembe	Regional Development Director
Mr. Mashuda	Regional Planning Officer
Mr. Chohollo	Regional Water Engineer
Mr. Mchinji	District Planning Officer Morogoro District
Mr. Mwansasu	District Planning Officer Kilosa District

We wish to express out gratitude for the assistance and co-operation of the authorities at the various administrative levels who have been contacted in the course of the survey.

2. SUMMARY

The Morogoro Domestic Water Supply Plan started in June 1977 with a geographical survey.
The following conclusions may be drawn from the geographical survey:

1. In the survey area one may distinguish three geomorphological zones, viz. the mountain areas, the transitional zone of foothills and steep piedmonts, and the flood plains.
2. In the Morogoro District the rural population is primarily found in the mountains and the adjoining piedmonts and in the foothills; in the Kilosa District the rural population is chiefly located in the foothills with concentrations in the northern part of this district and along the major roads.
3. The majority of the settlements in the survey area have a dispersed pattern.
4. Villages are mainly administrative units of varying size (between 400 and 5,000 inhabitants); the majority of the villages have a population in the range of 500 to 1,500 inhabitants.
5. The survey area has good inter-regional road connections; the intra-regional network is less well-developed, particularly in the mountain areas. Here, villages with about 20% of the total rural population of the survey area cannot be reached by car. The quality of the intra-regional roads is in general poor in the mountain areas and in the flood plains, particularly during the wet season.
6. The majority of the rural population make use of non-improved types of water supply; 20% of the rural population are served by improved types.
7. The survey area is rather well endowed with surface water resources, rivers and streams being the major sources of water supply, both during the wet and the dry season.
8. Local variations in availability and quality of drinking water are related to geomorphological zones. In the mountain areas there is sufficient water of good quality throughout the year.
   In the foothills and the piedmonts and in the flood plains there are water shortages during the dry season with the exception of those areas where perennial streams occur, while during this period water frequently contains a high concentration of salt.
9. In the survey area the following improved systems of water supply may be distinguished in order of importance:
   - gravity piped water supply;
   - pumped water supply from a well in or along the riverbed;
   - pumped piped water supply from a borehole or shallow well;
   - shallow well with a handpump.

10. The location of the problem villages shows that there are three priority areas for further investigations in the Morogoro and Kilosa Districts:
    - the northern part of the Kilosa District

- the Ngerengere area
- the area between Mbigili and Manyinga

11. The Regional Officers consulted on the identification of problem areas and individual problem villages agreed with the priorities established.

The water supply section of the MDWSP started its surveys in October 1978 and carried out the following activities:

- an inventory of the existing water supply facilities;
- a survey of the physical, chemical and bacteriological water quality and the availability, accessibility and reliability of the present facilities;
- a survey of the public health conditions in the project area, especially an inventory of the occurrence of water-related diseases;
- a survey of the domestic water demand based on consumption data and additional criteria for projections of future water demand.

The present village water supply facilities may be distinguished in:

- traditional and semi-improved systems (hand-dug holes, rivers, streams, springs and lined open shallow wells);
- improved systems (lined shallow wells with hand pumps, piped gravity supplies and piped pumped supplies).

The survey revealed that the majority of the rural population (67% during the wet season, 72% during the dry season) still uses the old traditional ways of obtaining drinking water.

Transmission and distribution mains of the improved systems are designed for a future water demand of 30 l/c/d and the consumption is assumed to take place during 6 hours a day.
Operation and maintenance of improved supplies is one of the major constraints in the functioning of such systems. Several pumped water supplies have regular breakdowns caused by poor condition of the water intake structure, failure of the pumping unit, lack of spare parts or lack of fuel.

The "Temporary Standards of Quality of Domestic Water in Tanzania" were used as the guideline for the evaluation of the water quality in the project area.

Water quality parameters having a negative health impact, such as fluoride and nitrate proved to be present in low or acceptable concentrations.

In three areas, viz. the Gairo division, the N.W. part of the Mamboya division and the Ngerengere area, the electrical conductivity, used as a measure for the total dissolved solids content, proved unacceptably high locally in the present water supply systems. Some 8% of all water samples analysed had an EC value over 200 mS/m.

Some 40% of all samples got a "poor" qualification as far as their turbidity, mainly due to clay and laom, was concerned.

The bacteriological quality was unsatisfactory for the majority of the water sources. Some water sources, including four piped water supply systems, were seriously polluted by faecal organisms (MPN > 100/100 ml) and regular occurrence of water-related diseases may be expected from such supplies.

From a number of monthly reports of medical centres over the year 1978, data were obtained on the first attendances for water-related diseases. It appeared that 30-80% of all diseases reported were water-related. A correlation study between the existing supply facilities and the occurrence of water-related diseases showed that no significant correlation existed between these two parameters.
This compares rather well with similar studies in rural areas of other Third World countries. Together with improvements in the availability and quality of water sources, comprehensive programmes on health education should be implemented.

The future water demands, based on a water allowance of 40 l/c/d and 30 l/L.U./d for domestic livestock (including 25% losses) have been estimated for 1983, 1988 and 1998, using the situation in 1978 as the reference level for estimates of population growth and livestock increase. The population increase is assumed to be 50% in 10 years and 100% in 20 years; for livestock 25% increase in 10 years and 50% in 20 years.
The identification of problem areas as to domestic water supply was based on an appraisal of the present water supply conditions of each individual village, using assessment criteria covering all aspects of the governmental policies towards rural water supply as laid down in the 1981 targets.

The following problem areas may be distinguished:
- the Gairo division and the N.W. part of Mamboya division
- the area along the Turiani-Kilosa-Mikumi road, covering parts of the divisions Turiani, Mamboya, Masanza and Ulaya
- the Ngerengere division
- the areas directly east and south of the Uluguru Mountains, covering parts of the Matombo and Bwakira divisions

It appears that the major problems in the present water supply conditions are related to the quality of the sources and to a lesser extent to the reliability of supplies and the water availability.

The hydrological and hydrogeological surveys for the assessment of the water potential of the project area started in May 1978 and were finalised in April 1979 as far as the Morogoro Domestic Water Supply Plan is concerned. After April 1979 discharge measurements were continued in the Ukaguru Mountains S.E. of Gairo within the scope of the Morogoro Gravity Plan, whereas the hydrogeological survey was continued for the siting of shallow and medium-depth well locations for the Morogoro Wells Construction Project.

Even during very dry (probability of non-exceedence 5%) and extremely dry (probability 1%) years the larger rivers, including their tributaries in mountainous areas, carry abundant amounts of water as compared with the amounts required for domestic water supply.

Opportunities for gravity supply systems are found in the mountainous areas and along the lower slopes or escarpments. Considering the small size of the villages and thus the small amounts required, even very small perennial streams or springs will do. In some areas it pays to combine the water supply of several villages. In some cases pumped water supply systems may become economically competitive.

Most villages in the Wami and Ruvu plains are situated too far from the mountains to be supplied by gravity. Some of these villages may be supplied from the large perennial rivers in these plains, using pumps and pressure lines. In many cases, however, shallow or medium-depth wells will offer cheaper solutions.

If no perennial surface water is available and the use of ground water is not acceptable, small earth-dam storage reservoirs, which are primarily suitable for cattle watering, may be considered as an alternative source for domestic water supply. The Ngerengere valley downstream of Morogoro and the upper part of the Berega catchment offer possibilities for this type of water source.

Ground water prospects are good to fair in most of the Mkata-Wami Basin and in the alluvial fill of many river valleys. Fair prospects for medium-depth (12-50 m below ground level) and deep (deeper than 50 m below ground level) ground water exist in areas where Karroo sandstones and cristalline limestones and dolomites occur. The metamorphic cristalline rocks, constituting large parts of the project area, offer poor to extremely poor prospects for both deeper and shallow ground water, mainly due to low permeabilities and often high salinities of the ground water.

Although seasonal ground water level fluctuations indicate recharge of the various aquifers by rain water, no quantitive information on recharge is available. However, as domestic drinking water supply requires relatively small quantities of water as compared with the average annual precipitation, the ground water potential is mainly governed by aquifer characteristics (depth, thickness and permeability) and the quality of the ground water (physical, chemical and bateriological properties), rather than by the quantities of ground water available. In other words, safe yield will hardly be a constraint in considering the ground water potential.

Rural water supply development programmes are divided into national and regional components.

The Government has formulated the following general guidelines for the development of the rural water supply sector during the Third Five Year Development Plan Period (1976-1981).

- Village water supply systems should consist of small, simple, cheap schemes.
- Various methods of water collection should be used, e.g. rainwater harvesting and charcos. Suitable water lifting devices are hand pumps and wind-mills.
- The development of water resources in the village should be such that by 1981 all villages are provided with at least one dependable water source.
- The village water supply programme is not primarily aimed at providing piped water. First of all, water should be made available at places where there is a shortage of water. Methods to be used are construction of shallow wells, and diversions from rivers and dams using a gravity transmission system.
- Water for live-stock and irrigation should be collected from rainwater reservoirs which are constructed using small dams. The villagers should be assisted with technical expertise to carry out such programmes.

Budget allocations can be divided between development budgets and recurrent budgets for both the national and regional level. Development budgets are used to finance the implementation of new water supply programmes. The recurrent budgets cover the regular staff (managerial, technical, administrative) and labour force for the day to day running of the Maji Departments and include the costs of operation and maintenance of implemented programmes.

All cost estimates for village water supply systems include the following cost components:

- material costs
- labour costs
- transport costs
- administrative overheads (1%)

The following conclusions can be drawn from the comparison of annual costs per capita of those typical village water supplies which were used for the costing operations:

1. The annual costs for shallow wells with handpumps are lower than those for pumped supplies with only rudimentary distribution facilities and any length of the transmission main, supposing both are for a design population less than 7000 people. For a design population between 7000 - 10,000 people the annual costs of pumped supply systems with a length of transmission main between 0.1 - 1 km are comparable to those of shallow wells with handpumps.
   The annual costs for shallow wells with handpumps are considerably lower than those for pumped supplies with extensive distribution systems.

2. The annual costs of gravity diversions with rudimentary distribution facilities are lower than those for shallow wells, if the transmission main length does not exceed 0 - 4.6 km, and depending on the design population. Shallow wells will have lower annual costs than gravity diversions with extensive distribution facilities if the length of the transmission main exceeds 1 km.
3. Where annual costs are equal, a gravity supply system may have a transmission main some 3 - 7 km longer than the transmission main of a pumped supply from a borehole, shallow well or riverside well, for a design population varying between 1000 - 10,000 people and a transmission main length between 500 - 10,000 metres.
4. Where annual costs are equal, a pumped supply from a shallow well or riverside well may have a transmission main some 0 - 2 km longer than that of a borehole supply, for a design population varying between 1000 - 8500 people and a transmission main length (of that borehole supply) between 500 - 10,000 m. At higher design populations, the borehole supply will have lower annual costs for otherwise similar conditions.

The development of shallow ground water resources (down to a depth of 12 m) appears attractive for the development of domestic water requirement in the project area.

The following areas have conditions suitable for shallow ground water development:

- villages along the Kinyolisi River and along part of the Berega River;
- villages along the Turiani-Kilosa-Mikumi Road;
- villages in the foothills of the E., S.E., and N.W. Ulugurus;
- villages along the Ngerengere River, downstream of Ngerengere Township.

Various other suitable sites are scattered over the whole survey area, at locations where sufficient deposits of alluvial material have created aquifer conditions suitable for ground water withdrawal.

It appears that suitable locations for medium-depth and deep ground water exploitation may be found in the following areas:

- the major part of the Mkata-Wami Basin (medium-depth and deep ground-water);
- the plain between the foothills of the Migomberame and Uluguru Mountains, or the area south of Mikumi and Mikumi Lodge (medium-depth and deep ground water);
- the foothills of the S.E. Ulugurus (medium-depth ground water).

It may be concluded that suitable sources for surface water supplies mostly occur in the following areas:

- the foothills of all mountains: Nguru, Kaguru, Migomberame and Uluguru Mountains. Numerous perennial streams and rivers emerge from these mountains;

- mountainous areas where small tributaries of major rivers flow throughout the year, especially in the Nguru and Uluguru Mountains;
- parts of the Wami and Ruvu plains were villages are located at reasonable distance from the rivers of the same name.

In conclusion, the MDWSP survey area is well endowed with both groundwater and surface water resources. In general there are no serious technical constraints to the utilization of these resources for village water supply.
In various parts of the survey area several suitable and dependable water sources exist for the development of future village water supply systems.
In some villages up to four alternatives may be distinguished for future water supply systems: shallow wells with hand pumps, pumped supply from a shallow well or riverside well, pumped supply from a borehole, and supply by gravity diversion.

On the other hand, a number of villages are located in areas where water sources suitable and dependable for village water supply development are virtually absent. In areas with such limited resources a choise has to be made between alternative recommendations such as installation of a very expensive system, provision of a system which is not in accordance with the current policies in domestic water supply development, or resettlement of the village in a more suitable location.

The proposed implementation programmes consist of a short-term and a long-term programme.
It is recommended that various projects be included in the short-term implementation programme.
- Water supply improvements for identified problem villages. The majority of the 82 problem villages can be provided with shallow wells with hand pumps, others can be served with a gravity system.
- Rehabilitation of various existing piped supplies.
- Additional projects. Some villages, not belonging to the 82 identified problem villages, can be provided with shallow wells or can be connected to a planned gravity scheme at relatively low cost.

The carrying out of the proposed short-term implementation programmes during the period 1979-1984 will require a total investment budget of approx. 107 million Tshs and annual O + M costs of 3-5 million Tshs (assumed annual price increase 15%).

The recommended procedures for the execution of the programme components are:
- the Morogoro Wells Construction Programme, started in 1979;
- the Morogoro Gravity Plan, which also commenced in 1979;
- the Morogoro Piped Water Supplies Project, to be started in 1980;
- several other piped water supply schemes for seven problem villages.

Once the short-term programme has been fully implemented, long-term programmes should be proceeded with consisting of:

- construction of additional shallow wells with hand pumps;
- construction of piped water supply schemes;
- extension of existing distribution systems;
- construction of small scale low-cost water supply systems for villages or clusters of households in mountainous areas.

The investment costs for these medium long-term programmes are estimated at Tshs 128 million, assuming the 1978 price level and the 1998 design population. Due to cost increases the actual costs in the period of execution will be considerably higher.

3. PRESENT WATER SUPPLY CONDITIONS AND WATER DEMAND

3.1. Introduction

A first inventory of the existing rural water supply facilities, in terms of the types of facilities, general quality, and population served was carried out in 1977 by two of the Consultant's geographers. This survey also included a general geographical and demographic survey, and a mapping of the (new) location of villages which resulted from the national resettlement programme. The geographical survey has been described in Part A. The results of the demographic survey have been discarded from the Final Report, as they were superseded by the more recent data of the Government's population census of 1978.
This first inventory did not include a detailed technical assessment of the existing facilities with regard to the identification of problem areas, and with regard to the definition of water resources development programmes for village water supply in the Morogoro and Kilosa districts. These development programmes should aim at providing the rural population of these districts with a safe and sufficient water supply in accordance with the Government's policies as laid down in the National Development Plans and the 1981 and 1991 targets.

The water supply section started its activities on October 1st, 1978. Within the scope of this part of the MDWSP study the following activities have been carried out:

- an inventory of the existing water supply facilities, including traditional and improved water supply systems;
- a survey of the physical, chemical and bacteriological water quality, its availability, and accessibility, and the reliability of the present facilities;
- a survey of the public health conditions in the project area, especially an inventory of the occurrence of water-related diseases;
- a survey of the domestic water demand based on consumption data, and additional criteria for projections of future water demand.

The results of these surveys, together with the results of the hydrological and hydrogeological surveys regarding the water resources potential, constitute the background data for the establishment of phased rural water supply development programmes, which are discussed in Part E.

3.2. The location and size of settlements and the road pattern

3.2.1. The rural settlement pattern

In the Morogoro Region some 800,000 people live in villages.
The rural population of the survey area was estimated at 557,000, in August 1978. The majority of this rural population are found in Morogoro District, i.e. 330,000 (59% of the total rural population of the survey area), while the remaining 227,000 (41%) live in Kilosa District.

The rural population in the Morogoro District is highly concentrated in a few areas: the Uluguru and Nguru Mountains and their adjoining piedmonts, and in the foothills. In the latter area the population has especially settled along the major roads. In the Kilosa District the rural population is mainly found in the foothills. Two types of concentration may be distinguished here: the area around Gairo and the Mamboya Division, and those along the major roads, i.e. the road connecting Kilosa Town with Mikumi and Gairo, and the one branching off at Dumila to the Morogoro District.

At present there are 360 villages in the survey area, i.e. 227 in the Morogoro District and 133 in the Kilosa District. These villages should not be associated with compact settlements but are administrative units. This is the result of the Government's policy of villagization, which came into effect in August 1974. The aim of this policy was to concentrate the nation's rural population in spatial units which would become the basis for future social and economic development. These units should preferably have the form of a nucleated settlement in order to facilitate the provision of services such as water supplies, health and educational facilities, agricultural extension services and marketing facilities.

In the survey area the villagization policy primarily resulted in what we would define as an administrative villagization, i.e. a number of small population clusters put together under an administrative umbrella, without generally achieving a single nucleated type of settlement.

Whenever a certain degree of concentration was achieved, it generally took the form of planned rows of houses. However, the majority of the villages in the survey area still consist of rather dispersed settlements, or even homesteads widely scattered over the village territory. This phenomenon is particularly common in the mountainous areas, such as the Uluguru, the Nguru and the Rubeho Mountains. In these areas the concentration of a large number of houses is hampered by environmental conditions. But even in the lower parts of the survey area with more suitable environmental conditions for concentrated habitation, compact villages are the exception rather than the rule. Consequently, the envisaged effects of the villagization policy have not yet materialized.

3.2.2. The size of settlements

In the present report the size of settlements is understood in terms of the number of inhabitants of villages, because planning activities at grass-roots level in Tanzania focus on these asministrative units. The average population size of the villages in the survey area is 1,500 persons. This average, however, is derived from a large range: the size of the individual villages varies between 400 and 5,000 persons. A frequency distribution of villages according to the total number of inhabitants reveals that some 60% of the villages is in the range of 500 to 1,500 inhabitants. Further details are given in the following table 3.2-1.

Table 3.2-1 Size distribution of villages (%)

size of village	under 500	500 - 1,000	1,001 - 1,500	1,501 - 2,000	2,001 - 2,500	2,501 - 3,000	3,001 - 3,500	3,501 - 4,000	over 4,000	total
	3	24	29	19	13	6	3	1	2	100

No specific relation was found between the size of a village and the location within one of the three geomorphological zones. In general, the present size is mainly the result of the recent villagization policy and is as such the outcome of the interpretation of the general directives by the various officers in charge of the implementation of this policy.

3.2.3. The road pattern

The map showing the pattern of roads and motorable tracks in the survey area - attached to this report - makes clear that the survey area has rather good inter-regional road connections. The Tanzam Highway, with a tarmac surface, runs in a nort-east/south-west direction, providing year-round transport possibilities with the coastal area and with the south-western part of the country. In addition, the main road to Dodoma passes through the area. This Morogoro-Dodoma road has a badly maintained gravel surface. Some parts of this road occasionally suffer flooding as a result of heavy rains.
There are plans to upgrade this road so that in the near future Morogoro Town will have a bitumized road connection with Dodoma.
The only major change in the inter-regional road pattern will be the construction of a bitumized road connecting Chalinze (Coast Region) with the area south of the Uluguru mountains across the Ruvu flood plain. This road will be constructed in the framework of the Rufiji River Basin Development Project and may give a strong impulse to the development of this sparsely populated area.

In contrast to the inter-regional road connections, the intra-regional road pattern is less well developed. Not all parts of the survey area are served by motorable roads and tracks. This applies in particular to the mountainous areas such as the Uluguru, the Nguru and the Rubeho Mountains, where some 85 villages with not less than 20% of the total rural population of the survey area cannot be reached by car.
Another difference with the inter-regional road connections is the generally poorer quality of the intra-regional roads.

Quality is interpreted here in terms of accessibility throughout the year and is expressed by the qualifications all-weather and dry-weather. The quality of the intra-regional roads differs per geomorphological zone.

In the mountainous areas transport is almost impossible during the wet season.
In the large flood plains of the Mkata, Wami and Ruvu Rivers accessibility is substantially reduce during the wet season when whole sections of the roads and tracks are flooded. On the other hand, the foothill area and the piedmonts are usually accessible throughout the year. Heavy rains may only cause occasional transport problems for short periods here. The combined effects of climatological characteristics and inadequate maintenance result in a deterioration of the quality of the intra-regional roads, particularly in the mountainous areas and the flood plains.

3.3. Appraisal of existing water supply facilities

Availability of a safe and reliable water supply in the villages is considered to be a major factor influencing rural development.
The survey area is fairly well endowed with surface water resources. A large number of rivers and streams are perennial and supply a considerable percentage of the area's rural population with sufficient and dependable water sources throughout the year. Groundwater resources, which are easily exploited by the villagers because of the high ground water table, are found in a limited number of areas, i.e. alluvial river valleys and some areas with swamp deposits.

This general picture, however, obscures local variations in availability, accessibility and quality of clean water. Such variations largely coincide with the geomorphological zones, especially with the mountainous areas on the one hand and piedmonts, foothill areas and flood plains on the other.
In general, water problems do not occur in the villages located in the well-watered mountainous parts of the survey area, i.e. the Uluguru, Nguru and Rubeho Mountains. In these areas the high average precipitation sustains a number of springs and large and small perennial water courses, which are exploited by the inhabitants as traditional water sources. In the remaining parts of the survey area, the problems encountered are related to the availability, accessibility and reliability of water supply systems. In these areas various types of traditional, semi-improved and improved water supply systems can be found.
The present village water supply facilities may be distinguished in:

- traditional and semi-improved systems, i.e. hand-dug holes (on village ground or in river bed), rivers, streams, springs, and lined open shallow wells. The lining of such shallow wells may consist of sheet metal (open ended oil drums), masonry or concrete work;
- improved systems, i.e. lined shallow wells with hand pumps and piped water supplies, either gravity or pumped diversions.

The relative importance of each of the various water supply systems is summarized in table 3.3-1.

Table 3.3.-1 Relative importance of various water supply systems (%)

Water supply systems	No. of people served (%) Wet season	Dry season
Traditional supplies	67	72
Semi-improved supplies	11	9
Gravity piped supplies	8	6
Pumped piped supplies:		
- river intake	6	5
- borehole	3	3
- shallow well	1	1
Shallow wells with hand pump	4	4
Total	100	100

It may be concluded from this table that in spite of all efforts and achievements, the majority of the rural population in the survey area still uses the old traditional ways of obtaining drinking water.

The piped water supply systems consist of fairly robust elements such as blockwork pumping houses, blockwork storage tanks and blockwork domestic waterpoints. The civil works of these structures are in general in good condition. Transmission and distribution systems consist mainly of PVC and galvanized steel pipes. The pipework is normally properly buried, and damage to these pipes can only occur in areas with substantial landslides.

On a few occasions it was observed that PVC pipes were exposed to direct radiation of ultra-violet rays in sunlight, and under such conditions quick aging of these pipes may be expected.

The water distributed from the semi-improved or improved water supplies is neither treated nor disinfected. Such water treatments only exist in some urban areas such as the Morogoro and Kilosa Townships.

The daily operation time of improved systems depends on the type of system.

Gravity mains are normally operated for 24 hours a day, and pumping equipment for pumped supplies for 8-12 hours a day. Transmission and distribution systems are designed for a future water demand of 30 l/c/d, and the consumption is assumed to take place during 6 hours a day: 3 hours in the morning (6-9 a.m.) and 3 hours in the afternoon (3-6 p.m.).

Operation and maintenance of improved supplies is one of the major constraints in the functioning of such systems.

Several pumped water supplies have regular breakdowns caused by poor conditions of the water intake structure, failure of the pumping unit, lack of spare parts, or lack of fuel.

The design and construction of intake structures often does not meet the technical standards required for a reliable supply and frequently causes breakdowns in other parts of the system. The sand and suspendded matter conveyed through the system may damage pumps, and cause clogging of appurtenances in the transmission and distribution lines.
The results of such failures will be that the villagers are forced to return to the traditional water sources, which in turn may have serious adverse public health effects.
Besides, the RWE's office has a serious shortage of skilled manpower, transport facilities, spare parts and tools. New projects suffer from the delays in delivery of essential items such as pipe materials and cement.

3.4. Water quality conditions

Fieldwork to investigate the physical-chemical and bacteriological water quality of existing water supply facilities was conducted in the periods October-November, 1978, and February-March, 1979. During these periods only part of the survey area could be covered. Heavy rains started towards the end of November, 1978, and interrupted the field survey considerably.
From the water quality investigations, it appears that the water quality is in general fairly good as far as physical and chemical aspects are concerned. The "Temporary Standards of Quality of Domestic Water in Tanzania" were used as the guideline for the evaluation of the water quality investigations.
Physical, and chemical water quality parameters which may restrict the use of water for drinking water purposes are:

- substances which are toxic;
- substances which effect human health;
- substances which effect the palatability of water.

Toxic substances are not very common in natural waters and are usually introduced in water bodies as a result of human activities, e.g. industrial development. Such activities are virtually absent in the survey area, and therefore the determination of possible toxic substances has not been considered in the water quality investigations.
Water quality parameters with a proven negative health impact, such as fluoride and nitrate, were included in the standard measurement programme for all water sources surveyed. It appeared that these components were present in low or acceptable concentrations.

The electrical conductivity, used as a measure for the total dissolved solids content, and influencing the general palatability of the water, indicated the occurrence of three distinct problem areas: the Gairo Division, the N.W. part of Mamboya Division, and the Ngerengere area. The electrical conductivity had quite acceptable values in the other parts of the survey area.

Some 85% of all samples had an EC_{25} level below 125 mS/m (1250 µS/cm) and only about 8% of all water samples contained high amounts of solids resulting in EC_{25} values over and above 200 mS/m. In some cases, the villagers have rejected such water sources *for human consumption*, and use them only for laundry and dish washing.

All water samples were classified as "good", "fair" or "poor" from their general appearance (by sensorial observation). Some 40% of all samples obtained a "poor" qualification, caused by relatively high levels of turbidity mainly due to clay and loam.
The improvement of the palatability of the water by decreasing these high turbidity levels should receive full attention in rural water supply upgrading projects.

The bacteriological survey has been carried out along with the physical, and chemical investigations. The bacteriological quality was unsatisfactory for the majority of the water sources. They contained lower or higher quantities of E.Coli, which indicates recent pollution by faecal matter of human origin. Even piped water supplies conveyed such suspects waters.
About 73% of the water sources sampled contained E.Coli (MPN > 1/100 ml), and should be considered to be suspect for domestic water supply. Some water sources, including four piped water supply systems, were seriously polluted by faecal organisms (MPN > 100/100 ml), and regular occurrence of water-related diseases may be expected from such supplies.

3.5. Public health conditions

An adequate supply of water for drinking, personal hygiene and other domestic purposes is essential for the public health and well-being of a society as a whole. Such a water supply is characterized by adequate standards with regard to quantity, quality, accessibility and reliability of the water supply system.
In order to assess whether a particular water supply is appropriate to the objective of improving the health of the people who use it, one needs to have a fairly precise knowledge of the relations between water, hygiene, sanitation and health. In tropical countries, between twenty and thirty different infectious diseases may be influenced by changes in water supply.
They are classified according to four distinct mechanisms by which a disease may be water-related: faecal-oral (water-borne or water-washed), water-washed, water-based and water-related insect vectors.
This classification of water-related diseases can facilitate the use of health improvements as design benefits and thus promote efficient resource allocation. If the principal water-related diseases in a region are identified and classified, then it is possible to identify the types of water supply improvements which will have the greatest impact on health, to consider the cost-benefit aspects of different schemes and to nominate local and regional priorities for supply development.

A more or less reliable evaluation of data from Government hospitals, rural health centres, and dispensaries on the prevalence of the diseases revealed that water-related diseases occur very frequently in the survey area.
From a number of monthly reports of medical centres over the year 1978, data were obtained on the first attendances for the following water-related diseases:

faecal-oral diseases	:	cholera, bacillary dysentery, diseases of the digestive system, diarrhoeal diseases;
water-washed diseases	:	skin and eye diseases, ulcers;
water-based diseases	:	schistosomiasis, helminthiasis;
water-related insect vectors	:	malaria.

In the health centres which were included in the evaluation, water-related diseases accounted for 30-80% of all diseases reported. Faecal-oral and water-washed diseases occurred throughout the survey area, and amounted to 15-60% of all diseases reported. Schistosomiasis had in general a low incidence, apart from some locations where schistosomiasis appeared to be endemic (5-25% of disease pattern). Malaria prevailed in the whole survey area (5-40% of disease pattern).

A correlation study between the existing water supply facilities and the occurrence of water-related diseases revealed that no significant correlation between these two parameters existed. This result compares rather well with similar studies in rural areas of other Third World countries. It appears, time and again, that improved village water supplies have only measurable effects on health if they occur simulateneously with extensive programmes on health education.

For village water supply, the high incidence of faecal-oral and water-washed diseases require development programmes which firstly concentrate on improvements in the availability and quality of water sources. Simultaneously, comprehensive programmes on health education should be implemented to make the rural population aware of the relation between water and health, and to improve individual hygienic practices.

3.6. Water demand studies

Water demand studies require input data such as water consumption per capita per day, present population in each supply area, and the estimated population growth in that area.
Additional water demand will be created by livestock, agriculture (irrigation), public and private institutions (e.g. schools, health centres, guest houses) and the industrial sector (e.g. sisal estates, sugar estates).

The MDWSP study is primarily concerned with domestic water supply for rural communities. Public institutions such as primary schools, rural health centres, and dispensaries constitute essential facilities for these rural communities, and the water demand generated by these institutions has therefore been included in the future domestic water demand projections.
Water demand for irrigation, industrial activities and private institutions such as missions has been left out of consideration. An exception has been made for domestic livestock, i.e. small groups of livestock returning to the homestead during the night, because they are considered part and parcel of the village community.

In conclusion, the following items have been included in the future water demand estimates:
- rural population
- village primary schools
- rural health centres and dispensaries
- domestic livestock

Data on the present population of the villages in the survey area are based on the Governments' population census in 1978, the results of which were obtained from the Bureau of Statistics. A similar census was conducted for livestock, and the relevant data were obtained from the Districts' Livestock Officers. Data on the location and enrolment of primary schools were collected from the Districts' Educational Officers, and data on the location of medical centres from Districts' Medical Officers.

The criteria required for the water demand projections are largely based on directives of the Maji Department. An essential aspect of these ministerial criteria is the policy of considering a water allowance rather than a water demand for future projections. This policy is part of the Government's directives to save capital expenditure on rural water supply systems, so as to provide as many people as possible with a dependable water supply. The Consultant has introduced some additional criteria, such as the incorporation of an allowance for leakages in transmission and distribution lines and wastage at the domestic water points.
It has been assumed that these total losses can amount to 25% of the water distributed from the source. No data are available on actual water losses, but the adopted criterion is comparable to the current practice in some other regions in Tanzania. In accordance with this the water allowance for the next 20 years for the population has been set at 40 l/c/d and for the domestic livestock at 30 l/L.U./d.
The application of a water allowance of 40 l/c/d may be considered to be quite acceptable for piped water supplies based on distribution via public domestic water points. The physical effort of carrying water over a certain distance to the homestead constitutes the main limiting factor for a further increase in the consumption.

The future water demands have been estimated for 1983, 1988 and 1998, using the situation in 1978 as the reference level for estimates of population growth and livestock increase. In accordance with the Ministerial directives for the design of piped water supplies, the population increase is assumed to be 50% in 10 years and 100% in 20 years; for livestock 25% increase in 10 years and 50% in 20 years.

The estimated water demand of the present population amounts to 268 l/s for a population of 557,000 people in 260 villages; the future water demand (1998) is estimated at 549 l/s or 17.3 x 10^6 m^3/year. The present and future livestock water demand are estimated at 89 l/s and 133 l/s respectively, based on a present livestock population of 225,000 livestock-units.
The estimated total present and future water demand will then amount to 357 l/s and 682 l/s, respectively.

A frequency distribution table for the population and livestock water demand for all individual villages in the survey area shows that the majority of the villages have a future population water demand (1998) less than 3 l/s, and a future livestock water demand (1998) less than 2 l/s. In other words, design and construction activities for individual village water supplies, catering only for the population, have to be focused on design capacities ranging between 0.5-3 l/s for gravity supplies operating 24 hours a day, and 1-6 l/s for pumped water supplies with a pumping schedule of 12 hours daily.
Detailed estimates of future population and livestock water demand are given for each village separately in Data BD 3.
For all divisions, the water demand is very small in comparison to the average annual precipitation, and no serious problems should be encountered in meeting this demand, as long as no specific adverse hydrogeological or hydrological mechanisms occur. Some areas do suffer from such drawbacks, and under these conditions transmission of suitable water over fairly long distances may be required, e.g. Gairo division and N.W. part of Mamboya Division.

3.7. Identification of problem areas

A first general inventory of the areas and villages experiencing problems in domestic water supply was given in the Integrated Development Plan for Morogoro Region.
A more detailed inventory was made during the MDWSP and the Consultant has undertaken to make an assessment of the present water supply conditions for all villages in the survey area in order to make sure that no needy villages were accidentally left out of consideration. The identification of problem areas was based on an appraisal of the present water supply conditions of each individual village using six assessment criteria. These assessment criteria cover all aspects of the Governmental policies towards rural water supply as laid down in the 1981 targets.

The targets established by the Tanzania Government with regard to the development of rural water supply are summarized below.

- To provide a source of clean, potable and dependable water within a reasonable distance of every village by 1981 as a free basic service.
- To provide a reliable water supply with clean potable water to the rural areas by 1991, so that all people will have ease of access (i.e. a distance of 400 m) to a public domestic water point. This supply should preferably consist of a piped system with communal water points, but a shallow well with hand pump also complies with the requirements.

Within the context of the national policies, the following criteria for the identification of problem villages have been adopted in the MDWSP study:

- ratio of the present water demand to the present water availability;
- quality of the water source (labelled good, fair or poor);
- average distance to the water source (km);
- reliability of the present facilities, expressed as the time period of the year (in %) during which water availability matches with water demand;
- quality of the water, using the electrical conductivity as the quality standard;
- size of the village.

The villages received a score for each of these six assessment criteria. The scoring procedure adopted is summarized in Table 3.7-1.

Table 3.7-1 - Scoring procedure for the assessment criteria used for the appraisal of existing village water supplies

selection criteria	scores		
	3	2	1
water demand/availability (ratio)	< 0.5	0.5 - 1.0	> 1.0
quality of source	poor	fair	good
average distance to source (km)	> 2.5	1.0 - 2.5	< 1.0
reliability of supply (%)	< 75	75 - 100	100
quality (EC in mS/m)	> 200	100 - 200	< 100
village population (1978)	> 2000	100 - 2000	< 1000

The aggregate score for each village for the six assessment criteria determined its ranking on the village assessment list.

The outcomes of the appraisal procedure have been visualized in Map B 1. This map shows that the following problems areas may be distinguished:

- the Gairo Division, and the N.W. part of Mamboya Division;

- the area along the Turiani-Kilosa-Mikumi road, covering parts of the divisions Turiani, Mamboya, Masanze and Ulaya;
- The Ngerengere Division;
- part of Mlali Division;
- the areas directly east and south of the Ulugurus, covering parts of the Matombo and Bwakira Divisions.

The 360 villages of the survey area have been divided in three categories in accordance with their aggregate score.
The 77 villages with a score of 12 points or more, and 5 villages with a lower score but being more than 2.5 km from the water source were classified in category I. This group of 82 villages has been selected as the most needy group which should get first priority in a short-term implementation programme aiming at the improvement of village water supply conditions. The villages of category I are listed in Table 3.7-2.
The second category includes 61 villages which experience moderate problems in their domestic water supply conditions, and the remaining group of 217 villages is considered to have no or slight shortcomings in regard to the 1981 targets.

A frequency distribution table of the scores for all assessment criteria shows that the major problems in the present water supply conditions are related to the quality of the sources, and to a lesser extent the reliability of supplies and the water availability. The average walking distance to the village water sources complies with the Government's targets for 1981 for the large majority of the villages. The EC values of the water sources are good to satisfactory for virtually all villages.

The people living in the problem areas, however, experience various difficulties with their water supply such as:
- serious water shortage for a fairly long period towards the end of the dry season;
- remoteness of suitable water sources and occasionally distances of 5-10 km have to be covered to arrive at the dry season water source;
- high salinity of water sources during part of the year or throughout the year.

The Tanzanian Government wishes to offer water supplies to as many rural dwellers as possible with the available budgets. Therefore, the implementation costs per capita of rural water supply development programmes play an important role in the final ranking of priority villages for implementation programmes. Such considerations are part of the more detailed studies in Part E (Volume V).

Table 3.7-2 - List of priority villages

village	agg. score	village	agg. score	village	agg. score
Bwakira Juu	12	Kondoa	12	Mtumbatu	13
Chakwale	12	Kunke	12	Mugudeni	13
Chanyumbu	12	Leshata	13	Muhenda	15
Chanzuru	12	Lubungo	14	Mwandi	12
Dakawa	12	Luhindo	10	Ngerengere	12
Difinga	12	Lukobe	13	Ngerengere Dar.	12
Diguzi	12	Mabula	12	Ngiloli	11
Dihinda	14	Machatu	14	Nguyami	14
Dumila	12	Madege	16	Nyarutanga	13
Fulwe	13	Madizini (Tur.)	13	Rudewa Batini	12
Gairo	12	Madudu	12	Rusanga	12
Gomero	14	Magubike	14	Sangasanga (Mla)	12
Ibindo	12	Maharaka	13	Sasasaga	12
Ibuti	12	Makuyu	12	Seregete A	13
Idibo	12	Mandela	12	Seregete B	12
Ihenje	14	Manza	12	Tabu Hotel	13
Ilakala	14	Maseyu	13	Tindiga	13
Iyogwe	12	Matuli	12	Tungi	14
Kambala	12	Mbigili	12		
Kibedya	12	Mbili	12		
Kidogobasi	12	Meshugi	13		
Kidudwe	12	Mfulu	12		
Kiegea	12	Mirama	12		
Kihonda	13	Mkalama	13		
Kilama	13	Mkambarani	12		
Kinonko	12	Mkonowamara	13		
Kiroka	13	Mkulazi	10		
Kisemu	12	Mkundi (Mam)	12		
Kitaita	13	Mkundi (Nge)	12		
Kitete	12	Mlilingwa	11		
Kiwege	14	Msonge	10		
Kiziwa	13	Mtamba	12		

4. WATER POTENTIAL

4.1. Introduction

4.1.1. Hydrology

The hydrological studies presented in this report were carried out to obtain a basis for the surface water potential with respect to the domestic water supply in the project area. The study aims in particular at the identification of sources of surface water (rivers and springs) which have a sufficient yield and an acceptable quality and which are situated at a reasonable distance from the supply area.
From a technical and economical point of view it is attractive to select water sources from which the water can be conveyed to the supply area by gravity. Several possibilities for gravity supply systems are discovered in the mountainous areas and along the lower slopes of the mountain blocs which are found in the project area.
In the plains and foothill areas the level differences are generally too small for gravity transport of the water. There pumped water supply systems can be applied.
For gravity water supply systems as well as for pumped water supply systems, seasonal storage facilities are generally very expensive. In both cases it is therefore attractive to base the systems on perennial rivers or springs which have sufficient amounts of water even during the dry season.

In this study the lowest flows which may be expected at the end of the dry season of a very dry year (10% and 5% probability of non-exceedence) were calculated. This means that if the extracted amount of water equals the lowest annual flow of a very dry year, the system will experience water shortage during a short period in less than, respectively, once every 10 years and once every 20 years.
Other factors which are taken into account in the selection of suitable rivers and springs are the distance and level difference from possible intakes to the supply area, as well as possible reduction of the flow due to extraction.

In some areas where no perennial rivers exist, and shallow and deep ground water is too saline to be suitable for consumption, small earth dam storage reservoirs based on ephemeral streams are considered as an alternative water source. The annual discharge volume of a very dry year and the sedimentation rate determine the hydrological feasibility of this type of water supply system.

4.1.2. Hydrogeology

The hydrogeology of the project area has been studied using the undermentioned data.

Existing data:
- existing geological maps and reports
- data on existing boreholes
- aerial photographs
- topographical maps

Data collected by MDWSP:
- Landsat Imagery studies
- hydrogeological and geological field data
- geo-electrical investigations
- seismic investigations
- hand drillings
- drilling of deep wells
- well loggings

Evaluation of these data is presented in Chapter D 3: Data Collection and Evaluation.
The combined studies resulted in the hydrogeological description of the project area (Chapter D 4) and in the compilation of the geological map of the project area (Map D 2), the map showing the prospects for medium-depth and deep ground water (Map D 3) and the map showing the prospects for shallow ground water (Map D 4).
With respect to the hydrogeology, the project area has been divided into areas where the prospects for ground water are good, fair, poor and extremely poor.

4.2. Scope of the hydrological studies

In the determination of the surface water potential several steps are involved.
Existing hydrological data were collected and scrutinized. As far as the data were of specific interest, possibly missing values were estimated and the homogeneity and reliability of the data series were checked.
Only few data were available on small perennial streams in mountainous areas and hardly any data on ephemeral rivers were collected in the past.
In particular for the estimation of the low flows of the perennial rivers additional flow data were collected in the field during the dry season of 1978.

Based on a general survey of the project area, a number of rivers which were considered attractive sources for water supply or which were of specific hydrological interest, were selected and incorporated into a regular measurement programme. The programme included collection of flow data and data on salinity. It was carried out on a monthly basis from August, 1978, up to December, 1978.

To form a notion of the feasibility of small earth dam reservoirs several existing reservoirs situated in flat or gently sloping areas were observed during the dry season and the beginning of the wet season.

One small catchment in the Uluguru Mountains - The Kikundi River - was measured and studied in detail. The measurements included continuous flow registration and sediment sample collection during floods. The data were used for various purposes but primarily to obtain an idea of the magnitude of the different components of the water balance of a small mountainous catchment. As the catchment is only sparsely vegetated, high erosion rates are observed. The sediment characteristics may be considered representative for the Uluguru Mountains, where the changes in land use keep favouring agriculture at the expense of the present rain forests.
The data of this study were also used as a basis for testing existing rainfall-runoff models and flood models.

Close to Morogoro Town the Mindu Reservoir is under construction. The reservoir will mainly be used for the industrial and domestic water supply of Morogoro Town. The reservoir may also be used for the supply of water to villages in the Ngerengere valley. Therefore, and because of its general importance, the hydrologic starting points have been re-evaluated.

4.3. Prospects for ground water

The prospects for medium-depth (12-50 m below ground level) and deep ground water (deeper than 50 m below ground level) are:

good (0.5% of area)	-	in parts of the Mkata-Wami Basin (unconsolidated sediments)
fair (20% of area)	-	in parts of the Mkata-Wami Basin (unconsolidated sediments)
	-	in the Karroo area south of Mikumi (sandstones)
	-	in the Karroo areas in the S.E. (sandstones)
	-	in a narrow zone, south of Kidugallo (crystalline dolomites)
poor (10% of area)	-	in parts of the Mkata-Wami Basin (unconsolidated sediments)
	-	in the area north of the Ulugurus (partly decomposed metamorphic rocks)
extremely poor (69.5% of area)	-	in the rest of the project area (metamorphic rocks, sandstones)

The prospects for shallow ground water (less than 12 m below ground level) are:

good-fair (15% of area)	-	in most of the Mkata-Wami Basin (unconsolidated sediments)
	-	in alluvium in many river valleys (unconsolidated sediments)
fair-poor (50% of area)	-	in small parts of the Mkata-Wami Basin (unconsolidated sediments)
	-	in the Karroo area south of Mikumi (sandstones)

	-	in the alluvium S.E. of the Ulugurus (unconsolidated sediments)
	-	in the Jurassic area (sandstones)
	-	in two areas east of the Ulugurus (crystalline dolomites)
	-	in the area North of the Ulugurus (soils decomposed gneiss)
	-	in the Ukaguru and Usagara Mountains (gneisses)
extremely poor (35% of area)	-	in the Nguru and Uluguru Mountains (granulites)
	-	in the S.W. part of the project area (gravels)

In the areas where the prospects for ground water have been classified as poor to extremely poor, ground water is only locally present, not present at all and/or saline.
Because of this, these areas are not of interest for exploitation of ground water and are not considered further.

In the areas where the prospects for ground water have been classified as fair to good, the maximum amount of ground water theoretically available is equivalent to the recharge.

4.4. Hydrological description of the project area

The project area is drained by parts of three big river systems which are from north to south the Wami, Ruvu and Rufiji. Most of the water contributed by the project area originates from five mountain ranges, which are the Uluguru, Nguru, Kaguru, Rubebo and Migomberame Mountains. In particular the Ulurugu Mountains which are drained by the Ruvu River, are considered one of the major water sources in Tanzania.

The region belongs to the tropical rain climate zone. The climate is strongly determined by continental air movements, which are mainly caused by low air pressure zones caused by the sun's maximum elevation. As a result of the air movements two rainy periods can be distinguished. On the average the so-called small rains start in November and last up to December.
January and February generally show less rain. During March, April and May most of the annual rainfall occurs.

The period from June up to October is generally very dry. Due to topographical factors rainfall varies also strongly throughout the region. In mountainous areas two or three times as much rain is observed as in the plains. Generally the rain falls during short time periods with high intensities. The storms are very local.

Because of this variation in rainfall and because of the strongly varying topography, vegetation cover and other geomorphological factors, runoff varies also strongly in place as well as in time. During the wet season runoff is abundant. High peak flows occur particularly in mountainous areas.
Plains may partly be flooded. From June onwards the discharges decrease steadily due to depletion of the ground water storage. In mountainous areas and particularly in forested parts, many rivers keep on flowing throughout the year. Except the larger rivers like the Wami, Ruvu and Mgeta, these rivers, however, stop flowing when passing the plains due to infiltration and evapotranspiration losses. The small tributaries which are found in the plains generally carry water only during short periods after storms. Most of the rainfall in this area is lost by infiltration and evapotranspiration.
On an annual basis in mountainous areas 30-60% of the rainfall is discharged by the rivers. A ratio of 0-10% is found in the plains and 10-30% for gently sloping foothills in between.

4.5. Main geological units

The rocks in the project area can be grouped according to their age into four major divisions:
- Precambrian rocks (appr. 70% of the project area)
- Karroo rocks (appr. 6% of the project area)
- Jurassic rocks (appr. 4% of the project area)
- Tertiary/Quaternary rocks (appr. 20% of the project area)

Precambrian rocks crop out in the mountain ranges and bordering foothills in the western and northern part of the project area as well as in the Uluguru Mountains and its foothills in the central part of the project area. They crop out also locally in the area enclosed by the Uluguru Mountains and foothills and the Mkata and Wami rivers.
The rocks are mainly meta-sedimentary and can be divided into three major lithological groups: acid gneisses, granulites and crystalline limestones.

The Karroo rocks occupy the area south and south-east of the Ulugurus as well as the southern most part of the Mkata Basin.
The rocks consist mainly of sandstones, siltstones and shales deposited in shallow fresh to brackish water.
Their age may vary from Permian to Triassic.

Jurassic rocks occur only in the eastern-most part of the project area. They consist of coarse sandstones, mudstones and oolitic limestones deposited in marine environments.

Sediments of upper Tertiary and Quaternary age occur in the downfaulted Mkata/Wami Basin.

They are 30 m up to 250 m thick and were deposited in fluvial, alluvial and swamp environments.
Probably only sediments of Holocene age are at the surface.

Limited occurrences of Quaternary fluvial deposits are found in the valleys of present rivers and streams.

4.6. Surface water potential

4.6.1. General

Even during very dry and extremely dry years the larger rivers, including their tributaries in mountainous areas, carry abundant amounts of water as compared with amounts required for domestic water supply. At the allocated amount of 40 l/day per capita a source of 1 l/s may supply approximately 2000 people when storage facilities for daily fluctuations are available.
The total demand of all villages in the project area in 1998 is estimated at 550 l/s (or 17.3 x 10^6 m^3/year). To give an idea of the amounts of water which are available during extremely dry and very dry years the lowest annual flows with probabilities of 1 and 5% (return periods of once every 100 and once every 20 years) are given for some larger rivers in Table 4.6-1.
Particularly in the Uluguru Mountains relatively large low flows occur. But also in the other mountainous areas relatively large perennial rivers are found.

Table 4.6-1 - Lowest annual flow (l/s)

Area	river	station	probability of non-exceedence 1%	5%
Uluguru Mountains	Ruvu	Kibungo	1810	2160
	Mgeta	Kisaki	550	690
	Mgeta	Mgeta	460	530
	Ngerengere	Konga	25	40
Nguru Mountains	Diwale	Turiani	100	270
	Mkindu	Mkindu	250	320
Kuguru Mountains	Tami	Msowero	50	80
Rubeho Mountains	Kisangate	Mvumi	140	200
	Wami	Rudewa	790	1075
Migomberame Mountains	Msowero	Msowero	160	200
	Tundu	Tundu	80	90

4.6.2. Gravity supply

Opportunities for gravity water supply systems are found in the mountainous areas and along the lower slopes or escarpments. Particularly in the Uluguru Mountains, but also in the other mountainous areas, almost all the villages may be supplied by small scale gravity systems with intake mains varying in length between about 1 and 3 km. Because of the inaccessibility of the terrain no specific intake sites were selected and detailed flow data are not available. Considering the small size of the villages in these areas and the small amounts which are required, even very small perennial streams or springs provide a sufficient basis for water supply purposes.

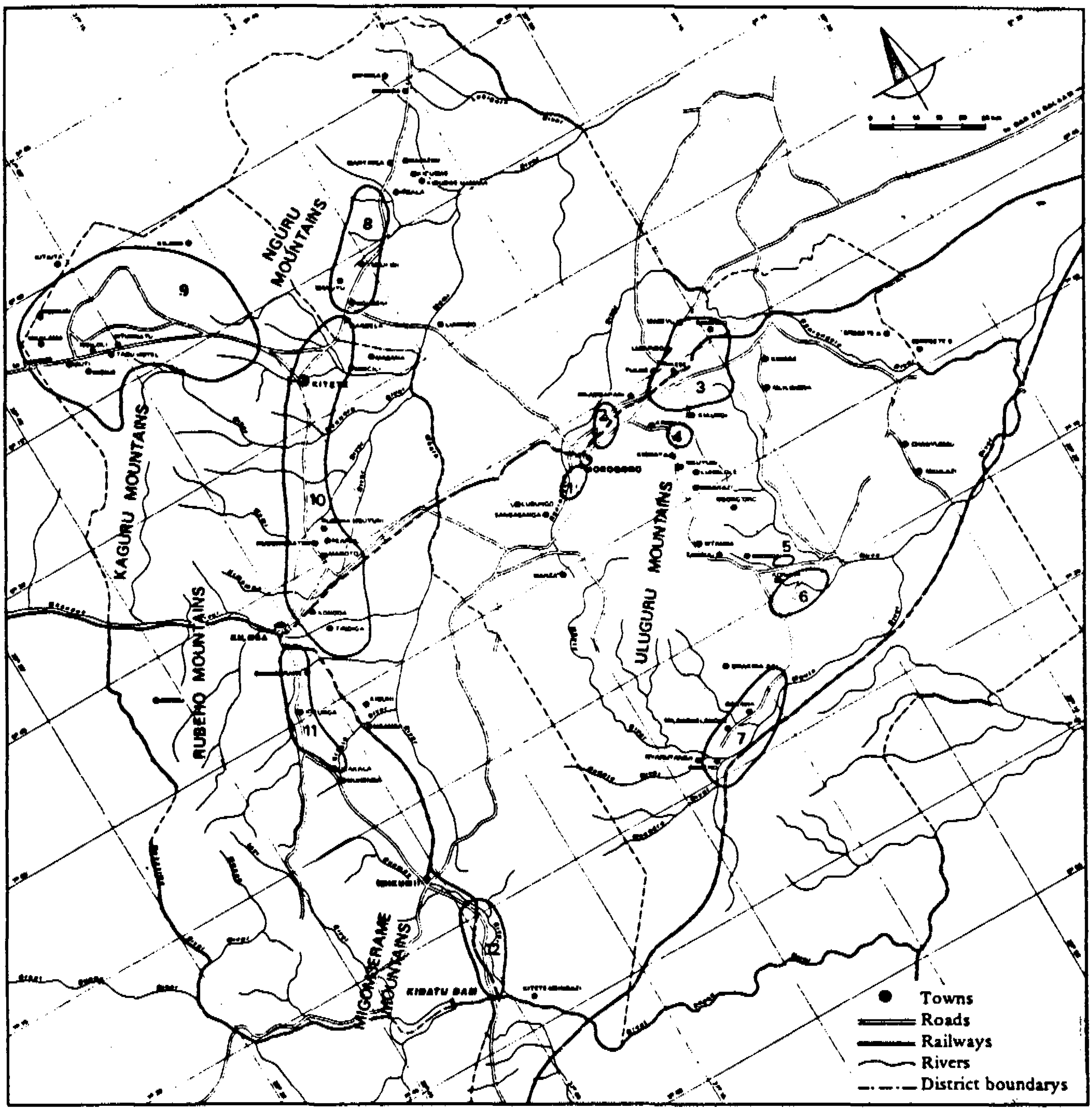

Figure 4.6-1 - Areas with possibilites for Gravity Water Supply

Table 4.6-2 - <u>Gravity water supply in areas along the escarpments and lower slopes of the different mountain ranges</u>

Table 4.6-2 - Gravity water supply in areas along the escarpments and lower slopes of the different mountain ranges

area		river	altitude supply area (m.a. MSL)*	altitude possible intake (m.a. MSL)*	level difference (m)	5% low flow (l/s)	10% low flow (l/s)	present use (l/s)	maximum extension of supply (l/s)
1	Uluguru Mountains	Ngerengere	520-550	600	50- 80	39	49	1,6	37
2	Uluguru Mountains	Mgolole	450-510	550-600	40-100	14	17	10	4
3	Uluguru Mountains	Mindu Reservoir	350-500			-	-	-	-
4	Uluguru Mountains	Kiroka	390-420	460	40- 70	4	6	-	-
5	Uluguru Mountains	Msonge Spring A	-	-	15	0,04	0,05	-	-
	Uluguru Mountains	Msonge Spring B	-	-	20	0,08	0,10	-	-
	Uluguru Mountains	Msonge river	-	-	15	10	15	-	-
6	Uluguru Mountains	Mngazi tributary	-	-	150	12	20	-	-
7	Uluguru Mountains	Mvuha tributary	-	-	150	300	350	-	-
8	Nguru Mountains	Mkindu	350-390	420-470	40-130	319	364	-	-
	Nguru Mountains	Divue	350-380	420-470	40-130	25	31	-	-
9	Kaguru Mountains	Upper Kitange	< 1325	1525	> 200	7	10	1	6
	Kaguru Mountains	Milindo tributaries				26	43	-	-
10	Rubeho Mountains	Kisungusi	430-450	600	150-170	167	191	-	-
11	Rubeho Mountains	Miyomobo (southern,	480-560	600	40-120	99	110	-	-
		middle and northern				12	14	-	-
		tributary)				506	564	-	-
12	Migomberame Mountains	Msowero	-	-	> 100	204	299	-	-
	Migomberame Mountains	Tundu	-	-	> 100	90	96	-	-
	Uluguru Mountains	Tambun Spring	-	-	20	1-2	2-4	-	-
	Uluguru Mountains	Mtamba Spring	-	-	15	1	1,5	0,25	0,75
	Uluguru Mountains	Mkuyuni Spring	-	-	40	0,75	1,25	-	-

* m.a. MSL = meters above mean sea level

For villages along the lower slopes and escarpments of the mountainous areas the topographical conditions are less favourable because longer intake mains are required to obtain sufficient level difference between intake and supply area. In these areas it pays to combine the water supply of several villages. In some cases pumped water supply systems may become economically competitive.

Areas which are from a hydrological and technical point of view attractive for gravity water supply systems are shown on Figure 1. Detailed information like altitude of the supply area and possible intake site, 5 and 10% low flows and possible, present use of the river water is given in Table 2.

The extraction of water from rivers will cause a decrease of the flow downstream of the intake point, which may be inconvenient for downstream users during periods with very low flows. Most of the rivers listed in Table 2 carry large amounts of water as compared with the amounts which are demanded for water supply. Downstream effects are negligible. In the case of the two small rivers Kiroka and Upper Kitange downstream effects do not play any role because these rivers usually run dry during the dry season before inhabited areas are reached.

Pumped water supply systems

Most of the villages in the Wami and Ruvu plains are situated too far from mountains to be supplied by gravity. Some of these villages are located close to the big perennial rivers and may be supplied with this river water using pumps and pressure lines. Suitable rivers are listed below.

Table 4.6-3 - Rivers suitable for water by means of pumps and pressure lines for villages in the Wami, Ruvu and Ruaha plains

Area	river	5% low flows (l/s)	10% low flows (l/s)
Ruvu plain	Ruvu	2000 - 2100	2100 - 2300
	Mgeta	450 - 530	500 - 575
	Mvuha	610	730
Wami plain	Diwale	250 - 270	320 - 340
	Mkindu	320	360
	Tami	80	120
	Kisangate	200	240
	Wami	1075 - 1550	1240 - 1930
	Mkondoa	450	500
	Myombo	500 - 620	600 - 690
Ruaha plain	Ruembe	50 - 340	75 - 400
	Great Ruaha	>1000	>1000

4.6.3. Small reservoirs

If no perennial surface water is available and use of ground water is not acceptable, small earth dam storage reservoirs, which are primarily suitable for cattle watering, may be considered as an alternative source for domestic water supply. Two such areas are identified in the project area:

- the Ngerengere valley downstream from Morogoro
- the upper part of the Berega catchment

In both areas the landscape is gently sloping. Rivers are emphemeral and carry significant amounts of water only during short periods of the rainy season. Mean annual runoff is less than 10% of the annual rainfall. The resulting runoff quantities are sufficient to fill up potential reservoirs which may meet the water demand and cover evaporation losses during the dry periods.

Also in the other areas with a runoff-rainfall-ratio of less than 10%, which show gently sloping areas and where no swampy areas or flat sand bodies are present, no difficulties exist from a hydrological point of view. In all other cases however, geotechnical aspects still have to be investigated before specific dam sites can be determined.

An explanation is given of the general approach used to estimate the annual sediment yield and the required catchment areas. For the Ngerengere valley and the Upper Berega catchment different results are obtained. In the Upper Berega catchment which is less covered with vegetation than the Ngerengere valley, much higher erosion rates are observed. In this area a larger volume for sediment accumulation should be allocated to obtain an acceptable lifetime of the reservoir.

4.6.4. Rainwater harvesting

Rainwater harvesting is rather unattractive, because large surface areas and big storage volumes are required. The rainfall in the project area is too low and too seasonal for this method to be worth using.

4.6.5. Influences of changes in land use on surface water potential

Land use has become one of the more important items in soil conservation policies and surface and ground water management in Tanzania, since large-scale deformation of mainly mountainous areas has led to disastrous erosion rates, high peak flows and low flow reduction in some parts of the country.
The problems are mainly related to the important role of vegetation cover in the hydrological cycle and soil conservation. A forest cover has the following properties:

- low peak flows

- large storage capacity of ground water
- slow depletion of ground water during the dry season

It may be obvious that domestic water supply systems such as gravity and pumped water supply systems based on low flows of perennial rivers from mountainous areas are strongly dependent on conservation of vegetation and soil cover of the catchment. If should be stressed that the present mountain forests, which are identified as main sources of water of sufficient quantity and quality during the dry season, should be protected against continuing destruction. Soil conservation is also important to reduce sediment accumulation in reservoirs.

4.7. Ground water potential

4.7.1. Renewable ground water

4.7.1.1. Mkata-Wami Basin

Seasonal waterlevel fluctuations measured in boreholes and shallow wells, which are in the order of 2 - 4 m, must be a result of recharge of the aquifers.
From waterlevels measured in boreholes at their time of construction (between 1938 and present), the phreatic surface of the ground water in medium-depth aquifers in parts of the basin could be determined; the hydraulic gradient is small; 2.5×10^{-4} - 4×10^{-4} and with moderate permeabilities the regional flow will be slow.
Ground water flows are in an eastern direction, towards the Mkata and Wami rivers.
Most recharge occurs in the western part of the basin, where sands are at the surface and where streams are influent.

In summary: hydrogeologically active flow systems exist in the Mkata-Wami Basin, with most movement occuring at shallow and medium depth, where recharge appears to be balanced by discharge.
The various shallow and medium-depth aquifers are interconnected locally.

The ground water potential in the Mkata-Wami Basin is equivalent to the recharge throughout the area.
Assuming that approximately 10 mm of the rainfall replenishes the aquifers, than 0.01 x 1.000.000 = 10.000 m^3/year per km^2 ground water is available for withdrawal.
This amount is equivalent to 27 m^3/day per km^2, which is sufficient for 675 people/km^2 per day if the daily demand is 40 l/c/d.

Withdrawals would change the present equilibrium and flow patterns, resulting in a decrease of natural discharge.
An increase in the amount of recharge may also be induced both directly from the infiltration of rainfall and from streams.

4.7.1.2. Alluvium

Although alluvial deposits (outside the Mkata-Wami Basin) make up less than 1% of the project area, thy are amongst the most important aquifers of the area because the ground water is renewable and permeabilities are moderate to high.
Waterlevel fluctuations have been observed in a number of wells, holes and piezometers in alluvial deposits throughout the project area.
Seasonal waterlevel fluctuations of about 0.5 - 2.0 m have been measured, clearly indicating actual recharge of the alluvial aquifers.
The ground water potential of the alluvium in the Berega area has been assessed during a special study (DA 5). The average ground water discharge through the riverbed aquifer is 4.500 m^3/day or 1.643 million m^3/year, which is equivalent to about 0.015% of the annual rainfall in the catchment area.
Assuming that the hydrogeological conditions in other alluvial areas are approximately similar to those in the Berega area, then the order of magnitude of the ground water potential in other alluvial areas can be estimated from the size of the catchment area and the annual rainfall.
Especially the ground water potential of riverbed aquifers in the western mountain ranges can thus be estimated.

4.7.1.3. Jurassic limestone zone

It has been demonstrated (DA 4) that probably considerable amounts of water infiltrate into the permeable limestone.
The discharge of the Ngerengere River, measured upstream from the limestone area is higher than the discharge downstream from the limestone area (see C 4.2.2., Volume III), which also points to recharge of the aquifer through the alluvial of the Negerengere River.
The volumes of ground water infiltrating into the limestones through the riverbed cannot be calculated because in between the two gauging stations, many small streams enter the Ngerengere River.
Recharge conditions in the limestone area are not known from observations of ground water levels.

4.7.1.4. Crystalline dolomite area

The many springs that occur in the area where crystalline limestone and dolomite crop out, point to the existence of active ground water flow systems, with ground water tables close to the surface.

The ground water is recharged by non-perennial streams descending from the Uluguru Mountains, west of the area.
The EC of the surface water is low; less than 10 mS/m. The EC of the ground water in the crystalline limestone and dolomite area is invariably between 45 and 50 mS/m. This is an indication that the average rate of flow through this karst area is not so high.

4.7.2. Non-renewable ground water

4.7.2.1. Mkata-Wami Basin

Geo-electrical soundings indicate the existence of sediments, 100 m up to 400 m thick, in the western parts of the basin.
Logs of boreholes drilled in these parts of the Mkata-Wami Basin indicate the presence of sand and gravel layers at depths between 50 and 200 m. Data on deeper aquifers are not available.
Sands make up from 10% to 25% of the sequences between 50 and 200 m depth.
Assuming an average aquifer thickness of 25 m, and a storage coefficient of 5×10^{-3}, the ground water potential would be $1000 \times 1000 \times 25 \times 5.10^{-3} = 125.000\ m^3/km^2$ of area, for the deep aquifers.
However, withdrawals of ground water from deep aquifers can largely be considered as mining operations because these aquifers most probably do not receive recharge. Although pumping from wells in deep aquifers might induce recharge of the aquifers, it is recommanded to install wells in medium-depth aquifers where possible.

4.7.2.2. Other areas

Data on ground water flow in the weathered parts of the basement, and in the Jurassic sandstones are not available.
The very low yields of boreholes in these rocks (< 1 l/s) point to very low permeabilities, and the high salinity of the ground water is an indication that the retention period of the ground water is very long. It thus may be concluded that ground water flow through these rocks is almost non-existent.
The only exeptions are faultzones, through which ground water might move at considerable flow rates as is demonstrated by relatively high yields of boreholes drilled in faultzones.

5. WATER SUPPLY DEVELOPMENT AND IMPLEMENTATION

5.1. Introduction

The Terms of Reference of the MDWSP study call for the definition of village water supply development programmes for those villages in the survey area which experience serious problems with their domestic water supply.
Such programmes should be based on detailed studies of existing water supplies, domestic water demand, and hydrological and hydrogeological conditions prevailing in the survey area.
The Consultant's recommendations should include a short term implementation programme for the problem villages which are identified aiming at providing these villages with water supply systems which comply with the Tanzanian Government's objectives as laid down in the 1981 and 1991 targets for rural water supply.
This chapter summarizes the water supply development studies. It contains a description of the current objectives and Government policy and the present design and construction practice for the rural water supply sector. Alternative construction methods for water works structures are described and cost estimates are given for various water works components and typical village water supply schemes.
The collection and processing of all relevant data has resulted in a detailed short term implementation programme and a phased, future, village water supply development programme with a view to the optimum realization of the national objectives.

5.2. Review of the current development in the rural water supply sector in Morogoro Region

The present study is part of the Government's efforts to speed up the development of the rural water supply sector in support of its villagization programme which was virtually completed in 1977. Tanzania has formulated its own national targets for domestic water supply to rural dwellers. These targets are comparable to, but more advanced than, the rural water supply targets which were formulated during the Habitat conference in Vancouver (1977).
The Tanzanian objectives for rural water supply development refer to the two targets years 1981 and 1991, and aim at the undermentioned provisions.

- A source of clean, potable and dependable water within a reasonable distance of every village by 1981 as a free basic service.
- A reliable water supply with clean potable water to the rural areas by 1991, so that all people will have ease of access (i.e. a distance of 400 m) to a public domestic water point. Preferably this supply should consist of a piped system with communal water points, but also shallow wells with hand pumps comply with the requirements.

Rural water supply development programmes are devided into national and regional components. Programmes are established for an annual or a five year planning period.

The Government has formulated the following general guidelines for the development of the rural water supply sector duting the Third Five Year Development Plan Period (1976 - 1981).

- Village water supply systems should consist of small, simple, cheap schemes.
- Various methods of water collection should be used, e.g. rain-water harvesting and charcos. Suitable water lifting devices are hand pumps and wind-mills.
- The development of water sources in the village should be such that by 1981 all villages are provided which at least one dependable water source.
- The village water supply programme is not primarily aiming at providing piped water. First of all, water should be made available at places where there is a shortage of water. Methods to be used are construction of shallow wells, and diversions from rivers and dams using a gravity transmission system.
- Water for live-stock and irrigation should be collected from rain-water reservoirs which are constructed using small dams. The villagers should be asssisted with technical expertise to carry out such programmes.

Budget allocations can be divided between development budgets and recurrent budgets for both the national and regional level. Development budgets are used to finance the implementation of new water supply programmes. The recurrent budgets cover the regular staff (managerial, technical, administrative) and labour force for the day to day running of the Maji Departments and include the costs of operation and maintenance of implemented programmes.

In Morogoro Region about 15% of the Government development budget for the third Five Year Plan period will be allocated to water supply. Rural water supply will obtain 9% and urban water supply 6%. The votes for annual development and recurrent expenditure for the budget year 1978/79 show that the total estimated budget for water supply amounts to Tshs 10,354,000 or 8% of the total development and recurrent budgets noted for Morogoro Region.
The allocation to rural water supply is 6% (Tshs 7,332,900), and that to urban water supply 2% (Tshs 3,021,500).

For the budget year 1978/79, the RWE's governmental budget for water supply development projects in Morogoro Region amounts to Tshs 4,190,000. The distribution is as follows: Tshs 1,350,000 for Morogoro District, Tshs 650,000 for Kilosa District, Tshs 1,100,000 for Kilombero District, Tshs 890,000 for Ulanga District, and Tshs 200,000 for surveys and investigations.

The 1978/79 annual development programme of the RWE's office for Morogoro and Kilosa districts included the construction of piped water supplies for six villages and shallow wells (for ten villages one shallow well each). So far, six shallow wells have been completed and two of the piped water supply projects are under construction. The other programmes have been cancelled or deferred due to lack of manpower and financial resources.
For similar reasons, about 50% of the designs which were prepared by the Project Preparation Division (Morogoro Region) during the last two years have not been proposed yet for implementation.

In 1972 the responsibilities of the Ministries were regionally decentralized and the district control of the majority of the rural and urban water supply programmes was handed over to the regional authorities.
From 1975 the Ministry of Water, Energy and Minerals has been the principal Government agency responsible for the domestic water supply sector. Annual development programmes are divided into national and regional components. Maji Headquarters plays a principal role in the planning of the national programme, but is not necessarily formally involved in the planning of regional programmes, which generate from the village level through the District and Regional Administrations and the Prime Minister's Office.
The highest officer for the Maji Department of the Ministry of Water, Energy and Minerals is the Principal Secretary who is directly responsible to the Minister for Water, Energy and Minerals. The Maji Department is divided into four divisions, and four units. The divisions are responsible to for activities closely related with water development, i.e. programme and man-power planning, construction, operation and maintenance etc. They are split up in a number of different sections. The units deal with administrative and financial matters.

At the regional level a similar organization structure is implemented. Some of the divisions, sections, or units mentioned above are combined in new groups, or are represented by the Regional Water Engineer (RWE). In 1978, the total number of employees in the Maji Department for Morogoro Region amounted to 435 persons. The functional managers are the RWE at the regional level, and four DWE's at the district level. The planning and project preparation division consists of 64 persons, the construction division of 67 persons, the regional maintenance unit of 126 persons, the finance and administration units together of 44 persons, and the urban water supply unit of 128 persons.

All construction works involved in domestic water supply systems are carried out under the responsibility of the Regional Water Engineer (RWE).
This functional manager has to report to the Principal Secretary on all matters and deals directly with regional and district officials on matters in their respective areas. The RWE's are not responsible for the construction works carried out by rotary drilling rigs and heavy dam construction units, which come under the direct supervision of Maji Haedquarters as part of the national development programme.

The Regional Water Engineers are technically responsible for the operation and maintenance of schemes completed by them. Recurrent funds for operation and maintenance are issued by the Ministry of Finance and Planning (Treasury) to the Regional and District Administrations (RDD's and DDD's) who act as the accounting officers. Funds are not allocated to the RWE but are advised of a vote number by the accounting officer who is responsible for the actual payment of expenses incurred by the RWE. One of the main constraints in the development of the rural water supply sector is the present level of Maji output. This output falls far short of that required to meet the official target of providing every village with an adequate water supply by 1981. The total implementation capacity of the present programme can just keep pace with the population increase, and in fact no significant improvements are being reached.

Another serious problem area is the operation and maintanence sector. A considerable number of supplies in the survey area are not operating at all or are subject to temporary interruptions because of the inadequate provision of manpower, or lack of operation and maintenance funds. Lack of spares and/or fuel are very often the cause of such interruptions.

Finally, it is obvious that the available development and recurrent budgets are far too small to cope with the financial resource requirements imposed by the 1981 and 1991 targets. Moreover, in Tanzania, domestic water supply is considered to be a basic commodity, which should be available free of charge for those who make use of communal facilities. Therefore, in general, no funds are generated at the village level to support operation and maintenance activities, although efforts are being made to stimulate villages to supply their own waterworks operators. It is estimated that the funds required to operate and maintain existing improved schemes in the survey area in a satisfactory manner amount to about Tshs 2,500,000 annually, which is about 30% more than the 1978/1979 allocation of some Tshs 1,900,000 for the Morogoro Region as a whole. Assuming that 65% of this budget is allocated to schemes in the survey area, the estimated budget requirements demand a 100% increase of the budget allocation to schemes in the survey area.

5.3. Design criteria and construction methods for village water supply systems

The design criteria normally applied by the Maji Department are contained in a Ministerial Note of 1975. Current construction methods are defined in standard construction drawings of various waterworks components as shallow wells, pumphouses, storage tanks, domestic water points and cattle troughs.

The Consultant has only suggested some slight alterations to the design criteria, as the majority of them are considered to be very suitable for the current conditions in village water supply.

The comments on some of the construction methods have been more elaborate.
It has been observed that the techniques applied by the construction division for the construction of shallow wells, deep boreholes and surface water intakes are below the appropriate standard, and obstruct a proper exploitation of water sources structures and water transport facilities.

The Consultant has comprehensively discussed these water works components and has suggested alternative construction techniques which are appropriate for the conditions prevailing in the survey areas. In addition, some simple water treatment systems werde discussed.

5.4. Cost estimates for village water supply systems

Cost estimates for capital investment of various waterworks components, such as water source structures, pumphouses and pumping equipment, transmission mains, storage tanks, distribution lines and domestic water points, have been discussed in detail.
All estimates given include the following cost components:

- material costs
- labour costs
- transport costs
- administrative overheads (1%)

Technical overhead costs for design and construction are not included in the estimates. The Maji Department has traditionally calculated with an overhead component of 20%. Recently many rural water supply projects were implemented with the assistance of bilateral or multilateral aid organizations and cost analyses of such projects indicate that the overhead costs incurred by expatriate assistance may add 50-20% to the direct construction costs. The WHO/World Bank study mentions an average overhead component of 60%. The Consultant suggests the application of this figure for general estimates of overall overhead costs.

The cost estimates are based on recent estimates by the technical staff of the Regional Maji Office in Morogoro Town, and estimates from local contractors and equipment supplies. In some cases, the cost estimates are the result of the Consultant's own judgement or recent experience, obtained from the construction of some waterworks as part of the MDWSP-programme (i.e. borehole programme). All cost estimates represent the 1978 price level.

The cost estimates have been used to derive cost functions for some typical village water supply schemes of various capacities and lay-outs of transmission and distribution systems.
Essentially, these typical designs only differ from each other for the type of water source (shallow well, riverside well, borehole or surface water intake), and transmission system (pumped or gravity diversion).

The typical designs are made for villages with a design population of 1000-10,000 people, and a length of the transmission main between 0.5-10 km. The cost functions are subject to the assumptions made for the topographical conditions of source and village area, the construction techniques and materials applied, and the services provided for.
A graphical presentation of the capital investment costs per capita versus systems considered is shown in Figure 5.4-1.

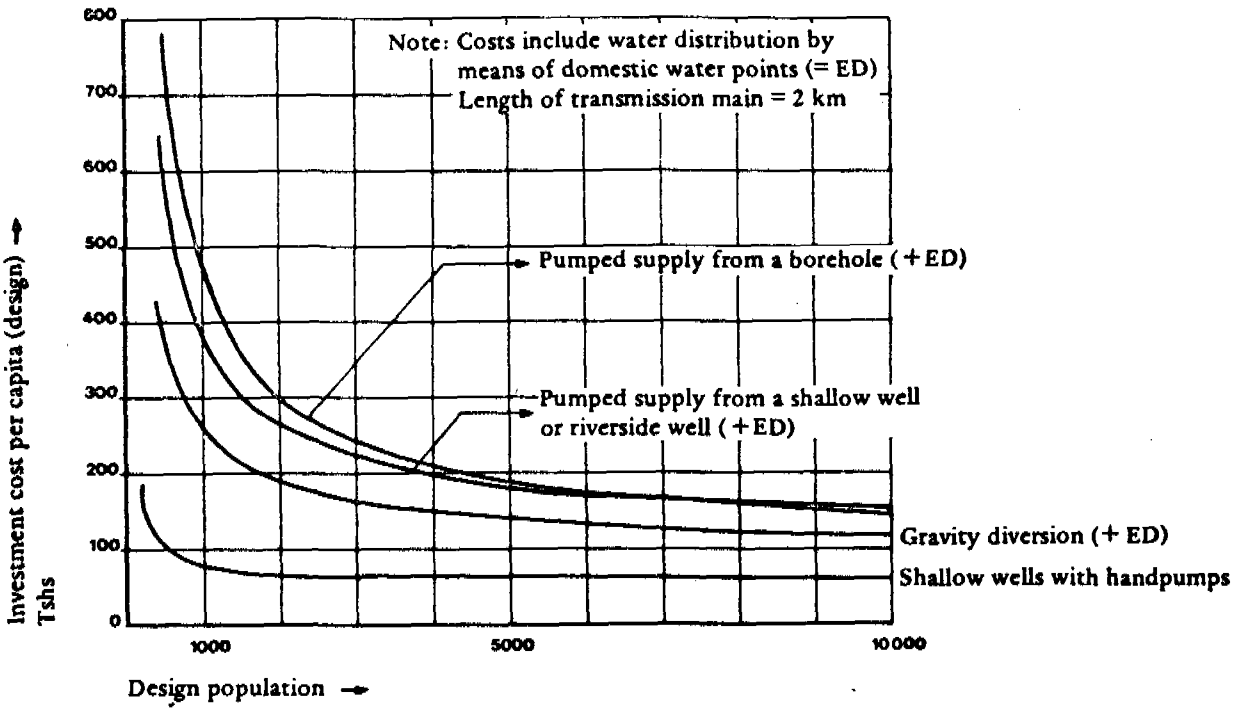

Figure 5.4-1 - Investment costs of village water supply systems

The economic choice between alternative systems for a projected village water supply schema should not be determined by the investment costs but by the annual costs, as these costs really reflect the total amount of yearly out-of-pocket payments which can be expected once a system is in operation.
In the comparison between gravity water supplies and pumped water supplies, it is of particular interest to evaluate the difference in transmission main length which can be allowed, for otherwise equal annual costs.

The following conclusions can be drawn from the comparison of annual per capita costs of those typical village water supplies which were used for the costing operations.

1. The annual costs for shallow wells with handpumps are lower than those for pumped supplies with only redumentary distribution facilities and any length of the transmission main, supposing both are for a design population of less than 7000 people. For a design population between 7000-10,000 people the annual costs of pumped supply systems with a length of transmission main between 0.1-1 km are comparable to those of shallow wells with handpumps.
   The annual costs for shallow wells with handpumps are considerably lower than those for pumped supplies with extensive distribution systems.
2. The annual costs of gravity diversions with rudimentary distribution facilities are lower than those for shallow wells, if the transmission main length does not exceed 4.6 km, and depending on the design population. Shallow wells will have lower annual costs than gravity diversions with extensive distribution facilities if the length of the transmission main exceeds 1 km.
3. Where annual costs are equal, a gravity supply system may have a transmission main some 3-7 km longer than the transmission main of a pumped supply from a borehole, shallow well or riverside well, for a design population varying between 1000-10,000 people and a transmission main length between 500-10,000 metres.
4. Where annual costs are equal, a pumped supply from a shallow well or riverside well may have a transmission main some 2 km longer than that of a borehole supply, for a design population varying between 1000-8500 people and a transmission main length (of that borehole supply) between 500-10,000 m. At higher design populations, the borehole supply will have lower annual costs for otherwise similar conditions.

5.5. Future village water supply development programmes

One of the essential issues in the design of future village water supply development programmes is the selection of a strategy regarding the staging of various planning phases.
Improved water supplies are normally constructed in one single phase for a design period of 20 years. In other words, schemes which are implemented have an over-capacity of about 100% and consume considerable amounts of capital and manpower which could have been allocated to other problem areas. The attainment of the Government's objectives puts a heavy burden on resources of money, manpower and administrative capacity which can be made available, and there should be no stone left unturned in the efforts to arrive at an optimum allocation of these resources.
The Consultant has opted for a division of future programmes into three more or less distinct phases of which phase one and part of phase two are applicable for the Consultant's assignment to design short term improvement programmes for problem villages.

Phase one: crash programme and source development

Emphasis is put on source development, i.e. the development of shallow wells, boreholes, pumped and gravity water supplies to such a degree that water is conveyed to a point at a reasonable distance from the village.
This phase includes for the piped systems a pumphouse, transmission main and storage tank for a design period of 20 years.
Distribution works, for a design period of 10 years are limited to an absolute minimum, e.g. a communal water distribution facility with a number of taps, located close to the storage tank.

Phase two: extension or scheme development

Emphasis is put on scheme development, i.e. up-grading of the basic facilities provided in phase one to a level which makes the waterworks comply with the long-term targets.
This phase will primarily involve the construction of more shallow wells with handpump, or, for piped water supplies, the development of distribution systems, so as to provide domestic water points within an average walking distance of 400 m (in accordance with the 1991 targets).
Alternative sources, such as boreholes, and piped water supply systems from nearby suitable river intakes, can be developed for larger villages and for a common water system to a group of villages (e.g. gravity schemes).

Phase three: water treatment

Once all villages are provided with a water supply system which has sufficiently high standards in quantity, accessibility and reliability, available resources can be allocated to essential water quality improvements.
Suitable water treatment techniques for rural water supplies include storage, plain sedimentation and chemical disinfection. More advanced treatment techniques are flocculation/coagulation and sand filtration.
Especially slow sand filtration is a very suitable technique, as it combines physical, chemical and bacteriological improvements of the raw water or pre-treated water.
Although it involves rather complicated purification mechanisms, slow sand filtration allows for relatively simple operation and maintenance operations at low recurrent costs, provided a suitable design has been made and no extensive pre-treatment is necessary.

Water supply development programmes should furthermore be based on the water resources potential, the water demand, and the present water supply conditions in each supply area.

Identification of suitable water sources for individual villages requires due attention to be given to small rivers, streams, springs and very small hydrogeological sub-areas. Such water sources may have no significance in a larger hydrological or hydrogeological context, and yet be essential to alleviate the present constraints to obtaining water for domestic consumption in villages.
The survey area's water potential for village water supply, as identified by the Consultant's hydrologists and hydrogeologists, is visualized in various maps. The shallow ground water potential is summarized in Map D 4, that of medium-depth and deep ground water in Map D 3 and the surface water potential is summarized in Map C 4.

The development of shallow ground water resources (down to a depth of 12 m) appears to offer an attractive method of catering for the domestic water requirements of villages in the survey area.
A comprehensive field survey, including numerous test drilling and pumping tests, was carried out by the Hydrogeological Section for the inventory of these shallow ground water resources.

The following areas have conditions suitable for shallow ground water development:

- villages along the Kinyolisi River and along part of the Berega River;
- villages along the Turiani-Kilosa-Mikumi Road;
- villages in the foothills of the E., S.E. and N.W. Ulugurus;
- villages along the Ngerengere River, downstream of Ngerengere Township.

Various other suitable sites are scattered over the whole survey area, at locations where sufficient desposits of alluvial material have created aquifer conditions suitable for ground water withdrawal.

The Consultant has also carried out a comprehensive survey for the inventory of the medium-depth and deep ground water resources. This survey included an extensive geo-electrical survey and an exploratory drilling programme in part of the Wami River Basin. Successful boreholes were completed in such a way as to make them suitable water sources for pumped water supplies. It appears that suitable locations for medium-depth and deep ground water exploitation may be found in the following areas:

- the major part of the Mkata-Wami Basin (medium-depth and deep ground water);
- the plain between the foothills of the Migomberame and Uluguru Mountains, or the area south of Mikumi and Mikumi Lodge (medium-depth and deep ground water);
- the foothills of the S.E. Uluguru (medium-depth ground water).

The survey area is fairly well endowed with perennial rivers and streams, which offer suitable possibilties for village water supply systems. The field survey and regular measurement programme of the Hydrological Section included numerous small rivers, streams and springs, which could be useful for village water supply.
It may be concluded that suitable sources for surface water supplies mostly occur in the areas mentioned below.

- The foothills of all mountains: Nguru, Kaguru, Migomberame and Uluguru Mountains. Numerous perennial streams and rivers emerge from these mountains.
- Mountainous areas where small tributaries of major rivers flow throughout the year, especially in the Nguru and Uluguru Mountains.
- Parts of the Wami and Ruvu plains were villages are located at reasonable distance from the rivers of the same name.

In conclusion, the MDWSP survey area is well endowed with both ground water and surface water resources. In general there are no serious technical constraints to the utilization of these resources for village water supply.
In various parts of the survey area several suitable and dependable water sources exist for the development of future village water supply systems.
In some villages up to four alternatives may be distinguished for future water supply systems: shallow wells with hand pumps, pumped supply from a shallow well or riverside well, pumped supply from a borehole, and supply by gravity diversion.
On the other hand, a number of villages are located in areas where water sources suitable and dependable for village water supply development are virtually absent. In areas with such limited resources a choice has to be made between alternative recommendations such as installation of a very expensive system, provision of a system which is not in accordance with the current policies in domestic water supply development or re-settlement of the village in a more suitable location.

The Consultant has made an inventory of possible village water supply development options for all villages in the survey area. Making a selection from those options for village water supply facilities which fit into both the short-term and medium/long-term water resources development programmes requires a decision operation which involves aspects such as:

- the requirements resulting from the Government's targets and policies;
- the economic feasibility of each of the various options;
- the economic feasibility of a sequence of certain options, when a phased development of the facilities is striven after.

Such a decision game is needed to prevent technical or financial conflicts of interest occurring between the short-term and long-term implementation programmes.

Taking all these aspects into account, the following strategy for the design of future village water supply development programmes is recommended.

1. Villages with suitable sites for shallow wells.

1a. Shallow wells are to be constructed in villages with a design population not exceeding 7000 people.

1b. Further investigations are required for villages with a design population above 7000 people.
Again shallow wells will be the appropriate solution, if:
   - no possibilities for gravity diversions exist;
   - the transmission main length is above 0.5-1 km for a gravity system; in each particular case the maximum permissible length of the transmission main should depend on the design population;
   - the population of a large village is so dispersed that the maximum walking distance criterion of the 1991 target (400 m) could only be achieved by a relatively expensive distribution system from a piped supply.

2. Villages without suitable sites for shallow wells.

2a. Depending on the design population, a gravity supply is to be selected if the location of the source requires a transmission main length which does not exceed the transmission main length of an alternative pumped water supply by more than 3-7 km.

2b. If a suitable water source for gravity water supply, in accordance with the conditions mentioned in 2a is not available, a selection is to be made between a pumped supply from a borehole and a riverside well (or shallow well at some distance from the village).
Pumped supply from a riverside well or shallow well is preferable for a design population not exceeding 8500 people, for equal lengths of the transmission mains.

3. Group supplies.
The guidelines given above are applicable to individual villages. The decision procedure for group supplies requires further investigation of the geographical and topographical lay-out of the cluster of villages under consideration. The main criterion will again be formed by the relation between total length of transmission main and total design population.
In each particular case expert judgement will be required to make the correct decisions.

The Consultant wishes to draw attention to the fact that the cost functions applied in the decision procedure described above are subject to certain conditions such as topography. It is obvious that if conditions deviate significantly from those adopted for the cost functions, a new appraisal of the alternative solutions will be required.

5.6. Proposed implementation programmes

The proposed implementation programmes are divided in two. a short-term and a long-term implementation programme.

5.6.1. Short-term implementation programme

It is recommended that the following projects be included in the short-term implementation programme (see also Table 5.6-1):

1. Water supply improvements for identified problem villages

   The villages where problems are experienced with the present village water supply were identified through the assessment of existing water supply conditions in all villages in the survey area (see Part B and par. 3.7 of this Volume).
   The group of villages which deserves first priority in the implementation of improved village water supply schemes consists of 82 villages which are summarized in Table B 5.6-2. For each of these villages short-term, improvement programmes have been recommended, based on the strategy as described in the previous paragraph together with data on the water resources potential (see Table E 4.1-2).
   It appears that the large majority of the problem villages can be provided with shallow wells with hand pumps. The second most important group is gravity diversion for the problem villages where shallow wells or other means of ground water exploitation are not possible.
   The proposed Gairo gravity scheme is by far the largest scheme of the proposed short-term implementation programme. It includes 15 problem villages and 10 other villages in the Gairo area.
   Pumped supplies from surface water sources are provided for a limited number of villages for which neither shallow nor deep wells nor gravity diversion are feasible solutions.
   Pumped supplies from a borehole will be offered to those problem villages where successful boreholes were constructed by Maji, or by MDWSP during the hydrgeological survey for the deep ground water resources.
   At present, some of these villages are also being provided with shallow wells within the framework of the MWCP project, since the completion of the boreholes may take another 2 years.
   The proposed improvement programme for problem villages is incorporated in Table 5.6-1.

2. Rehabilitation of various existing piped supplies

It has been observed that the majority of the existing piped surface water supplies suffers from serious drawbacks such as a poor water intake structure, a limited capacity or regular operation and maintenance problems. The performance of these piped supplies can be improved a great deal by some rehabilitation works, covering the water intake structure and an overhaul of the pumping equipment. The following existing piped supplies are recommended for the rehabilitation works: Turiani/Kilimanjaro, Lukenge, Mvumi, Msowero, Kivungu, Kilangali, Berega, Mlali/Kipera and Kiswira.
The programme should be supported by an appropriate training course (including on the job training) for pump attendants to make them more familiar with operation and maintenance, trouble-shooting and repair of pumping equipment.

Rehabilitation of existing supplies is also proposed for some villages which are provided with run-of-the river gravity diversions from the River Mgolole. It is recommended that the villages concerned, Kitungwa, Legezamwendo, and Kisinga be provided with a storage tank and communal water distribution facility so as to secure a more reliable water supply to these villages.

3. Additional projects

A substantial number of the problem villages are located in the Gairo division. In this area a large scale gravity diversion scheme from sources in the Mamiwa Forest Reserve has been proposed. It is recommended that 10 more villages, located in the same area and having moderate problems in the supply of domestic water, be included in the Gairo gravity scheme.

Other schemes which are recommended for incorporation in the short-term implementation programme, include:

- The completion of water works for 4 MDWSP boreholes which are located in villages not belonging to the group of most seriously hit villages (see under 1), but which regularly experience problems in their domestic water supply. These villages are Dakawa - Wami, Dibamba, Makuyu (Tur.), and Mbwade (Mas.).
- Gravity diversion schemes to Sangasanga and Konga/Vikenge in the Upper Ngerengere area, and Misongeni in the Mgolole area. The Maji Department has recently completed designs for these gravity diversions, and financial resources have been secured as well (UNICEF).

- Gravity diversion to five villages in the foothills of the Migomberame mountains. These villages, Msowero, Iwemba, Tundu, Kifinga en Ruaha at present use the traditional ways of obtaining water for domestic purposes. No suitable hydrogeological conditions exist for the construction of shallow wells, whereas the proposed gravity diversion from Tundu River can be constructed at relatively low costs due to the short length of the transmission main.
- Pumped water supply schemes to Kibati village and to Lukobe village. The Maji Department has recently completed designs for these projects, and financial support has been promised by international donor organizations.
- A shallow well construction programme for those other villages in the survey area, where shallow wells with hand pumps are considered to be a viable undertaking (see Map D 4). Some 98 villages are to be included in this programme, requiring about 726 shallow wells.
- Finally, the lower Ngerengere area between Kihonda and Ngerengere is considered to be an area where the suitability of shallow wells is doubtful. The construction of a gravity water supply scheme to 13 villages in this area from the future water works of the Mindu Dam site is recommended if further investigations indicate a low feasibility for shallow well construction. Once this gravity scheme is decided upon, it should become part of the programmes which require implementation immediately, as the villages concerned are problem villages.

The estimated investment for the construction of the various water works facilities included in the proposed short-term implementation programme amount to about 64 million Tshs at the price level of 1978. These estimates cover the net construction costs and do not include cost components such as survey and design, establishment of transport and workshop facilities and technical overheads.
The carrying out of the proposed programmes (excluding the possible lower Ngerengere gravity scheme) during the period 1979-1984 will require a total investment budget for the construction works amounting to about 107 million Tshs. This estimate assumes a constant annual expenditure rate during the six year construction period (based on the 1978 price level), and an annual price increase of 15%. The future annual O & M costs will be of the order of 3-5 million Tshs thus requiring a significant increase of the RWE's budget for O & M activities.
It is obvious that bilateral and multi-lateral aid organizations must be contacted and requested to offer assitance in the procurement of sufficient financial resources to carry out the proposed programmes.

The manpower requirements for the execution of the proposed programme during a period of some 6 years are estimated to be about 480 persons, including labour force and technical staff. The Maji Department will not be able to fulfil these high manpower requirements. Thus it is recommended that local contractors and appropriate local and expatriate sources of manpower be invited to assist in the carrying out of the works.
The implementation of the proposed short-term programme requires careful planning of the execution of the different activities involved in the various components of the programme.
These activities include:

- detailed hydrogeological surveys for the siting of suitable shallow well locations, taking into account also factors such as village lay-out and population distribution within the village;
- detailed hydrogeological surveys for the siting of suitable locations for the construction of intake wells along river beds as part of the proposed rehabilitation and pumped water supplies programme;
- detailed topographical surveys for the design of transmission mains, reservoirs and distribution works of various proposed piped water supply schemes;
- procurement of sufficient stocks of equipment and materials to secure an uninterrupted completion of the works;
- enrolment of appropriate manpower at various levels, and acquisition of sufficient financial resources for the implementation of the proposed programmes;
- provision of facilities for manpower development, training, transfer of technology and on-the-job training.

The Consultant is of the opinion that part of the survey activities, in particular for small separate schemes such as shallow wells and piped water supplies for individual villages, can best be carried out on a basis of day to day engineering. Such an approach requires the setting up of a sufficiently skilled and independent survey crew, but it will result in considerable savings in terms of time and costs. This survey group should be considered as a support group for the construction crew, and its work schedule should enable an uninterrupted implementation of the construction works.

The various parts of large schemes such as the proposed Gairo and Tundu gravity schemes are largely interdependent, and smooth running and operation of these schemes can only be secured if the systems are based on a detailed hydraulic design of all their components. Such schemes, therefore, require the full completion of survey and design activities before the procurement of equipment and materials, and the construction itself can start.
The survey team should produce all relevant design and construction drawings and specifications required for the completion of these gravity diversion schemes.

The recommended procedures for the execution of each of the programme components are discussed in brief below.

Shallow wells: The Morogoro Wells Construction Project

The proposed short-term implementation programme recommends the construction of 427 shallow wells in 56 problem villages, and 726 shallow wells for 98 other villages in the survey area, giving a total of 1153 shallow wells. A shallow well construction programme, the Morogoro Wells Construction Project (MWCP) was started in the survey area in September, 1978, as part of the Dutch bilateral aid programme.
The Terms of Reference of the MWCP call for the construction of 550 shallow wells in Morogoro Region in a period of two years. An essential aspect for the project is the training of siting and construction crews that can execute shallow wells programmes for Maji Departments in various regions in Tanzania.
It is recommended that the MWCP project, in its present structure, be extended by at least two years to assure the completion of the major part of the estimated 1540 shallow wells which will be required for the survey area (1153 wells) and other parts of the Morogoro Region (about 385 wells).
Moreover, the construction crews should be given sufficient opportunity for training and experience so that the shallow well programme can be successfully continued afterwards. See Figure 5.6-1.

Large gravity schemes: The Morogoro Gravity Plan

The proposed gravity schemes for the Gairo area and the villages in the foothills of the Migomberame Mountains (the Tundu gravity scheme) require various survey, design, costing and planning activities before their construction can be started. It is recommended that a special survey team for these two gravity projects be established, with the task of preparing detailed design and construction drawings complete with technical specifications, bills of quantities, cost estimates, and tender documents for those works which require the services of contractors.
Cost estimates for the construction of the designed schemes can be drawn up on the basis of unit costs of construction components on the one hand and bills of quantities on the other hand. These cost estimates are essential for the procurement of sufficient financial resources for the implementation of the proposed schemes.
It is estimated that this "Morogoro Gravity Plan" survey will require a period of about one year provided the services of 3-4 experienced surveyors and design engineers are available.
The proposed Gairo gravity scheme is to supply water to a number of seriously hit problem villages. It is therefore recommended that the implementation of the scheme should be proceeded with as soon as the survey has been completed and sufficient financial resources have been secured.
The manpower enrolment should be such that the construction works will not take more than 3 years, so that the delay in attaining the 1981 targets for the villages concerned is limited to a minimum.

The proposed Tundu gravity scheme covers 5 villages where at present slight to moderate problems are experienced in the domestic water supply conditions. Its inclusion in the Morogoro Gravity Plan is recommended because of the availability of the MGP survey team, whose manpower and equipment can be utilized to carry out the survey for the Tundu scheme at minimum costs.
The implementation of the scheme may be delayed by a few years, and it is recommended that construction works should be started at the completion of the proposed Gairo gravity scheme.

Borehole schemes and rehabilitation programme: The Morogoro Piped Water Supplies Project

The recommended short-term implementation programme includes construction works for a number of piped water supplies. For part of these schemes designs have already been completed by RWE's office, financial resources were obtained from the Ministry or other institutions, and construction is underway or will start shortly. These works will be carried out by the Construction Section of the RWE's office.
Another group of proposed schemes still requires survey and design work and procurement of financial resources for their construction. These schemes include:

- the completion of pumped supplies for 13 villages from 12 boreholes which were constructed by the Maji Department and the MDWSP survey team;
- the rehabilitation of intake structures of nine pumped, surface water supplies for 11 villages and an overhaul of their pumping equipment;
- the construction of some water works components (reservoirs and communal water distribution facilities) for existing gravity diversions from the River Mgolole, and the construction of a gravity diversion scheme for Msonge village.

The implementation of these schemes will require significant enrolment of manpower for survey, design, and construction works. It is considered that the relevant divisions of the RWE's office are insufficiently staffed to carry out the proposed programme in addition to their current activities.
Therefore, the setting up, in close co-operation with the Maji Department of a new temporary project organization, the "Morogoro Piped Water Supplies Project", similar to the Morogoro Wells Construction Project is recommended.
This organization should be made responsible for carrying out the works and training sufficient and appropriate manpower to operate and maintain the schemes once they are completed. Similar to the MWCP project, survey and design of the various relatively small and independent schemes should be carried out on a basis of day to day engineering, and close co-operation should be secured between the project preparation and construction teams.

The Morogoro Piped Water Supplies Project (MPWSP) will require a period of about two years to implement the proposed schemes, provided only rudimentary distribution facilities, i.e. a communal water distribution facility at the storage tank, are ensured to prevent any disruptions during the construction programme. The MPWSP should have a central yard with facilities similar to the MWCP, and consideration of close co-operation between the two projects is recommended.

Other piped schemes

The proposed short-term implementation programme contains seven more piped water supply schemes for seven separate problem villages. Three of these villages, Kihondo, Tungi and Mkonowamara, are located in the part of the Ngerengere Division where a large gravity diversion scheme may be required if shallow wells turn out to be unsuccessful.
It is recommended that the outcome of the pilot shallow well programme in this area should be awaited before taking further action on the implementation of separate schemes for these 3 villages.
Three other villages, Seregete A, Seregete B, and Kilama are located in areas with very unfavourable conditions for domestic water supply. These fairly small villages, therefore, require transmission of water over long distances, incurring high capital and recurrent costs. It is recommended that all parties concerned first consider the alternative of resettlement before further steps are taken to implement systems at high costs.
A similar procedure should be followed for Kitaita village, which is included in the proposed MGP survey. Its inclusion in the construction programme may, however, meet financial objections.
Finally, for Mbigili village, a pumped water supply from the River Mkundi has been suggested, but, as an intermediate solution, some shallow wells could be constructed on the banks of the River Mkundi. The MWCP will survey the feasibility of medium-depth wells within the village itself, and it is therefore suggested to opt for the given intermediate solution until the data from such detailed surveys are known.

The Lower Ngerengere gravity scheme has been suggested as an alternative water supply to 13 villages in Ngerengere Division if shallow wells do not prove able to provide a dependable water supply system. It is most likely that this information will be known by the end of 1979, and it is suggested that a decision is as to whether or not carry out a detailed survey for the gravity scheme during the 1980 season should be taken on the basis of these data.

5.6.2. Recent developments in the bilateral co-operation between the Governments of the Netherlands and Tanzania

In april, 1979, during the bilateral meetings between representatives of the Governments of Tanzania and the Netherlands, it was agreed that the Netherlands would provide financial and technical assistance for the execution of the recommended Morogoro Gravity Plan and the Morogoro Piped Water Supplies Project.
It was agreed that the financial resources required will be made available by the Government of the Netherlands as part of its bilateral aid programme for the year 1979, while DHV Consulting Engineers will be made responsible for the implementation of the projects.

In November, 1979, an agreement was reached and a contract was signed between the Ministry of Water, Energy and Minerals and DHV Consulting Engineers for carrying out the Morogoro Gravity Plan survey and for the implementation of the MPWSP.

The proposed short-term implementation programme is summarized in Table 5.6-1, which also indicates the present status of the various parts of this programme. A lay-out for a general bar-chart of activities for rural water supply development programmes, including the different components of the short-term implementation programme, is given in Figure 5.6-1.

5.6.3. Long-term village water supply development programmes

The Government's targets stipulate that by 1991 each villager should have access to a dependable source of clean water at a maximum distance of 400 m from the homestead. Since properly located shallow wells with hand pumps fulfil these requirements, the provision of villages with shallow wells, whenever suitable hydrogeological conditions occur, is recommended. All other villages which lack provisions complying with the 1991 targets, will have to be provided with a piped water supply, together with extensive distribution facilities.

It is recommended that the following programmes be proceeded with, once the short-term programme has been fully implemented.

1. Construction of additional shallow wells with hand pumps in those villages where this has proved to be a viable undertaking, thus making sure that the number of shallow wells in each village keeps pace with the increased population.

2. Where no suitable conditions for shallow wells exist, construction of piped water supplies with extensive distribution systems in those villages with only traditional water supply provision. First-of-all, villages with moderate problems in the supply of domestic water should be considered, and after that villages with only slight problems.

Table 5.6-1 - Summary of proposed short-term implementation programme

programme components	villages: nos.	villages: names	remarks			status of different programme components
1. Improvement programme for problem villages	82	see Table E 4.1-2	type of system	no. of systems	no. of villages	
			shallow wells with hand pumps	403*	50	MWCP (1978-1980)
			gravity diversion	2	16	MGP-survey (1979-1980) for Gairo area, and MPWSP for Msonge village
			pumped supply from shallow well or riverside well	7	7	postponement of implementation recommended
			pumped supply from borehole	9	9	MPWSP (1980-1982)
2. Rehabilitation programme						
- pumped supplies	11	Turiani/Kilimanjaro, Lukenge, Mvumi Msowero (Mas), Kivungu, Kilangali Berega, Mlali/Kipera, and Kiswira.	rehabilitation of intake structure and overhaul of pumping equipment			MPWSP (1980-1982)
- gravity diversions	3	Kitungwa, Legezamwendo, Kisinga	construction of storage tanks and some rudimentary distribution facilities (see Table EA 2-1)			MPWSP (1980-1982)
3. Additional programmes						
- gravity diversions	10	Ikwamba, Kisitwe, Kitange I, Kitange II, Kwipipa, Luhwaji, Majawanga, Msingise, Rubeho, Ukwamani.	Part of Gairo gravity scheme, see Table EA 2-1			MGP-survey (1979-1980)
	2	Konga/Vikenge, Sangasanga	Maji Project, see Tables E 3.1-4 and EA 2-1			construction underway
	1	Misongeni	Maji Project, see Tables E 3.1-4 and EA 2-1			construction underway
	5	Msowero, Iwemba, Tundu, Kifinga, Ruaha.	Tundu gravity supply scheme, see Table EA 2-1			MGP-survey (1979-1980)
- pumped supply from a borehole	4	Dakawa-Wami, Dibamba, Makuyu (Tur), Mbwade (Mas).	MDWSP boreholes constructed during hydrogeological survey, see Table EA 2-1			MPWSP (1980-1982)
- pumped supply from a riverside well	2	Lukobe, Kibati	Maji Projects, see Tables E 3.1-4 and EA 2-1			construction not yet started
- shallow wells	98	see Table EA 2-1	construction of 726 shallow wells			MWCP + extension (to be considered)
4. Lower Ngerengere gravity scheme	13**	Kihonda, Tungi, Mkambarani, Mkonowamara, Fulwe, Lubungo, Maseyu, Ngerengere Darajani, Mikese, Muhungamkola, Kinonko, Kiwege, Mlilingwa	this gravity scheme is proposed as an alternative to a shallow well construction programme, if practical experience shows that shallow wells do not offer a dependable solution			not yet under discussion see Remarks

* *Excluding 24 shallow wellsin those villages where borehole supplies will be installed in due course*

** These villages are included in the improvement programme for problem villages (see remark)

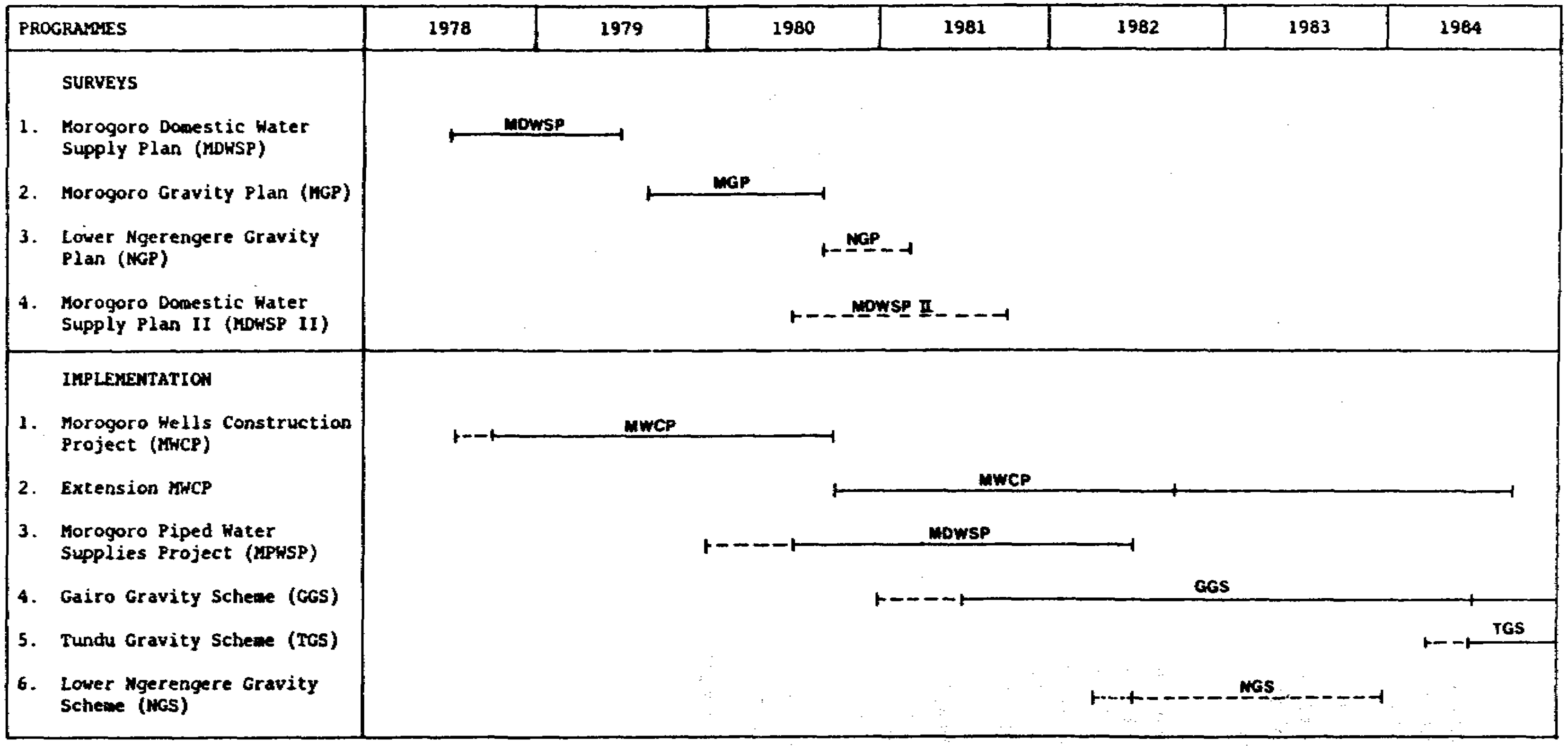

Figure 5.6-1 Proposed general bar-chart for rural water supply development programmes in Morogoro Region.

3. Construction of extensive distribution systems for those villages which were provided with piped water supplies during the short-term implementation programme.

4. Construction of small scale low-cost water supply systems for villages or clusters of households in mountainous areas using appropriate technologies such as (run-of-the-river) bamboo systems, simple ferrocement or wooden storage tanks, and concrete or wooden hydraulic rams.

It is estimated that the investment costs for these medium/long-term programmes amount to Tshs 128 million, assuming the 1978 price level and the 1998 population as design population. These programmes, however, are only to be carried out after completion of the short-term implementation programme, and it may be expected that considerable cost increase will occur due to price increases and population growth.

The total investment budget required is estimated to be Tshs 528 million at an overall yearly cost increase of 10%, and Tshs 1080 million at an overall yearly cost increase of 15%. This estimate assumes that carrying out of the programmes will start in 1985 and last a period of 15 years.

The manpower requirements for the completion of the proposed programmes during a period of 15 years are estimated at 200 craftsmen and 20 technicians, or about three times the present enrolments in the RWE's project preparation and construction divisions.