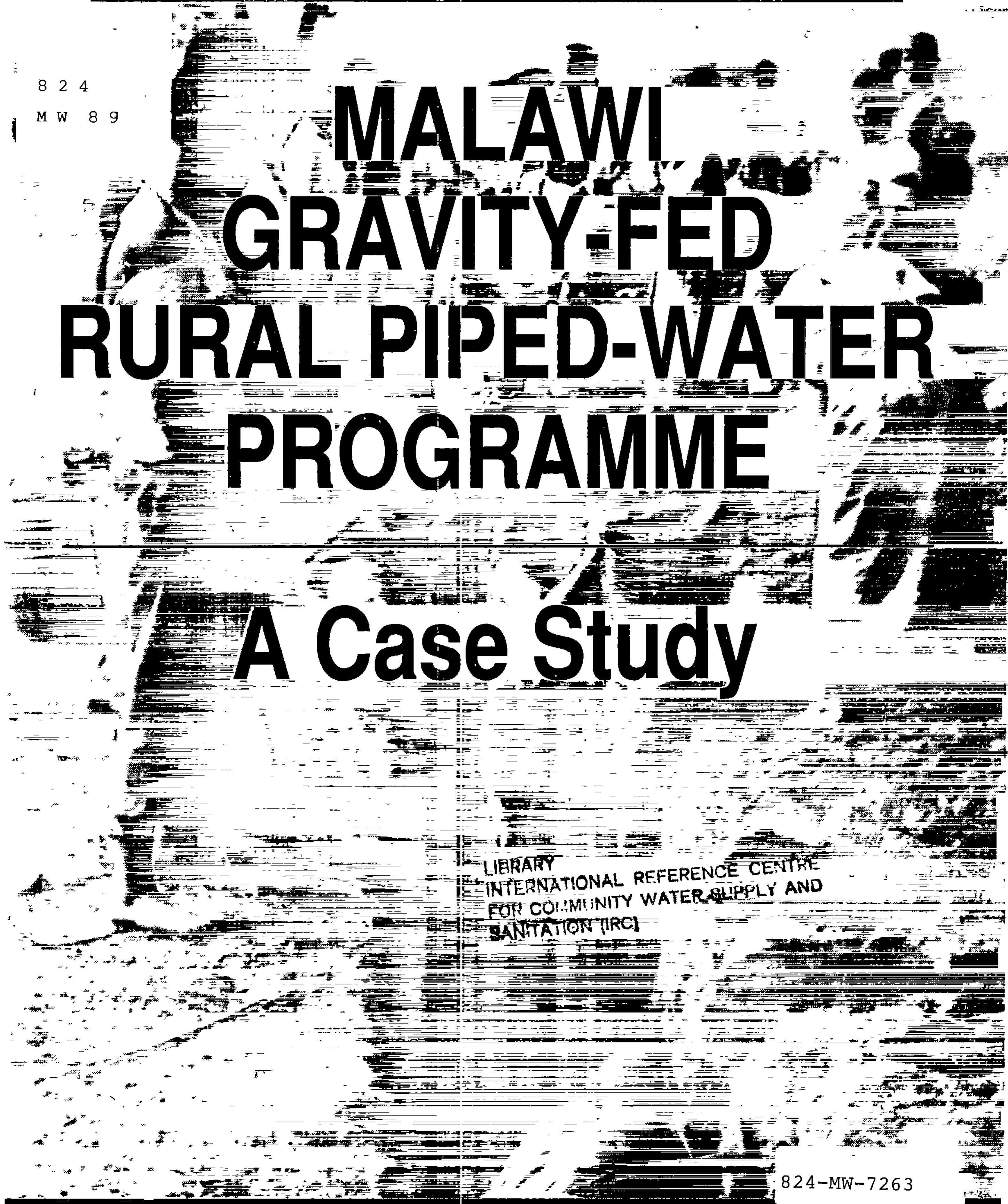
UNITED NATIONS CENTRE FOR HUMAN SETTLEMENTS (Habitat)

MALAWI GRAVITY-FED RURAL PIPED-WATER PROGRAMME

A Case Study



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Nairobi, 1989

Foreword

Approximately half the world's population does not have access to safe drinking water. This is particularly the case in rural settlements. Although most rural settlements have developed where water is available, many rural residents still have to travel long distances to a water source, usually of dubious quality. Even these sources of water often run dry during periods of dry weather, necessitating the abstraction of water further afield.

The problem of supplying water to rural settlements is complicated by many factors not least of which are the limited ability of users to pay for service, the dispersed nature of the settlements, the lack of awareness of the benefits of safe water, and the gross numbers lacking service. In the face of limited investment resources and equally limited revenue-generating prospects, innovations are required to install self-sustaining water-supply programmes. The dissemination of information on successful experience should aid in dealing with this problem.

The Malawi gravity-fed piped-water programme is an example of what can be achieved, despite constraints peculiar to rural settlements. The involvement of beneficiary communities at all stages of project implementation and the emphasis given to operation and maintenance are two exemplary features of the programme. The positive impact of the programme and its ability to be self-perpetuating should encourage governments and local administrations to address the problems of providing water to rural communities. I am confident that this publication will provide useful insights to policy-makers, engineers and other professionals who are actively engaged in extending water-supply services to rural communities.

I gratefully acknowledge the assistance of Dr. M.G. McGarry in the preparation of this report.

Dr. Arcot Ramachandran
Under-Secretary General
Executive Director

TABLE OF CONTENTS

Annexes

List of tables

Page

List of figures

Executive summary

The Malawi rural gravity-fed piped-water programme began in 1968 when the only protected rural water supplies were approximately 1,000 boreholes serving 6 perc ent of the population. The piped-water programme grew out of a request for water from a group of villages, encouraged through discussion with the Ministry of Community Development and Social Welfare. After the successful completion of the first scheme, an institutionalized programme was established. The capacity to execute projects was expanded, with each project relying on the previous to generate demand and train personnel.

By 1987 there were 47 completed gravity-fed piped-water schemes with nine under construction. They serve 1,010,000 rural inhabitants or 13 per cent of the population with a minimum of 27 litres per day per person of untreated water. By 1990, gravity- fed piped-water schemes are expected to serve 1.5 million people, representing 20 per cent of the population. In the long term, the number of people who can be served by piped-water schemes will depend on the development of appropriate water-treatment and dam technologies which increase the number of feasible sites.

A rural gravity-fed piped-water scheme consists of two main elements - the physical installation and the people supporting it. The physical installation is an intake, screening and sedimentation tanks and piping carrying the water by gravity down to the community. The main groups of people supporting the physical installation are the users, the Malawi Congress Party (MCP) and the Government. The users, who include every adult in the community, are organized into three levels of committees, elected by the users to represent and supervise them in planning, execution, operation and maintenance. Members of MCP participate fully in projects, as community members and in their official capacities as co-opted members of certain user-committees: the MCP organizational structure is made available to the project to assist in supervision and motivation. The Government's Ministry of Works and Supplies, Rural Water Section, provides the logistical support, materials and technical advice required by users to construct and maintain their scheme.

From the inception of the first project, a number of principles have served to guide the programme. These guiding principles are:

- The scheme belongs to the users;
- The users need to be involved to the maximum in every aspect of their scheme: planning, execution, operation and maintenance;
- The Malawi Congress Party needs to be involved as one of the driving forces in the community.
- The role of project staff is exclusively advisory (the responsibility for making programmes, assigning tasks and supervising labour belongs to local leaders);
- Procedures are standardized wherever possible, in order that the best of the cumulative experience is employed on current projects, and the supervision required reduced;
- Evaluation and continual improvement are needed to stay abreast of new situations and opportunities.

There are two elements of the Malawian context which have contributed significantly to the piped-water projects:

- The existence of numerous perennial streams the water of which can be used untreated and the location and discharge of which are such that water can be distributed to thousands of inhabitants merely by the force of gravity.
- The Malawi Congress Party is well organized and its authority respected right down to the village level.

All levels of staff have contributed substantially to the smooth operation and effective participation of users. Staff effectiveness and dedication are due to:

- A rigorous selection process which retains only people well adapted to the job;
- Intensive and practical training courses with annual refreshers;
- A policy of promoting from within the programme before recruiting from outside;
- Strong leadership;
- A challenging job with deadlines and obstacles plus sufficient support to achieve the goal of a completed project.

To satisfy user-needs in the long term, the physical installation of a scheme is designed in the following way:

- The physical installation is conceptually very simple;

- Scheme components are standardized wherever possible, to simplify training, supervision and stocking of spare parts;
- The scheme is easily installed using unskilled labour-intensive techniques and simple tools;
- The system is easily operated, even by young children;
- The scheme is easily maintained by users, involving a minimum of time and people;
- The scheme is easily repaired by users, with techniques employed during construction;
- Materials are selected for a scheme according to availability consonant with construction deadlines;
- Materials and equipment are easily transported on rough roads in four-wheel-drive vehicles (volume and weight are kept to a minimum);
- Cost of construction is reasonable enough to be acceptable to donors;
- Cost of operation is low enough to be supported by users;
- Cost of maintenance and repair is minimal, so that it can be supported by users and government without looking for donors;
- The system supplies enough water to meet user-needs;
- The system is reliable, i.e., frequency of breakdown and length of time before repair are acceptable to users.

Aspects of planning and execution which contribute to programme success are:

- Every project is initiated by the users;
- Before construction begins, users are well aware of what the physical installation is like and what their role will be;
- Scheduling of project activities is adjusted to the daily and annual work-patterns of the users;
- Details of planning, division of labour and supervision of labour are done by local leaders.

Most of the operation and maintenance is controlled by factors already discussed under guiding principles and technical design. Additional factors contributing to long-term maintenance are:

- Spares are available to users, both physically and financially;
- Maintenance staff, known to the community from the construction phase, is available for technical assistance;
- A monitoring programme keeps track of scheme condition, encourages users to continue maintenance activities and prevents some failures.

Although the Malawi rural piped-water programme has been and is a resounding success, there are a few aspects which need to be improved. The most serious is that the project has not been able uniformly to teach users the concepts of wear and preventive maintenance, with the result that a continuing staff presence is required in the form of a monitoring programme. Secondly, there are no women on staff, and women's participation in user committees decreases as the level of importance of the committee increases. Although women support water schemes fully and participate well in the areas where they are involved, their dedication and sense of responsibility could be improved by sending out female staff to give women particular attention. Spare parts are currently obtained from the surpluses of construction projects and commodity aid. They are distributed to users free of charge, with the exception of taps which are subsidized to two thirds of the cost. This cannot go on indefinitely, as construction is likely to slow considerably in the 1990s. There are currently nine engineering staff positions in the rural water programme, of which only two are filled by people working on the programme. The number of staff positions reflects accurately the amount of work there is to do. The two existing engineers have made exceptional efforts to keep the programme running smoothly since the departure of the principal water engineer one year ago. However, it is unreasonable to expect that their unaided performance can be sustained.

I. INTRODUCTION

This case study has been written to document how one rural water- supply programme, the Malawi Rural Gravity-fed Piped-water Supply Programme, has been able to supply at least 27 litres per capita per day 90 per cent of the time for 19 years. This remarkable record has earned it the reputation of being one of the most successful rural water-supply programmes in Africa. Its success, as with any water- supply programme, has been measured by the degree to which the water- delivery system is operational. In describing the various aspects and phases of the Programme, special attention is given to the factors contributing to the continued operation of the water-delivery system.

A. Malawian context

Malawi is a small landlocked country, surrounded by Zambia to the west, the United Republic of Tanzania to the east and Mozambique to the south (see location in figure 1). It has a total surface area of 118,482 km 2 degrees stretching over 855 km in length and an average of 145 km in width. More than one fifth of this area is occupied by Lake Malawi.

The country is divided into three geographic zones - the Rift Valley, the Plateau and the Highlands. The altitudes, climates and land uses of these three zones are quite distinct. The Rift Valley which is the southern end of the East African Rift, lies between 50 and 150 metres above sea level (masl). It is hot, 4 degrees C higher than the national average, and used for agriculture where the availability of water permits. The rift-valley walls generally rise in an escarpment to the surrounding plateau. The plateau zones lie between 900 and 1500 masl and are inhabited by the bulk of the population. The highland zones are a series of erosional remnants, rising abruptly over the surrounding plateau to heights of 2000-3000 masl; their climate is cool and wet. All of the highland areas are protected as national parks, forest or game reserves.

There is one rainy season, occurring between November and April. About 90 per cent of the country receives over 800 mm of rainfall annually, with the windward slopes of highland areas receiving 2000 mm annually; the national average is 1125 mm. The rest of the year is effectively without rain. Temperatures are at a peak just before the rains break in October/November and are at a minimum in June and July.

Hydrologically, Malawi forms one unit, with all waters, including Lake Malawi, draining into the Shire River. The Shire flows into Mozambique to the Zambezi River and, finally, out to the Indian Ocean. Perennial rivers originate in the highlands and are augmented seasonally by flow from the dambos of the plateau areas. Dambos are broad treeless valleys lined with alluvial clays and sands. The clays store water throughout the year but become supersaturated during the rains, causing overland flow to the rivers.

Malawi has an abundance of water resources relative to demand. The total available surfacewater plus groundwater resources are estimated at 54.5 million cu m/day (Ministry of Works and Supplies (MOWS) and UNDP, 1986). The estimated daily requirement for 1985 was 140,000 cu m/day, and, even in 2000, the requirement is estimated at only 730,000 cu m/day.

Land use reflects both the geographic features of the country and the interests of the Malawian people and Government. Table 1 presents the main uses of land.

Table 1. Land use
(after MOWS and UNDP, 1986)
(Percentage)

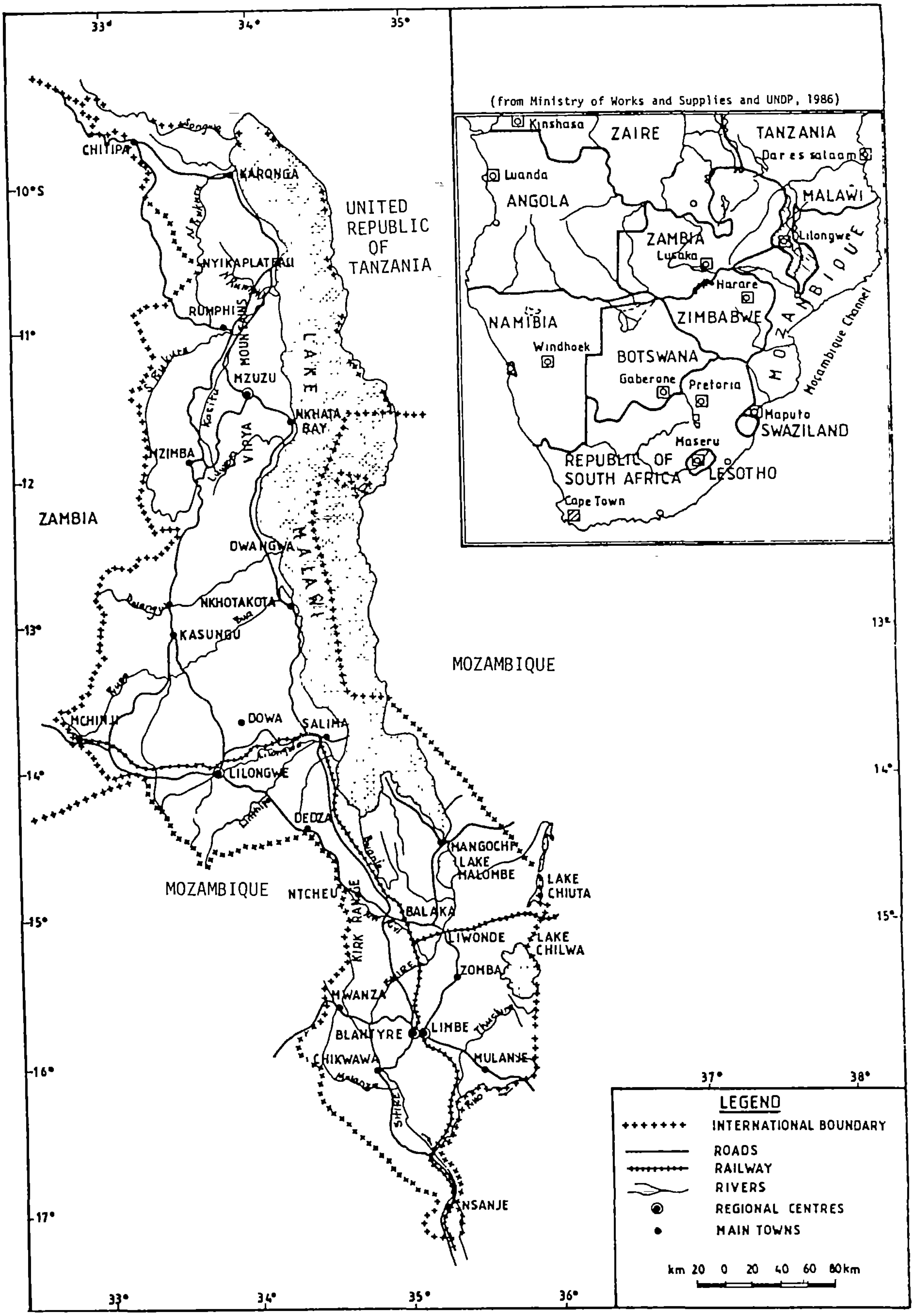
Vacant land	26.2
Steep slopes (12%)	25.1
Agricultural activities	21.3
National parks, forests, game reserves	19.3
Swamps, flood plains	6.6
Human settlements, infrastructure	1.5
Total	100

The high percentage of steep slopes provides many potential sites for distributing water by gravity, while the high percentage of national parks, forests and game reserves provides intake sites where the water does not require treatment.

The 1977 census of Malawi showed a population of 5.5 million people, with an average annual population growth of 2.9 per cent: assuming this growth rate has remained constant, the 1987 population is roughly 7.5 million. Rural dwellers make up 90 per cent of the total population (6.7 million people): this proportion of the population is not expected to change over the foreseeable future. (Mainala, 1986) Malawi is one of the world's poorest nations with a per capita GNP of $US230 in 1980 and average life expectancy at birth is 44 years (1980). About 95 per cent of rural dwellers are involved in farming (80 per cent in subsistence farming of maize, groundnuts and cassava, and 20 per cent in estate farming to produce the export crops of tobacco, tea and sugar).

Most rural inhabitants live in houses constructed of compacted earth bricks or mud packed

Figure 1. Malawi



into a bamboo/wooden-pole lattice. The roofs are of grass thatch over a bamboo/wooden-pole frame. Floors are of compacted earth, and windows are shuttered. The common house improvements - fired-brick walls, galvanized-iron roofs, concrete floors and glass windows - are still relatively rare. Easton's survey of the Champira North rural piped-water project area (Easton, 1985) indicated that only 12 per cent of houses had one of these improvements, and 7 per cent had two or more. Other sources indicate that 55 per cent of houses have latrines and that 67 per cent give a "general impression of being clean and neat." (Warner and others, 1986) About 46 per cent of the rural population in 1985 had access to an improved water source: either boreholes, protected dug wells or piped-water taps. (MOWS and UNDP, 1986)

In the absence of mineral and forest resources, the Government has recognized that the economic potential of Malawi lies uniquely in agricultural production. National policy has favoured rural development, through economic incentives, technical-extension services, community self-help construction activities and functional national infrastructure. The Government has conserved the authority of the traditional chiefs (TAs) and has built a parallel complementary structure (The Malawi Congress Party), to deal with matters of political interest. The result has been the creation of a stable rural environment, conducive to developmental activities.

B. Rural water supply

The first effort to supply the rural inhabitants of Malawi with improved waterpoints was the sporadic drilling of boreholes by the Geological Survey in the 1930s. Boreholes were drilled consistently between 1947 and 1969, when approximately 100 boreholes per year were drilled. In 1968, when the first rural gravity-fed piped-water scheme was built, there were roughly 1,000 boreholes serving only 6 per cent of the population. Since the 1970s, drilling has been steadily increased to 400-500 boreholes per year, and there are currently 7,000 boreholes. The average cost of installation is currently $US17 per capita, and the average annual maintenance cost $US0.60 (after Mainala, 1986) The Ministry of Community Development and Social Welfare also began digging shallow wells and protecting them with locally manufactured hand pumps in the 1970s, in response to the expressed needs of the communities. There are currently 3,800 shallow wells.

The Ministry of Community Development and Social Welfare began the rural gravity-fed piped-water programme in 1968. There are currently 47 completed projects, with 6,685 taps installed. The average per capita construction and maintenance costs are $US13 and $US0.15, respectively. (Warner and others, 1986) The list of completed and current projects is in annex I and II. Locations of projects are in figure 2.

The Government of Malawi has taken two actions in response to the United Nations International Drinking Water Supply and Sanitation Decade. The first was to unite all the sectors of the Government dealing with water, i.e., gravity-fed piped-water schemes, dug wells, boreholes, urban water supply, hydrology and irrigation, into one department. This facilitated the co-ordination of the water-supply sector and made resource-evaluation capacity accessible to the water- supply sector. The other was to commission and execute the National Water Resources Master Plan. The Plan, published in 1986, evaluates the national surfacewater and groundwater resources, the projected water needs and the projected service levels up to the year 2000. Table 2 shows recent and projected rural water-supply service levels.

Table 2. Rural water-supply service levels (Mainala, 1986)

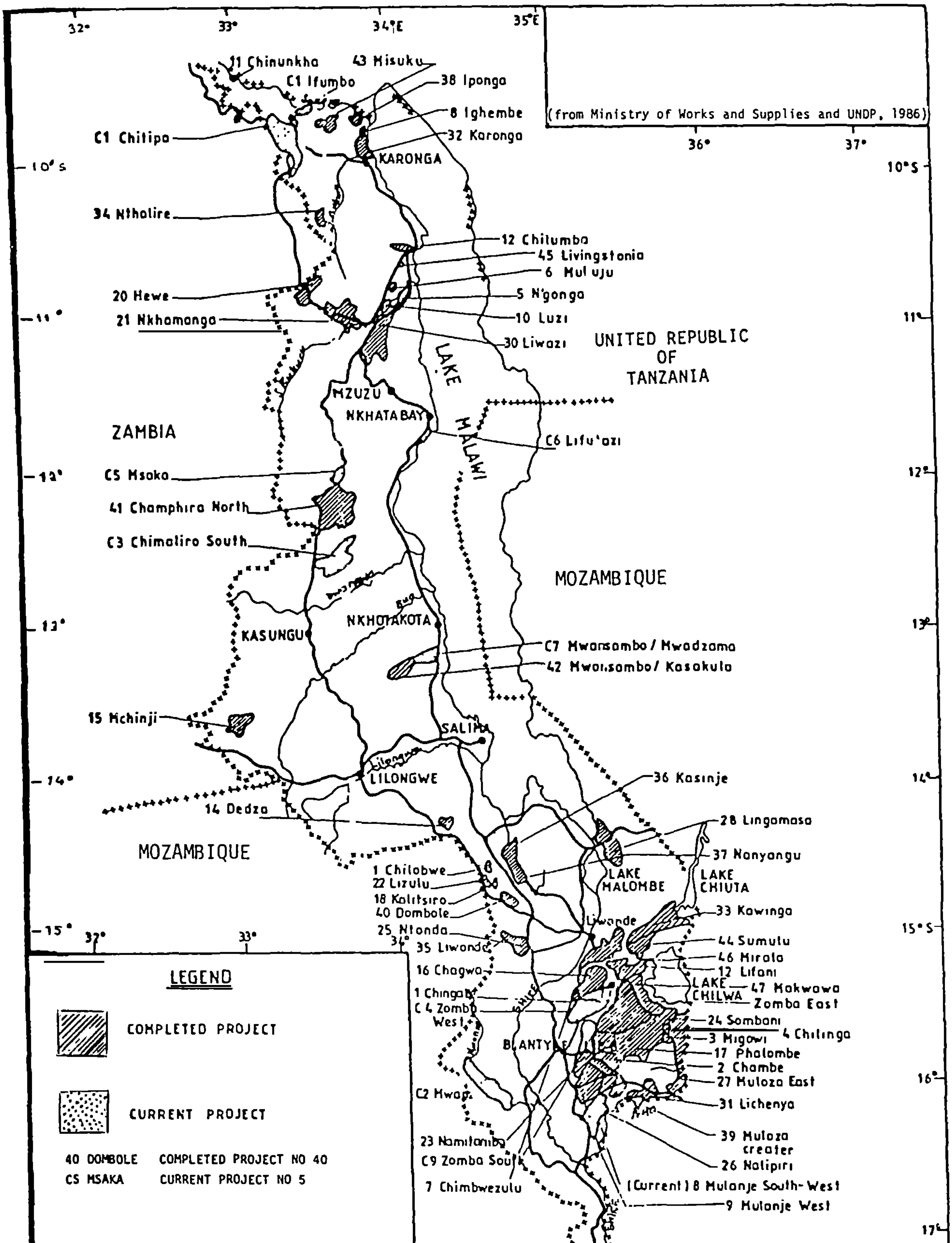
	Approximate waterpoints	population served (millions)	Percentage rural population served
Year 1985 (actual)			
Boreholes[a]	5,900	1.475	23.08
Protected dug wells[b]	3,000	0.375	5.87
Piped-water taps[c]	6,677	1.068	16.72
Year 1990 (projected)			
Boreholes[a]	8,400	2.100	28.11
Protected dug wells[b]	4,500	0.563	7.54
Piped-water taps[c]	9,350	1.496	20.00
Year 2000 (projected)			
Boreholes[a]	13,400	3.350	32.09
Protected dug wells[b]	7,500	0.938	8.99
Piped-water taps[c]	10,500	1.680	16.09

a/ Boreholes
- excludes motorized boreholes
- one borehole is to serve 250 people
- assumes an average annual production of 500 boreholes

b/ Protected dug wells
- one protected dug well serves 125 people
- assumes an average annual production of 300 dug wells

c/ Piped-water taps
- one tap serves 160 people
- assumes construction of all feasible gravity-fed piped- water schemes

Figure 2. Malawi - rural piped-water projects



The number of people who ultimately can be served by piped-water schemes will be determined by the extent to which the new technologies of water treatment and river damming prove themselves to be operable and maintainable. The more operable and maintainable they are, the more sites will be considered suitable for new schemes.

C. History of the Gravity-fed Piped-water Programme in Malawi

The Ministry of Community Development and Social Welfare (MCDSW) started an integrated rural-development project in 16 villages of the Chingale area in 1968. The Ministry planned to initiate classical activities of promoting adult literacy, income generation for women, and self-help construction of primary schools and health posts. The 16 villages were asked to form a committee capable of representing their area. MCDSW staff then met with the committee in order to identify what the community felt were its needs and to discuss what could be done to meet those needs. A recently recruited engineer was part of the MCDSW staff working with the Chingale community. He had already lived in rural Malawi for almost 10 years as a missionary before joining the Government and so had a good understanding of local community organization and co-operation. He had previously installed a small gravity-fed piped-water scheme for a mission station in the Mulange area and was confident of the potential for using the perennial freshwater streams flowing off the highland areas to serve the populous and seasonally-dry plateau below.

When the committee from Chingale identified lack of water as its main problem, the engineer asked to be taken to the nearest perennial stream. He identified a potential intake site and marked a possible pipeline down to the village with the help of the committee. It took persistence on the part of the engineer to convince the committee that water could flow the entire distance from intake to tap including the uphill sections. Again, it was the engineer who was able to convince a donor that the scheme was feasible. He came back to the committee to make a formal proposition: the Government would provide pipes, materials and technical supervision, if the villagers would dig the trenches and provide all labour. The committee agreed, and the project was completed under the close supervision of the engineer and several community-development assistants. The project was a success: water flowed through 25 km of pipeline to 25 taps serving 3,000 people.

Encouraged by the results of the first scheme, MCDSW decided to repeat the experience the following year but, this time, on a large scale. The Chambe area of Mulanje District was already active in an MCDSW adult-literacy programme and in self-help construction of primary schools. Although the Chambe area lies adjacent to the third highest mountain in Africa, Mulanje Mountain, from which numerous perennial streams flow, the plains below are dry. Leaders from Chambe were taken to Chingale to see the finished product and to speak with the people of Chingale, to find out how much work was involved and whether they considered it worthwhile. After leaving enough time for word to spread and demand to build up, the Chief (TA) called a public meeting at which MCDSW offered the same arrangement whereby the Government would provide supervision if the people would provide labour. By the following year, the project was completed: 30,000 people were being served by 97 km of pipeline and 180 taps.

At this point, MCDSW decided that gravity-fed piped-water schemes were both viable and desirable. The Water Project Section (WPS) was created, in order to provide a national structure for an ongoing programme of rural piped-water projects. The engineer who had begun the projects became Senior Water Engineer and he was assigned three community-development assistants who had proved themselves on the previous projects. WPS planned a consolidation phase of two projects, Mulanje West for 75,000 people and Phalombe for 90,000 people, both around Mulanje Mountain. These were used to train staff and form them into a team, to develop standardized procedures and techniques for all field activities and to improve the technical standards of design and construction.

From the successful completion of the consolidation phase which had built up the capacity of WPS to execute projects, a full programme was elaborated. The full programme involved continuous expansion, hiring and training of new staff and upgrading of old staff. The rate of expansion was carefully limited to the rate at which sufficient experienced staff could be created. In order to generate grass roots demand for subsequent projects in areas where gravity-fed schemes were feasible, six small demonstration projects dispersed throughout the country were initiated.

WPS limited itself to sites where streams were of sufficient discharge to serve the target population and the water was of high enough quality to be distributed without treatment. However, by the mid-1980s, most of these sites had been used requiring current and future schemes to treat water and/or dam the stream.

From the point of view of intervention by the government, the WPS installations were initially believed to be maintenance-free. All that was anticipated was the regular cleaning of tanks and intake plus tap and washer replacement by users. However, pipe breakages and intake washouts became regular occurrences, and WPS felt the need to develop a maintenance programme, providing technical training for selected users, spare parts, and support staff. Later, it was found that the gradual deterioration of the whole system, due to erosion and wear, was not being addressed by the repair-oriented maintenance programme. For this reason, plus the need to evaluate system performance, a monitoring programme was developed, to inspect all system components twice annually.

There are several things to be highlighted in this history of the gravity-fed piped-water programme. First and most important, the programme began as a response to an expressed need; the users set the ball rolling. It was only secondarily that donors were brought in and an institution built to service the need. The principle of users initiating projects has been followed in all subsequent projects, with requests coming from the villagers or, in new areas, villagers' interest being stimulated through demonstration projects. Secondly, the programme began as one very small project, designed for a specific population. It was only after the feasibility of the new technology had been proved and the problems worked out on a small scale that the idea was generalized into a programme. Thirdly, the rate of growth was controlled, with new projects being taken on only when there was sufficient experienced field and supervisory personnel. Fourthly, the abilities of the initiating engineer were exceptional. He was able to visualize potential for potable water supply on the plateau from the perennial highland streams, he foresaw the maintenance and cost benefits of community participation, he was technically competent in designing and supervising the construction of a system that worked with a minimum of operation and maintenance, he was able to build the staff into a dedicated team and he was sufficiently skilled in the boardroom to create the necessary institutional and financial support. Fifthly, although the schemes are very simple, they still require some governmental support to ensure effective maintenance.

The Malawi rural piped-water schemes have been implemented through three main bodies:

a) Users;

b) Malawi Congress Party (MCP);

c) Government of Malawi (GOM).

These three bodies have a complex web of relationships which the rural piped-water schemes use and strengthen to the advantage of all concerned.

A. Users

The users of the entire gravity-fed piped-water programme are 1,010,000 rural inhabitants living in the ways of their traditional society. These people are grouped by village under the authority of a headman who, with other headmen, is under the traditional authority (TA) of the Area Chief. The TA is responsible for judging all non-criminal disputes, for the allocation of land and, generally, for looking out for the development of his area.

B. Malawi Congress Party

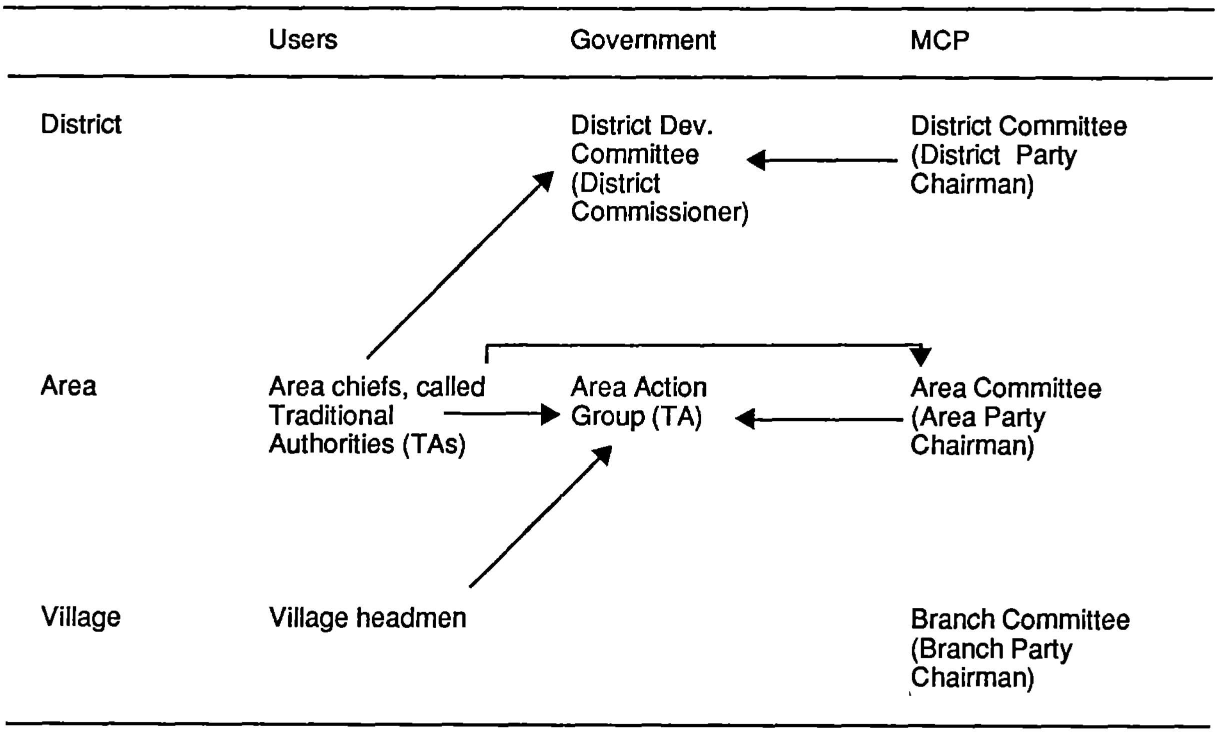
MCP is a strong and unified organization, stretching from seats in Parliament to the villages through five levels of committees - national, regional, district, area and branch. MCP has two sub-units to deal with the mobilization and concerns of their particular membership - the Malawi Women's League and the Malawi Youth League. These have independent structures but send representatives to their equivalent MCP committee meetings. TAs are linked to MCP at the area-committee level as co-opted members.

C. Government of Malawi

1. *District Development Committee*

Malawi is divided into 24 administrative districts, each encompassing three to six TAs. The district's head is the District Commissioner who serves as the Chairman of the District

Figure 3. Institutional structure of rural Malawi



Committee chairpersons in parentheses.
Arrows indicate membership

Figure 4 Users at work

Development Committee which meets annually to programme, co-ordinate and follow-up development activities within the district. All of the TAs and representatives of the MCP have seats on this committee, with the result that project users, MCP and Government have a history of working together on development projects. This committee refers much of its supervisory and follow up work to subcommittees, called Area Action Groups, under the leadership of each TA. MCP holds at least one seat on each Area Action Group, so that all three bodies are working together at this level also.

2. *Ministry of Works and Supplies*

The team of professionals and technicians who have been responsible for the development and implementation of the rural piped-water schemes started out as a handful of people within MCDSW. In 1979, the team was regrouped, with all other water- related services, under the Office of the President and Cabinet's Department of Lands, Valuation and Water. Then, in 1984, the water-related services became the Water Department attached to MOWS. The institutional structure of the Water Department is shown in figure 5. The Rural Water Supply Section is responsible for the gravity-fed piped-water programme: figure 6 details the structure of the Section.

The origins of the Section, within MCDSW, have given it a bias towards the community, which is the Programme's strength. When the Section moved to MOWS, its technical ability was reinforced, without jeopardizing the community foundation. Thus, the Programme has profited from its institutional framework.

The Principal Water Engineer (Rural) is responsible for the long term planning and administration of the Programme. He is, also, involved in on-the-job training of new engineers and in supervision of most construction engineers. The Senior Water Engineer (Rural) is responsible for a limited number of engineers constructing schemes, the entire maintenance programme, research and evaluation. The engineers carry out feasibility studies, preliminary designs, ordering of materials and supervision of construction for one or more projects.

Figure 5. Organizational chart of the Water Department,
Ministry of Works and Supplies

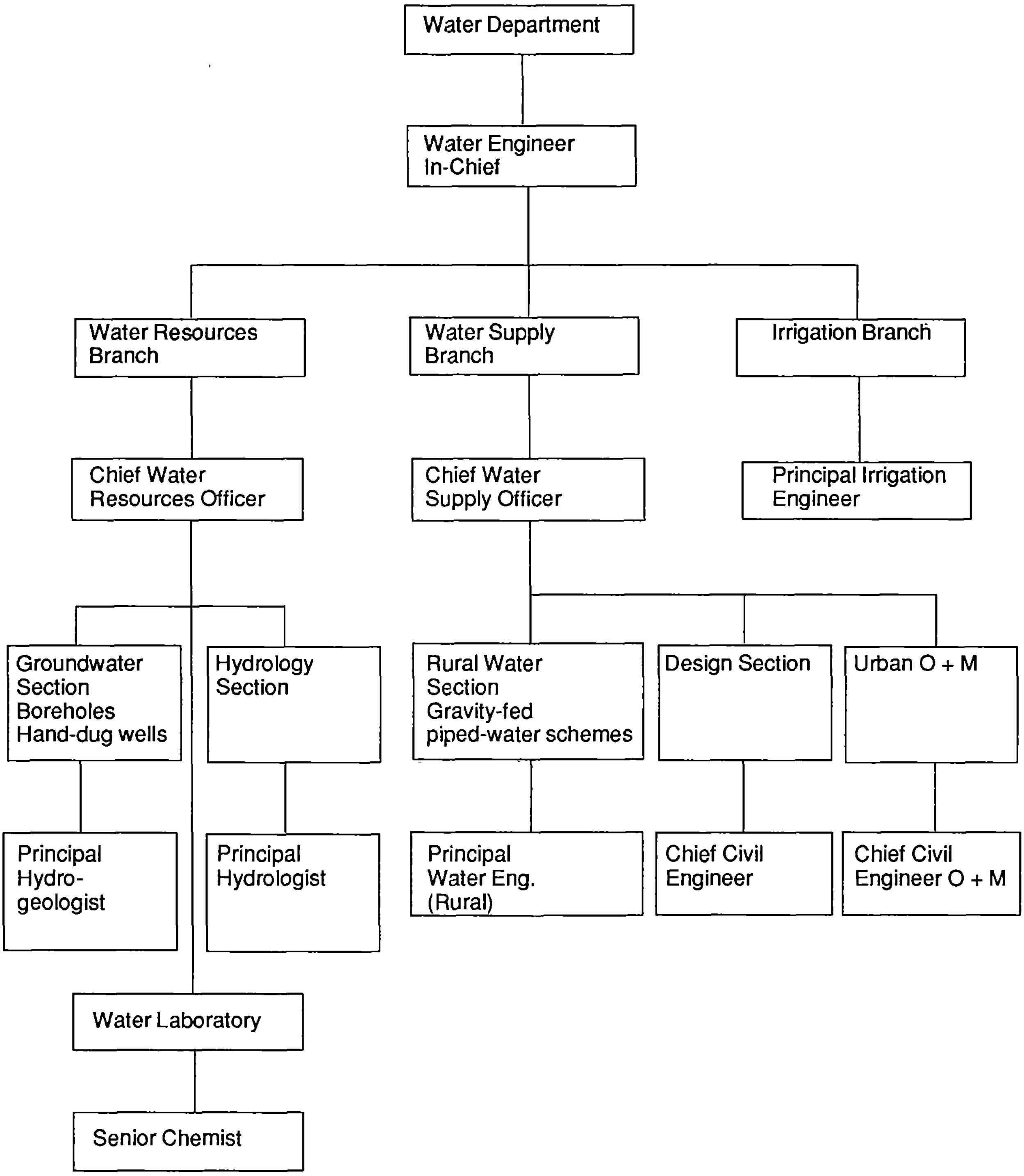
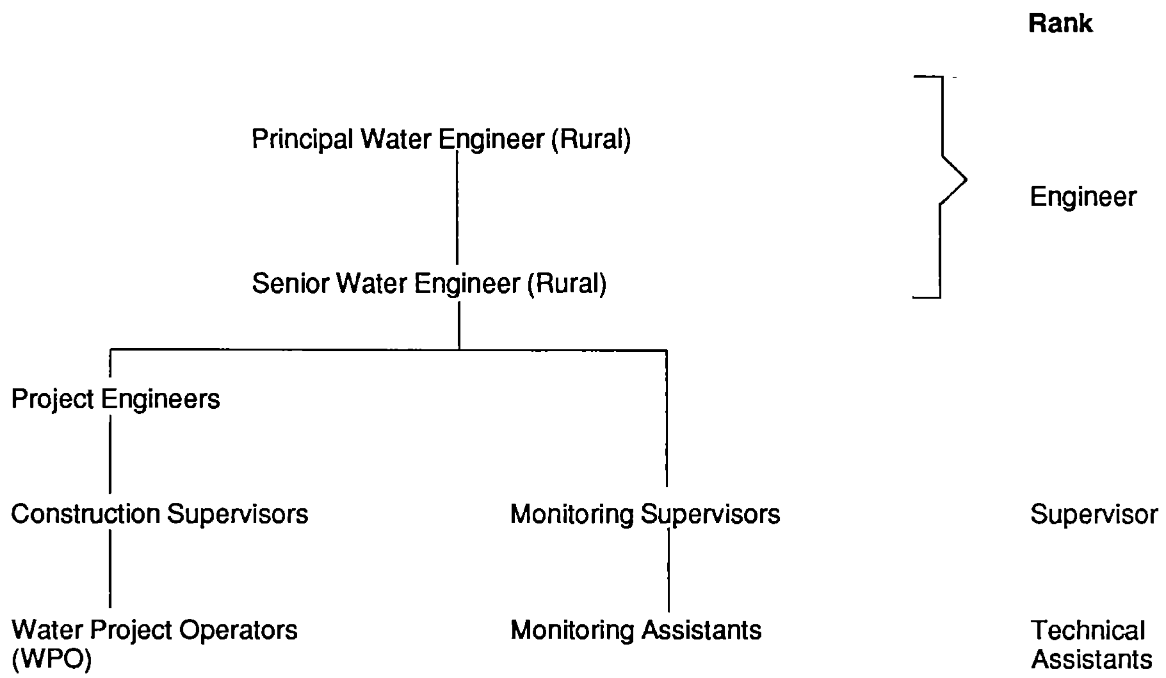


Figure 6. Organizational chart of the Rural Water-supply Section



Supervisors are divided into two categories - construction and maintenance. Construction supervisors, in fact, do most of the supervision of construction, because they are generally more experienced and more in touch with the state of the project than the engineer. They are responsible for the quality of the physical installation and adherence to programme schedules. Monitoring supervisors are responsible for programming the monitoring activities and for maintaining the quality of repairs (see section VII.B for details of maintenance and monitoring). All supervisors are responsible for supervising and training technical assistants and for maintaining good relationships with users and MCP. Technical assistants are the backbone of the programme. On a day-to-day basis, they work with users in the trenches, maintaining motivation and technical standards. This close contact with the people allows them to do informal training on the benefits of potable water, water use, community organization and technical skills.

In July 1987, staff numbers were two engineers (no principal or senior water engineers), six supervisors and 98 technical assistants. With so few high-ranking staff members, those present are overworked, and low-grade staff members are taking on responsibilities above their grade. For the moment, this appears to be working, because of the dedication of the Section's staff, but it is unlikely that it can be sustained.

III. PERSONNEL

One of the most striking aspects of the Section is the dedication and team spirit manifested by its staff. All the psychological elements for creating team spirit are present. Staff members have a clear goal towards which they are working - to get and keep water flowing from all taps in their project: construction staff members have practical deadlines in the form of the onset of the rains - otherwise excavations collapse, and sites become inaccessible. In spite of the obstacles, the goals are achievable within the deadlines, because staff members are given sufficient training and leadership plus necessary technical, logistical and financial support to get the job done. In addition, procedures have been developed in personnel selection, promotion and training which contribute to the competence of individual staff members and job satisfaction. These are described in the following sections.

A. Selection Criteria

The selection of all staff from the most junior to senior follows the same basic criteria.

The first criterion is that the recruit must be content working and living in a rural setting. Since technical assistants and supervisors work and live in the field and engineers spend much of their time there, it is essential that they be satisfied with rural life and have an empathy with the people there. This criterion, plus the fact that Malawi produces few engineers, has made it difficult to recruit Malawian engineers into the Section. To date, there are only two who have stayed, resulting in the use of expatriate engineers, many of whom come to Malawi as volunteers (VSO, Peace Corps).

The second criterion is personal maturity. Because the success of project execution and maintenance hinges on the ability of the field staff, especially technical assistants, to motivate users, the field staff must first gain the users' respect. The qualities likely to gain respect are politeness, morality, good communication skills and sensitivity to the feelings of the users.

The third criterion is made up of educational and technical qualifications. Technical assistants need eight years of primary education with the ability to read, write and do simple calculations. Supervisors are upgraded from technical assistants or, occasionally, are recruited from the graduates of the polytechnic post-secondary school. Engineers are either upgraded from polytechnic graduate supervisors or brought in from other countries, but in future, some might be recruited from the new engineering programme at the University of Malawi. The required educational level at intake is intentionally kept low, so that the incumbent feels he has obtained a good job for his standing, is satisfied and stays with the Section. Training or expérience in any of the basic project skills, i.e., community organization, plumbing or masonry, is considered an asset for any post.

B. Recruitment

Since most recruitment for high-level staff comes from the lower levels, the main point of entry into the hierarchy is at the bottom - the ungraded technical assistant. Openings for technical assistants are publicly advertised in the press, usually resulting in more than 1,000 applications. After screening of the applications for appropriate technical and education background, all eligible (approximately 300) candidates are tested for basic reading, writing and arithmetical skills, and are interviewed to evaluate their maturity and interest in living in the field. Finally, twice the number of candidates as the number of posts available are sent to a rural setting, to be trained and further evaluated in technical and social skills (see section III.C). At the end of the training/selection, candidates are again tested, and the required number offered a post. This rigorous selection procedure allows for valid evaluation of the candidates and selection only of people who are well suited to the work. This is witnessed by the fact that, over 19 years of operation, fewer than five employees, or 4 per cent of the intake, have left by choice.

The selection process, so far, has resulted in an all-male staff. It is necessary that steps be taken to favour the hiring of women, particularly for the field, in order to facilitate project rapport with female users. Female users are essential to piped-water schemes, contributing over 50 per cent of the construction labour, constituting 70 per cent of tap-committee members (Msukwa, 1986) and being the principal drawers and administrators of water.

C. Training

The period from January to March each year is reserved for training courses for every member of staff. This time period has been chosen to take advantage of the lull in project fieldwork due to increased agricultural activity. The programme is organized by the Senior Water Engineer (Rural), and the training is done by supervisors, thus refreshing their skills and building team spirit amongst all levels of staff.

There are refresher courses for all staff members who have been in their current post for less than two years. These courses are one week long. The main objectives are to share and discuss experiences of the participants and to review the contents of the Rural Water Operator's Handbook.

For those who have been in their post for more than two years and have attended at least one refresher course, there is a two-week upgrading course at which technical and social skills of increasing complexity are taught.

Some of the people attending the course (depending on the number of vacancies) are then selected for promotion, on the basis of a test at the end of the course and the recommendations of their supervisors reflecting their performance on the job.

For prospective technical assistants, the training/selection course is short (two weeks) but effective. Through demonstrations and practical experience, candidates learn how to use tools, how to use construction materials, how to dig a trench, how to lay pipe and how to mix concrete to required standards. The necessary traits of a technical assistant - politeness, honesty, enthusiasm and maturity - are taught by role-playing. It is stressed that their role vis-à-vis the community in which they are to live and work is one of adviser and model, i.e., they have no authority. The lines of traditional and Section authority and communication are explained for the technical assistants' use when they encounter a problem.

In order to reduce the time spent by senior staff in project preparation and to make documents as simple as possible for those reviewing projects, the planning procedure has been standardized. This procedure is presented in the flow chart in figure 7.

A. Project identification

Requests for water projects generally come to the Section from groups of villagers through their TAs and the District Development Committees. In addition, many requests come from other ministries, e.g., Agriculture or Health, which need water to initiate or augment their programmes. All requests are referred to local leaders, asking them to complete a simple application form providing enough information to evaluate their interest. Only when the application has been received does the Section proceed with the feasibility study.

B. Feasibility study

The feasibility study, called a preliminary report, is the most important step in project selection. If the engineer preparing the study indicates that the project is well founded, approval and funding are usually obtained. The feasibility study contains the following standardized list of information covering all project criteria, with the exception of political considerations and cost:

(a) Project-area outline with consideration of political (i.e., TA) boundaries and previous water-project boundaries;

(b) Estimation of current population and potential population (maximum population sustainable by subsistence farming);

(c) Estimation of quantity of water required to serve the potential population;

(d) Area hydrology, evaluation of the quantity of water available;

(e) Evaluation of water quality, both bacteriology and turbidity;

(f) Evaluation of the topography for the pipeline route;

(g) Evaluation of roads, bridges, fuel, stores and office space;

(h) Evaluation of enthusiasm for a water project, including experience on other development projects;

(i) Evaluation of agricultural potential of the land;

(j) Evaluation of potential health benefits based on the prevalence of water-related diseases e.g., schistosomiasis, trachoma and diarrhoeal diseases.

Feasibility studies are reviewed for technical feasibility, logistical feasibility and anticipated social and health benefits by the Section. Acceptable projects are prioritized and returned to the engineer who did the feasibility study to proceed with the preliminary design.

C. Preliminary design

As with the feasibility study, the preliminary design concentrates on a standardized set of information specified in the Design Engineer's Manual. This information includes:

(a) Exact project boundaries;

(b) Current and design population for whole project;

(c) Location of all villages with their current and design populations;

(d) Tap sites plus 10 per cent for future allocation;

(e) Pipeline layout, sizes and flows;

(f) Tank locations and sizes;

(g) Fitting locations and types;

(h) Quantities of pipes, fittings and other materials;

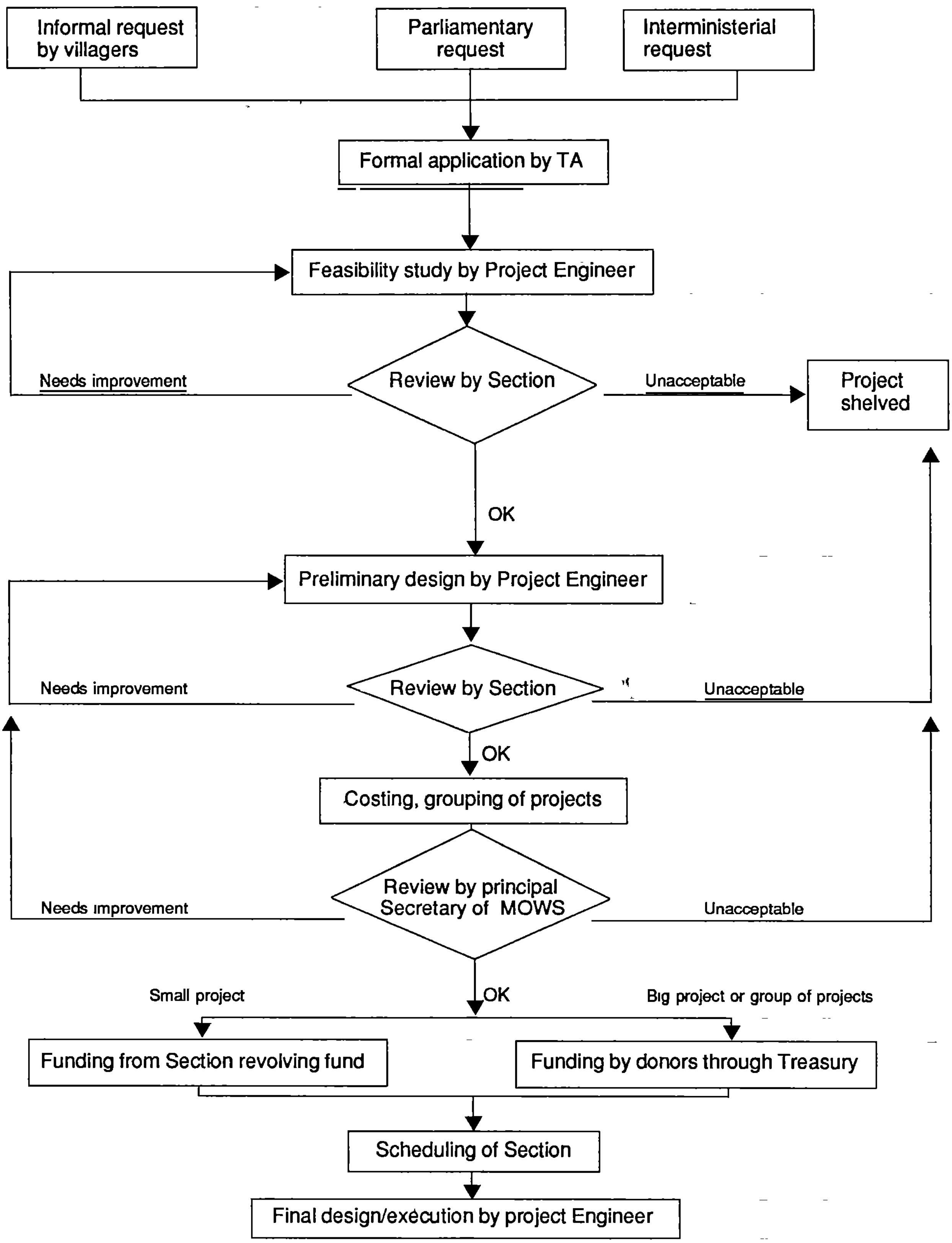
(i) Quantities of equipment and transport;

(j) Quantity of personnel;

(k) Offices and storage space required.

The preliminary design is reviewed first by the Section. If the project is considered feasible, the cost is calculated. Large projects are sent singly and small projects are grouped together for submission to the Principal Secretary of MOWS for final approval. The project's relationship to other developmental activities, cost and political considerations are evaluated at this level. Some politicians try to influence the approval and scheduling procedures, in order to bring improvements to their electorate as soon as possible. The effect they are able to have generally depends on the prestige of the politician involved, as senior Water Department and Section staff members try to balance their effect with other relevant factors. Once approved, small projects might be funded from the Section's revolving fund, or with large projects, donors are sought through the Treasury. Since the successful completion of the first two pilot schemes in 1970, the discovery of donors has rarely been a problem.

Figure 7. Flow chart of project planning



D. Scheduling

The approved and funded projects are then fitted into the existing programme, according to availability of staff and equipment. When the project begins, it is the engineer who designed the project who becomes project manager. He draws up a project timetable and arranges the procurement of materials. At this point, project planning and execution overlap.

Because of the self-help nature of the projects, timetabling is done in accordance with traditional work patterns. Calculations of the time required for each stage of construction assume that the community will work mornings only, just as they would in their fields, leaving the afternoon for domestic chores. Staff members continue working in the afternoons, checking the morning's work, preparing for the next day and doing work which cannot be done bv the community.

Projects are scheduled around the cycle of activities of subsistence farming on an annual basis. The construction of the intake and headworks is done when stream flow is low, i.e., during the dry season. The surveying and marking of lines and tanks is done before planting, because visibility is good and crops are not trampled. Digging and laying of pipe plus the excavation and construction of tanks are done in the lull between planting and harvesting and after the harvest into the dry season. Taps can be installed at any time. A large effort is made to lay pipe in all trenches before the main rains, to prevent cave-ins and redigging the following year. Small projects take about a year to complete, while large projects might be spread over several years.

E. Final design

The final design is done by the engineer, once he is in the field to begin execution. He sites, marks and surveys all of the critical components (intake, headworks, mainline, tanks, river crossings, high-pressure and low-pressure points), adjusting the preliminary design as necessary. Marking of branch lines is left to the water project operators who follow the preliminary lines marked by the engineer on aerial photographs. When all branch lines are marked, it is the villagers who site the taps, following the engineer's allocation of the number of taps for each village.

A. Design Procedure

One of the advantages of the Malawi Rural Piped-water Project is that the design work follows standardized procedures and employs standardized components. This keeps the engineer's design time to a minimum, improves the reliability of the design, permits a certain interchangeability of materials between projects and simplifies training of field staff. The iterative nature of this work, with more than 90 projects designed, has allowed for continual improvement.

Design begins with the design population (that envisaged 20 years on or the carrying capacity of the land, whichever is the less) and distributes the taps as a function of population distribution. The taps are then connected with branch lines, and the branch lines connected to the main line leading from the intake. Pipe flows and pipe size are then calculated, and tanks and valves added as necessary. Preliminary designs are done in the office, based on site visits and the report of the feasibility study. The final design, being a modification of the preliminary design in light of field conditions and user preferences, is worked out in the field during execution.

B. Scheme components and function

The components of a rural piped-water scheme are the intake, screening tank, sedimentation tank, pipelines, storage tanks, river crossings, valves and taps.

Water flows into the system at the intake. Intakes are placed in perennial streams above the area of cultivation, to reduce turbidity and bacteriological contamination. Often, the intake is in a forest reserve or national park, ensuring that there will be no cultivation in the future. The intake consists of a one- to two-metre length of slotted or perforated galvanized-steel pipe fitted with an end cap (see figure 8). It is projected into the river upstream of a weir, naturally occurring if possible, and well below the minimum flow level (see figure 9).

From the intake, water flows, through galvanized-steel piping, out of the river and into a screening tank, where plant and mineral matter is removed (see figure 10). The rectangular tank has a series of three chambers - an upward flow chamber, a screened horizontal flow chamber and an outlet chamber. Screening tanks have been omitted in recent projects, because they are easily blocked by plant matter and it is believed that their function can be met by the sedimentation tank.

The sedimentation tank is situated shortly after the screening tank, with the purpose of retaining water for a minimum of two hours, during which time all suspended material settles. Its design is identical to that of a storage tank, in order to simplify construction. Some sedimentation tanks double as header and storage tanks, in which case the size chosen is larger than is necessary for a sedimentation tank.

Water flows from the sedimentation tank, down the mainline and into one or more storage/break-pressure tanks, before being diverted into branch lines and additional storage tanks and, finally, flowing to the taps. The pipeline steps down through 13 standard diameters, as a function of the flow required, as it moves towards the taps. Most pipes are made of polyvinyl chloride (PVC) produced in Malawi, although asbestos-cement (AC) previously was used for the large diameters, when it was easily available and less expensive than PVC. Galvanized steel is used where piping is exposed at intakes and river crossings. The pressure class of the pipe is kept to one of three standard classes. The mainline is laid 1.2 metres below ground, while PVC branch lines are 0.75 metres deep. Where possible, the pipeline is laid in PVC underneath a river bed; otherwise galvanized-steel piping is suspended above the flood-water level. Trenches are over-backfilled to form a ridge, and the ridge is planted with Paspalum grass, to reduce erosion and permanently mark the line.

Air valves are installed at all high points on the pipeline profile, and flush valves are installed at all low points. Gate valves follow immediately after every tank and head every branch, to reduce water loss in the event of breakage.

Tanks are used to break pressure on rapid descents from the intake and to provide eight hours of overnight storage. There are seven standard sizes. All are circular reinforced-concrete tanks, with a fixed reinforced concrete roof supported by internal pillars. Tanks are one metre in the ground and one metre above ground but are designed to stand unsupported above ground (see figure 11). A float valve closes the tank inlet when it is full, to allow higher-level tanks to fill rather than have water flow to waste through the overflow. Only the tank diameter and the arrangement of reinforcing bars are modified to give tanks of different sizes: this makes construction simple for contractors who build from memory.

The last 0.6 metres of pipe before each tap are in 15mm steel, and this connects to 1.4m of vertical standpipe, also in 15mm steel. The standpipe is supported over its full length, by encircling the steel pipe with a 100mm PVC pipe and filling the PVC pipe with concrete. The tap is a 15mm brass crutch-headed bibcock. A 2.7-metre diameter concrete apron is constructed around the standpipe, sloping away to a 3-metre drain and a soakaway pit, 1.8 metres in diameter and 1.8 metres deep, filled with large stones. The foundation of the apron and drain is of stones or broken brick, and a large flat stone is cast into the apron directly below the tap to reduce wear on the concrete.

Treatment works have been added to several recent schemes; however, they are not well enough established to be considered standard.

C. Specified design criteria

In designing a gravity-fed piped-water scheme, the Design Engineer's Manual specifies the following set of criteria in order to standardize the service levels to each scheme:

— 36 litres per capita per day (old schemes used 27 l/c/d);

— 0.076 litres per second minimal flow from all taps open simultaneously;

— 16 hours' continuous service per day - which allows the inflow to a sufficiently large storage tank to be only two thirds of the daily outflow (calculating 36 l/c/d for a 16-hour flow of 0.076 l/s gives 120 people served per tap);

— 500 metres maximum walking distance to a tap.

These criteria provide a service level within the range proposed by the World Health Organization for standpipe water- supply projects (i.e., 20 to 60 l/c/d at a maximum walking distance of 500m) (WHO/IRC, 1979).

D. Unspecified design criteria

The specified design criteria deal exclusively with the engineering aspects of design. In fact, the Malawi gravity-fed piped-water projects fit a number of other criteria which have ensured that each project is adapted to prevailing conditions. These unspecified criteria are enumerated below.

1. *Conceptual simplicity*

The principles on which the scheme operates are both conceptually simple and visible. Villagers can actually see water flowing into one end of a pipe, follow the pipeline and see the water coming out of the tap at the other end. Nothing needs to be taken on faith, with the result that the people who build the system understand why they need to do each construction task and, when there is a malfunction, they have a good idea what the causes could be.

Figure 8 Perforated galvanized steel water intake pipe.

Figure 9. Intake pipe located behind overflow weir designed to maintain an adequate head of water above pipe invert.

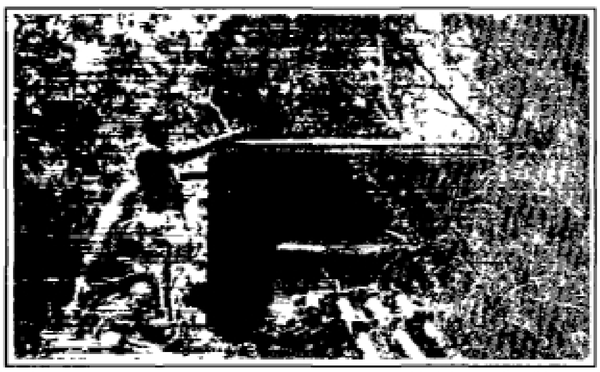


Figure 10. Screening tank showing inlet and overflow pipes.

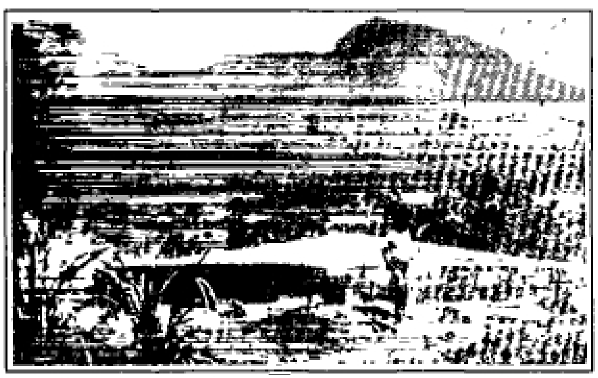


Figure 11. Water storage tank

2. *Ease of installation*

In order to maximize the use of self-help labour and supervision, the Malawi schemes chose construction (and, therefore, repair) techniques which are simple and do not require high standards of skill. For example, trenches are dug by hand, PVC pipe is easily fitted, and tank designs are standardized for unschooled masons.

3. *Ease of operation*

Operation of the system must be within the physical capabilities of women and children, the principal drawers of water. Turning on a tap fits this criterion well.

4. *Ease of maintenance*

The less routine maintenance is required, the less often the system is likely to fail. Also, the less complex and exacting is the execution of maintenance, again, the less likely the system is to fail. Maintenance of a piped-water scheme is simply the cleaning of intakes, tanks, aprons and soakaways, plus the replacement of tap washers. Only the replacement of tap washers requires some skill, but the cleaning of the intake and screening tank requires dedication, because of the frequency required. The users of many projects now hire someone to do the intake and headworks maintenance.

5. *Ease of repair*

Repairs need to be as straightforward as possible, to permit maximum participation of users. Users get the job done quickly and at little expense. Since it is the villagers who install and supervise much of the installation, they obtain most of the skills required for system repair on the job. Also, certain design features, such as easy tank and valve access and ability to isolate small sections of the system using valves, facilitate repairs. Since the pipelines are clearly marked by Paspalum grass, breaks can be readily traced.

6. *Durability*

The longer the system lasts the better, although durability criteria usually need to be balanced against cost. Durability affects not only system life but also frequency of repair. Durability is particularly important in the choice of materials, and, in the Malawi project, PVC is used for most of the pipeline, because it is resistant to acidity and soil compaction or expansion. Steel is used for exposed sections of the line to reduce breakages, and a stone is placed directly below the tap to cut down wear on the concrete apron.

7. *Availability of materials*

Only materials which can be delivered by the time they are required, plus a month or two buffer, allowing for the inevitable delays in international transport and local manufacture, are selected. Some items, which are not available in Malawi, must be procured internationally, e.g., AC pipes, steel pipes and fittings. Other items purchased locally are produced elsewhere and imported, e.g., vehicles: their delivery time depends on current stock and back orders. Use of locally produced materials, such as the Malawian PVC, provides a flexible delivery schedule and a minimum of transport delays. Owing to the importance of the Section's business for the local pipe-extruder, the producer is generally willing to alter production schedules to accommodate project needs. This criterion might seem trivial, but delays in delivery can seriously retard the project timetable and jeopardize community motivation.

8. *Ease of transport*

The projects are executed in rural areas with dirt roads and questionable bridges. Often, large sections of the project area are not serviced by roads, especially around the intakes. Materials must be transported either on a village-made road or by foot, and therefore, materials and equipment need to be as light, compact and resistant to breakage as possible: again, PVC pipes fill all the criteria, making them the ideal choice. PVC pipes of several sizes are nested inside one another, to reduce volume during transport and storage.

9. *Construction cost*

Construction costs need to be kept to a minimum, in order to obtain financing. Once a donor is identified, costs again need to be kept to a minimum, to serve the maximum number of people with the funds available and assure the donor that the investment is worthwhile. In 1968, when the technology of the gravity-fed projects was as yet untested, it was useful to do the pilot project on a small scale, so that the risk to the donor was proportionately small. Now that the programme has proved its worth, cost is no longer a critical factor in finding funding. However, the Section has maintained the habit of running on a tight budget: materials are selected with an eye to cost, e.g., the use of AC pipes for large diameters, and there is careful surveillance of transport.

Some of the ways the Section has kept down the cost to project donors are:

(a) Heavy reliance on self-help labour and supervision;

Table 3. Summary of other support to USAID Programme 1980-1988 (after Warner and others, 1986) (US Dollars)

Source	Amount ($US)	Proportion of total (Percentage)
USAID (materials, equipment, vehicles salaries)	6,145,000	68.3
Community (labour, land)	937,000	10.4
Government of Malawi (salaries, overheads)	927,000	10.3
Government of Japan (pipes)	670,000	7.5
Government of United Kingdom (expatriate support)	165,000	1.8
Government of the Netherlands (expatriate support)	90,000	1.0
VSO/Peace Corps (volunteers)	40,000	0.5
UNICEF (vehicles)	20,000	0.2
Total	8,994,000	100.0

Note: Owing to the fall of the value of the Malawian kwacha relative to the United States dollar from 1980 to 1986, the community contribution cited in this table is significantly undervalued

(b) Contributions by the Government of Malawi for salaries and overheads;

(c) Contributions by other donors to the Section's programme as a whole rather than to individual projects.

USAID has evaluated and projected the contributions to its programme from 1980 to 1988, and table 3 shows the total cost and breakdown of other support to the USAID programme.

The USAID programme includes the construction of 18 projects designed to serve 36 litres per capita per day to 421,800 people, as well as support for maintenance, research, evaluation and a health-education and sanitation programme. This gives a per capita cost of $US21.30 for the whole programme but only $US14.60 for USAID. Looking exclusively at construction costs, USAID paid $US13.10 per capita - a figure which compares favourably with other water-supply projects supplying the same level of service.

10. *Operational and maintenance costs*

Although some governments are initially willing and able to cover operational and maintenance costs, escalation of costs, owing to the increasing number and age of schemes, soon leaves them unable to do so. Donors are rarely interested in funding operational and maintenance programmes, especially if they did not fund the construction. Given the inability of Government and the lack of interest of donors, it is essential that cash costs be kept to a minimum.

Because of the design, the operational cost of the Malawi schemes is zero. Each user turns the tap for her/himself, and there are no other energy or labour costs. Maintenance cash costs are kept down primarily by the user-intensive approach to planning, construction and maintenance. This approach has the cost benefit of contributing all labour, reducing field staff, reducing transport needs, reducing system wear by proper operation and reducing vandalism. Other steps taken to reduce cash costs are the solicitation of commodity aid and overestimation of materials on construction projects.

USAID has analysed the cost of one year of maintenance on five schemes of different ages. Based on these limited data, it found an average maintenance cost of $US0.15 per capita per year. However, 50 per cent of that cost was covered by community in- kind contributions, leaving $US0.07 per capita per year cash cost: 88 per cent of the cash requirement was covered by the Government.

So far, this level of cash flow and in-kind community contribution has been sustainable. Looking ahead, five schemes which are under construction have geographically unfavourable sites resulting in complex technical designs, (i.e., treatment works, dams, elaborate intakes), and USAID estimates that the per capita annual operational and maintenance cost of these schemes might reach $US0.20 (Warner and others, 1986). The Section needs to consider how these supplementary costs will be covered in the future.

A. User organization

So that thousands of users can be involved in the execution of their water-supply system, a number of user committees are formed at the time of execution, as described in section VI.B. Figure 12 outlines the user-committees, their lines of authority and their external support. The main committee is responsible to the TA and District MCP Chairman for division of labour for the construction of the main supply line, the creation of section and branch committees and the establishment of the extent of user participation.

Section committees (which only exist in the case of a large project) and branch committees are responsible to the main committee for division of labour, supervision and maintenance of standards along the pipeline in their domain, and encouragement of participation. Village committees are responsible to the branch committee for attendance on days designated by the branch or main committee, organization and supervision of labour and installation of their standpipe, apron, drain and soakaway.

B. Execution procedure

Once a project is approved and funded, the District Development Committee is officially informed. When the plant and vehicles have been procured, materials ordered, office and storage space identified, and staff transferred and hired, the project is ready for execution. The District Development Committee calls a public meeting, at which the local Member of Parliament reads the official letter announcing the project and its conditions. The points included in the letter are:

- "The Government is ready to assist you with the construction of your Rural Piped-water Supply which will be the property of your community;
- Because of the communal ownership of the supply, no private connections are allowed;
- The water can be used for any activity;
- All water must be carried away from the tapstand;
- Water is free of charge;
- The Government will assist the community by providing skilled labour and all materials;

Figure 12. User organization and support

Users		MCP	Government	
Construction Phase	Maintenance Phase		DDC	MOWS
TA + District Party Chairman	TA + District Party Chairman	District Committee	DDC	Project Manager
↓ Main Committee	↓ Main Committee	Area Committee	AAG	Project Manager Supervisor
↓ Section/Branch Committee	↓ Section/Branch Committee	Branch Committee		Supervisor Technical Assist.
↓ Village Committee	↓ Tap Committee	Branch Committee		Technical Assist.
↓ Villagers	↓ Villagers			Technical Assist.

- The community will provide all unskilled labour and is responsible for the proper and fair organization of the self-help labour;
- The community is responsible for the maintenance and proper care of the supply once operational. (McPherson, 1987).

The TA then asks the people if they agree to the conditions. They do, and the TA declares publicly that they will participate fully in the project. The project engineer (the same who did the feasibility study and preliminary design) then explains the layout of the scheme - project boundaries, intake site, pipeline routes and tank sites: he also gives the broad work schedule. The supervisor explains what is involved in terms of labour and committees. The main project committee is then elected by the people, to represent and supervise them.

In order to create understanding of the forthcoming project and create a strong desire for it, a film of project construction and the finished product is shown in various user-villages. Local leaders are taken to visit an existing project, where they see for themselves what a scheme looks like. They also meet leaders there to discuss their experience of construction, system performance and maintenance.

The main committee meets with the project supervisor, to decide how to apportion the work required for the construction of the headworks. This meeting is the first of many meetings between user committees and project staff where the role of the staff is:

(a) To describe the work to be done - usually enumerating it task by task;

(b) To provide information to the population of every village, so that work can be distributed equitably;

(c) To suggest methods of dividing work, e.g., every village to be assigned one work-day per week or every village assigned a task to complete within a deadline.

The committee members decide how best to divide the work and assign villages to do it. They also draw up a supervisory programme, so that at least one committee member is present at every work site, to check attendance, motivation and work quality. The villages involved are then informed.

The intake is built by water project officers (WPOs) and supervisor(s) under the direction of the project engineer, to achieve a high-quality structure. This is necessary because the intake is usually the most vulnerable part of the system; its failure would affect every user, and it is difficult to repair. In addition, intake design is project-specific, and, usually, only the engineer can read design drawings. Users assist by collecting, loading and unloading sand and gravel, unloading pipes and other deliveries, transporting materials to areas inaccessible by vehicle and providing any other manual labour required.

When the headworks are finished, the main committee meets again, to plan the labour for the mainline. Unless the project is small, the committee divides the mainline into sections, calls a public meeting in each section and supervises the election of section committees who are responsible to the main committee. These section committees then meet with the supervisor and WPO, in order to plan the labour input and supervision of their sections.

Tank sites are surveyed by the project engineer. Tanks are built as soon as possible afterward by contractors from the community who have been trained on previous piped-water schemes. Users excavate the sites and collect, load, unload and, in some cases, transport sand, gravel, pipes and other materials.

Pipelines are excavated by users with picks, shovels and hoes. When large rocks are encountered, they are heated by fire for six hours, quickly cooled by water and battered with sledgehammers: this method has proved very effective and inexpensive and can be used anywhere. The treatment is repeated if necessary, or dynamite is used. Users lay pipes and collars alongside the trenches, fit PVC pipe, place PVC pipe in the trench, backfill and plant Paspalum grass over the pipeline. WPOs fit AC and steel pipe, because of the skill and high quality control required.

Once the mainline is completed, the section committees have no further role and generally disband. Again, the main committee meets with project staff, to examine and modify, if necessary, the grouping of people by the branch lines proposed in the preliminary design. The main committee calls a public meeting for each of the branches and supervises the election of branch committees who are responsible to the main committee. The branch committees, assisted by the WPOs, draw up the schedule of village participation and supervision by the branch committee.

As each village is approached by the branch committee to participate, it is encouraged to form a committee. The committee or headman is responsible for village attendance and for supervision of labour. As the branch line approaches, the village selects its tap site(s) and constructs its own apron(s), drain(s) and soakaway(s).

Finally, when all of a village's labour is complete, a tap- opening ceremony is held, with attendance by dignitaries, singing and dancing: the tap is installed on the standpipe and turned over to the village. Water use, system operation and maintenance are explained.

C. Motivation

Motivation of the users to continue working on construction is not to be taken for granted. Initially, there is a lot of enthusiasm generated by the public meetings, films and other project visits, but, after three or four months of digging trenches (see figure 13), the novelty wears off. It is at this point that the foundations of the scheme come to the test.

First of all, the TAs are responsible for keeping up attendance. It is they who asked to have a water project and the chief who agreed publicly to the terms. It is the users' representatives - their committees - who have allocated the work and are on site to supervise.

When a segment of the population starts having a low turn- out, the WPO goes to the village headman(men) and inquires about the problem. If the problem continues, the WPO contacts his supervisor who contacts the section or branch committee. If, after its intervention, there is still no improvement, the main committee, which always includes MCP, steps in. It calls a public meeting where the reasons for the water project and the progress are reviewed. If there is a specific block, it is dealt with by either the TA or MCP, and the community is asked to return to work. So far, this procedure has always been effective.

The daily distribution of labour at the work site is kept equitable, so that the willing users do not get overworked while the less willing sit back. One village leader's job each morning is to assign specific tasks to individuals as they arrive on site. For example, if the task is trench digging, each group of two to three people is assigned a marked 2-metre length to dig to 0.75 metres deep. The group works at its own pace, and, when the work is finished and has been checked by the local leader in charge of quality control, the members are free to leave.

The WPO himself is constantly being evaluated by the people. When he is mature, technically competent and a good communicator, the people have confidence in him and will respect his advice. WPOs are trained to train users by demonstration, with the result that they can often be found working along with users in the trench, encouraging them on. Project managers do everything in their power to ensure that materials and transport are available when needed, to keep the work moving.

Work is planned to begin at the top of the scheme - the intake - and be built systematically downline to the taps. As soon as a pipeline is complete, it is pressure-tested and becomes operational. In this way, there is a sense of progression and visible achievement. Taps are installed only when each village has completed its contribution, to prevent complacency.

D. Women's Participation

Traditionally, water is in the women's domain. Women collect, transport, store and allocate water. They are also the principal consumers of water in bathing children, doing laundry, washing dishes, cooking and serving drinks. Because of their responsibility for water, it is essential that they participate fully in the piped-water schemes.

During construction, women contribute over half the labour, doing everything except the heaviest work, such as carrying steel pipe and digging through laterite. Women do most of the routine maintenance, e.g., cleaning the apron, drain and soakaway, because it is similar to traditional women's work. In contrast to labour, where women participate in most activities and make up at least half the force, their participation on user-committees is inversely proportional to the authority and prestige of the committee. In a study of 17 schemes (Msukwa, 1986), women were found to make up 69 per cent of tap-committee members, including 63 per cent of chairpersons and 64 per cent of secretaries. However, on the 17 main committees, there were only three women. Assuming 10 members per committee, women make up 2 per cent of main committee members, and, in no instance, were these women chairperson or secretary. Of 103 repair-team members interviewed in the same study, 2 percent were women. Msukwa attributes this disparity in women's participation to "societal attitudes towards women" and a "bias on the part of water department officials" who are all male. Rural Malawian women repair their village's handpump, so the step to rural women repairing piped-water schemes would not be difficult, but the step to women's participating on high-profile committees will take time and animation. The animation would be assisted by the demonstration effect of female staff in the Section.

E. Field staff administration

In order to direct and keep track of what literally thousands of villagers and tens of staff and vehicles are doing, the project engineer relies on standardized procedures which have been developed over the years. As already mentioned, the project engineer draws up the work schedule in broad terms, and the committees detail the schedule and allocate work to specific villages. Each WPO draws

Figure 13. User participation in trench digging

up his two-week workplan on a simple form provided by the project and submits it to his supervisor. This encourages the WPO to keep a balanced coverage of the work being done and feel responsible for his own performance: also, it gives his supervisor a good idea of where to find him. At the end of every week, the WPO completes another short form reporting on progress and any problems encountered.

A project staff meeting is held one afternoon per week. WPOs give a verbal report, and then supervisors and project engineers discuss points of concern. The next week's programme is discussed, and supervisors co-ordinate the use of transport as a function of WPO's work plans. These meetings are used for training, by re-emphasizing procedures, and for building team spirit through mutual support.

F. Transport

The heavy transport, i.e., seven-ton and five-ton lorries of differing structures for pipes or materials, is shared amongst several projects and is administered from programme headquarters. At the project level, there is generally a three-ton truck and a four-wheel-drive pickup, with an overhead frame for pipes and planks, which are easily manoeuvrable on rural roads, although they do not carry much in one load.

The project manager has a one-ton pickup: he balances his supervisory movements with delivery requirements. Supervisors use project motorcycles which are well adapted to the paths, by which most projects are accessible, as well as to mud. WPOs receive an allowance for the upkeep of their personal bicycles for use on the project: WPOs who do not initially own bicycles are encouraged to buy one with a two-year governmental loan. Judicious use is made of all transport. The loads of pipes and materials for each vehicle type is in the WPO's manual, and supervisors enforce these standards, cutting down waste from underloading and excess vehicle wear from overloading.

VII. OPERATION AND MAINTENANCE

A. Operation

The ingenious aspect of the rural piped-water scheme design is that the work is done by gravity. The only operation required is the turning of a tap to allow the flow of water. The skill and physical effort required are attainable by a two-year-old: in fact, operation is so easy that young children must be disciplined by parents not to play with the tap. Users are trained in tap use at the tap-opening ceremony, and instructions are given to close the tap after use, to prevent wastage, but not to over-tighten the tap, to reduce wear on the washer.

B. Maintenance

1. *Staff*

The key staff members in the maintenance system are the monitoring assistants. Monitoring assistants are selected from among the WPOs who participated in the construction of the scheme to be maintained. Because the post carries more responsibility with less supervision than construction, the most dedicated and competent WPOs are chosen. Each monitoring assistant covers an average of 30,000 beneficiaries or 250 taps on one or more schemes. Each is responsible for monitoring the state of all installations, reporting findings, initiating the cleaning of tanks, evaluating the cause of failures and assisting in the repair of failures which exceed the competence of the beneficiaries, e.g., fittings or steel piping. Monitoring assistants keep stocks of spare parts and tools, are transported on their own bicycles (the same arrangement as for WPOs) and are housed by the Government.

Monitoring supervisors are selected from among the experienced construction supervisors. They need to be the most reliable staff, for the same reasons that monitoring assistants need to be reliable. Supervisors are responsible for an average of 10 monitoring assistants, which necessarily covers several schemes. Supervisors make up the six-month work programme for each of their assistants, receive their reports, verify the reports with field visits and assist at the repair of serious failures. They keep an extensive stock of spares, have a large vehicle for transporting spares and a motorcycle for personal transport. They are housed, by the Government, next to the maintenance stores.

There are two evaluation officers who compile the maintenance assistants' reports, in preparation for interpretation by an engineer. Engineers are called upon occasionally to interpret the six-month maintenance reports or to redesign problem-prone sections of existing schemes. The senior water engineer has overall responsibility for maintenance, and he reviews maintenance reports, designates portions for redesign and initiates research activities to solve ongoing maintenance problems.

2. *Users*

As the construction phase of a project draws to a close, the project supervisor and WPOs meet with the main committee, to discuss the future of the project. The maintenance programme is presented, and the main committee agrees to continue supplying and supervising labour with technical and material support from the Government. The committee might revise its composition at this point, to reflect the interest of the members. The main committee's principal responsibilities are to organize and supervise labour in case of a serious breakdown, supervise repair teams and the intake caretaker, and supervise the collection of Malawian kwacha (MK) 1.00 ($US0.40) per tap with which to pay the caretaker. The section and branch committees have no formal role and generally disintegrate through lack of use. They can be revived by the main committee in the event of activity in their domain.

Village committees are divided into tap committees (see figure 14). Each tap committee is responsible for the correct use of its tap, for keeping the surrounding area clean, for emptying the soakaway when full, for replacing the tap or tap washer (both labour and financing) and for contributing to the intake caretaker's remuneration.

After installation of all taps on a branch, each village selects four manually skilled people for training by the Section. They learn PVC and AC pipe repair, valve locations and operation, tap and tap-washer replacement and maintenance motivation skills. Because of their previous participation in project construction, these people are already familiar with most of the techniques, and the training is done by the WPO for two hours one afternoon per week for four to five weeks, taking in all villages on the branch. The trainees select 10 people amongst themselves, from widely scattered villages, to become a "repair team", and a repair-team member or committee member, who is centrally located, keeps tools, a stock of pipes and solvent cement for the team's use. Team members are responsible for repairing breakages of PVC and AC pipes or for replacing taps when called by a tap committee: they are responsible to the main committee and are given the authority to close down a leaking tap, if the tap committee consistently refuses to replace it.

The intake caretaker is selected by the main committee from the village closest to the intake: he is chosen for his interest and aptitude shown during construction. He is responsible to the main committee which pays him a small fee. The caretaker is responsible for keeping the intake free from obstruction, cleaning the screening tank and patrolling the intake and uppermost pipeline which is subject to washouts. Caretaker duties take one to two hours per day.

3. *Routine maintenance*

The maintenance necessary to keep water flowing is minimal, owing to the design. It consists of:

(a) Intake caretaker's duties cited above;

(b) Occasional cleaning of tanks, organized by the main or branch committee;

(c) Daily cleaning of aprons and drains plus occasional emptying of soakaways, organized by each tap committee.

4. *Repairs*

Taps are the components which require the most frequent repair, because they are the only moving part in the system. Washers need to be replaced every three to six months, and, when the tap is installed at the tap-opening ceremony, a spare washer is presented to the tap committee. Subsequent washers are handed out, free of charge, by the monitoring assistant, but, in spite of the fact that washers are freely available, tap committees tend to leave them to work beyond their limit of effectiveness, causing damage to taps. In order to reduce the judgement required on the part of the tap committee, the Section is now introducing washer replacement every three to four months as routine maintenance.

Taps need to be replaced after 5 to 20 years, depending on whether the washers have been replaced when worn. Taps are sold to tap committees, at a subsidized rate, by the monitoring supervisor or assistant, and tap committees collect the necessary funds from users. Recently, committees have begun organizing communal banana fields or communal labour on private farms, to raise funds for the purchase of taps. The replacement of washers or taps is done by a committee member, usually one of the four who have been trained by the Section: on some of the older projects, there might not be a tap user who feels confident enough to do the replacement, in which case the tap committee calls a member of the repair team.

A sudden drop of pressure at the tap is recognized by all users to be a pipe break. The tap committee immediately contacts a member of the repair team - there is usually one in every village. Together, they follow the pipeline upward, until the break is located. The repair-team member shuts the first gate valve above the break to prevent wastage of water, if the break is in PVC or AC pipe, the repair team takes care of it, but if it is in steel

Figure 14. Members of tap committee at village standpipe fitted with concrete apron, drain and soakaway

pipe, the monitoring assistant is called. Digging up and backfilling the line is done by the users concerned, and broken piping is saved for inspection by the monitoring assistant, so that he can evaluate the cause of failure.

To date, no tank has failed. Small leaks develop from time to time but they generally heal over by the natural dissolution and recrystallization of cement in the fissures, as water flows through. Should a leak be persistent enough to need repair, the contractors who built the tank come from the community and can be called by the main committee.

Failure of the intake and upper mainline is not uncommon, owing to the rough terrain and torrential rivers. As the design engineer's handbook says, the perfect intake site does not exist; engineers must pick the best site and make do. It is the caretaker who usually notices intake failure first, while the tanks are still draining: he contacts the monitoring assistant who, in turn, calls his supervisor. It might take some time to obtain steel pipes and fittings. The replacement is done by the supervisor and monitoring assistant, aided by the repair team and users, but it might be necessary to have the main committee organize a rota of labour. In the case of washouts, the supervisor contacts the senior water engineer, to verify and, if necessary, modify the intake design.

5. *Monitoring programme*

The monitoring programme is carried out by the monitoring assistants, in accordance with a semi-annual plan drawn up by their supervisors. Just as construction WPOs draw up two-week workplans, submit weekly reports and attend weekly meetings, the monitoring assistants do likewise. Every six months, the monitoring assistant inspects:

- Every tap and tap committee (once);
- Every metre of pipeline, including river crossings (once);
- Every tank (once);
- The intake and sedimentation tank (twice);
- Every repair team's stock and his own stock of materials (once).

For each type of inspection, there is a simple but thorough form to be completed by the monitoring assistant: this ensures that the inspection is complete. For example, the tap-committee form records tap flow, whether the tap leaks, apron and drain condition, soakaway condition, presence of a spare washer, protection of the gate valve, cleanliness of surroundings, activity of the committee, any recommendations made to the committee, and the date set to return and check on the results of the recommendations.

Completed inspection forms go to the supervisor who looks through them and makes field visits to verify them. They are, then, sent to the evaluation office where they are consolidated at the end of the six-month cycle. An engineer interprets the results and writes the semi-annual maintenance report, in which chronic problems are identified and their possible causes discussed. A few projects have been fitted with flow meters, placed in the mainline and at the taps, in order to measure water consumption and loss through the system. In the Mulanje area, water loss measured through AC pipes and their frequency of breakage led to a programme of gradual replacement of AC pipes by PVC pipes.

6. *Spare parts and materials, tools and transport*

Spare parts and materials for repairing existing projects are supplied free of charge to the project users, by systematically over-ordering on new projects. About 10 per cent is added to all orders of small pipe, 3 per cent to large pipe, and fittings and solvent cement are quantified generously. Recently, commodity aid from Japan has also contributed spare parts. For the time being, this procedure works well, and a large stock is always on hand, having been obtained at tax-free and bulk prices. When construction of new projects slows, this will no longer be sufficient. Every six months, the monitoring assistants report on materials consumption, so that they and the repair teams can be restocked. Likewise, inventory is done at the supervisor's storage space every six months, and stock transferred between projects (supervisors) as required.

Taps are the exception to the above procedure, in that they are sold to the tap committees. This helps to reduce tap abuse. The Section sells them at Mk 5 ($US3), whereas retail stores are selling them at Mk 27 ($US15).

The tools and transport used in the maintenance programme have been left over from the construction programme: this keeps the maintenance costs to a minimum, while augmenting the construction cost. As with spare parts, this procedure works well and is likely to continue to do so, as long as the construction programme is sufficiently large to support it. However, a new procedure needs to be developed, before the point of insufficiency is reached.

A. Water coverage

The number of people served to date by the Malawi rural piped-water schemes is approximately 1,010,000, representing 13 per cent of the population. They have at their disposal 36 litres per capita per day (or 27 l/c/d for projects designed before 1983), although metering studies show that consumption is closer to 17 to 20 l/c/d. Water flows through the taps more than 95 per cent of the time, with the exception of projects using AC pipes, where reliability might be as low as 75 per cent; 90 per cent of all breakages are repaired within two days. People walk an average of 200 metres to their tap (Warner and others, 1986; Easton, 1985), which is well within the design criterion of 500 metres.

The bacteriological quality of several schemes, as tested in the Water Department Laboratory, shows dry-season counts for both taps and intakes to be less than 30 faecal coliforms/100ml and less than 50 faecal streptococci/100 ml (Warner and others, 1986). Early rainy season results are higher than this, averaging 63 faecal coliforms/100 ml and 56 faecal streptococci/100 ml (based on data from Senior Chemist, 1986-1987).

B. Time savings

One of the impacts anticipated from any rural water-supply project is time saving by the drawers of water, usually women. This saving is brought about by bringing the year-round waterpoint close to the domicile. Because the domiciles served by a particular waterpoint are dispersed, the distance to the water point is discussed in terms of the average distance. In any given case, there might be a large spread of values on either side.

In the Malawi schemes, time savings are not always obtained. A study of the Zomba East scheme, which has relatively numerous traditional water sources, shows that its average distance to the tap is similar to the distance to the traditional water source; therefore, no time is saved (Warner and others, 1986). In contrast, a study of the Champira North scheme, which is in a dry region, shows that the distance to the tap is an average of 55 per cent shorter than to the traditional water source. Using a plausible set of assumptions, it is calculated that the average woman on the Champira North scheme could save more than 30 minutes per day. The average daily time saving for the whole rural piped-water programme is not known, because time studies have been done on only a few schemes.

C. Health

The impact, other than time saving, anticipated from rural water-supply projects is improvement in health. Of the various diseases which can be reduced, the Malawi rural water project, with the associated health-education and sanitation promotion (HESP) project, has been able to document reductions in the prevalence of trachoma, schistosomiasis contact and diarrhoeal disease. In the Mwanza Valley, a rural piped-water scheme is under construction with several branches already functioning. Although it is too early to measure the effects of the introduction of the rural piped-water scheme, the results of the Lower Shire Valley Ocular Disease Survey, which covered several areas of the Mwanza Valley scheme, permit prediction of impact. It found the prevalence of inflammatory trachoma in the area to be about 40 per cent for children five years of age or less (Warner and others, 1986). Another study in the area, by Keyvan-Larijani and others, found that the prevalence of inflammatory trachoma is strongly related to distance to water source (Shire River) and to frequency of face-washing (Warner and others, 1986). Since the piped-water scheme is expected to bring water close to the house, i.e., 500 metres or less, as compared to 74 per cent of the population surveyed by Keyvan-Larijani on the west bank being 1 kilometre or more from the river, it is anticipated that the incidence of inflammatory trachoma in the Mwanza project area will decrease significantly.

Schistosomiasis is a serious health problem in several areas of Malawi, and the prevention of skin contact with schistosomiasis-contaminated water has been documented in studies of several developing countries as an essential element in the reduction of the disease. A study of the Champira North rural water scheme by Young and Joseph, in 1986, showed that, when the tap is significantly closer to the house than the traditional water source, people do transfer their water-related activities to the tap (Warner and others, 1986). Therefore, with the documented move away from the (contaminated) traditional sources, a reduction in schistosomiasis is probable. No epidemiological data are available to measure this reduction.

Two studies of the incidence of diarrhoea in children five years and under have been done, one in the Zomba West Scheme by Linskog and Linskog in 1985 and one in the Zomba East scheme by Young and Briscoe in 1986 (Warner and others, 1986). They have shown that the installation of a rural water-supply scheme was a necessary but insufficient condition for the reduction of diarrhoeal disease. It is only with the addition of the HESP programme, including health education, construction of latrines and encouragement of full breast-feeding, that the prevalence of diarrhoeal disease was reduced by 20 per cent. Both these studies documented that the distance to water was not reduced by the piped-water scheme nor the quantity of water used increased. Since diarrhoeal diseases are both water-borne and water-washed, it is expected that reductions in the incidence of water-washed diarrhoeal disease are being experienced in other schemes where taps are closer to the home than traditional sources, owing to an increase in the quantity of water used.

It is hypothesized that water-supply projects can bring about health improvements not only through the improved quality and quantity of water but also indirectly through time saved. The time saved by drawing water close to the domicile can be put to use on health-related activities, e.g., overseeing children's hygiene, doing laundry, preparing meals, growing vegetables and attending under-fives clinics and immunization programmes. Improvements in all of these health-related activities have been commented on by users of Malawi piped-water schemes and reported by field staff (personal communication Y. Nyasulu and N. Chaya). However, only improvement in attendance at immunization programmes has been documented. WHO did an evaluation of its Expanded Programme on Immunization in Malawi which showed a significant improvement in the level of full immunization (three doses of DPT, three of polio, one of tuberculosis and one of measles vaccine). About 49 per cent of children are fully immunized in areas with both a rural piped-water supply and a hygiene education and sanitation-promotion project, as compared with 24 per cent immunization in areas with neither improvement. However, areas with rural piped-water supplies but no HESP project showed no significant improvement at 23 per cent. Warner and others (1986) interpret this as meaning that the improved water quality, community organization and time saved by the implementation of a piped-water project are necessary but insufficient to generate full participation in immunization programmes. They also suggest that acceptance and, therefore, impact of an HESP project were assisted by the skills and goodwill toward technical assistants generated during construction of a piped-water scheme.

D. Agriculture

Several projects were selected with the specific objective of opening up land which was previously uninhabitable owing to lack of water, *viz*, Chitipa, Mpira/Balaka and Mwanza projects. All of these projects are still under construction, but the Chitipa project, of which some branches have been operating for several years, has already experienced an increase in population (personal communication N. Chaya). Since 95 per cent of the rural population is engaged in agriculture, the area must already be under increased cultivation.

The increase of community organization, i.e., committees, and, in some cases, the increase in time and water available have permitted the development of communal gardens. In the Mulanje area, these are generally banana fields, but some villages choose to irrigate vegetable gardens with water or wastewater from the tap. Earnings from the sale of these gardens' produce are used to maintain the tap.

E. Local industry

Improved community organization and increased availability of water in some villages have permitted the production of bricks. In turn, the bricks are being used to improve housing and build schools. Improved availability of water has also stimulated the brewing of millet beer (personal communication N. Chaya).

At the national level, the Rural Water Sector is the largest customer of Pipe Extruders Ltd. in Lilongwe which produces PVC pipes and fittings for the schemes. The market created by the Section has encouraged both diversification of products and increased volume of production.

F. Employment

There are over 90 full-time staff positions (permanent and temporary) in the Rural Water Sector. These range from professional staff members to storekeepers. From time to time, a particular scheme might employ 10 to 20 labourers to construct otherwise inaccessible intakes and sections of mainline. On some recent projects, e.g., Dombole, Mwanza and Mpira/Balaka, labourers have been hired to construct and maintain treatment works.

Outside the governmental payroll, contractors are engaged on a task basis, to construct tanks. These contractors are rural masons, trained by the Section, who have each created their own enterprise of three to five men. Various research projects have created short-term employment for a limited number of professional Malawians. The most notable example is the hiring of the Centre for Social Research by USAID to do studies on impact assessment of rural piped-water schemes.

G. Spin-off projects

1. Health-education and Sanitation-promotion Programme

In the early years of rural piped-water projects, the WPOs did some hygiene education with the users but were independent of Ministry of Health (MOH) sanitation programmes. Then, in 1980, USAID funded a project, twinning the construction of rural piped-water schemes with a health-education and sanitation-promotion programme to be developed within MOH. The objectives of the HESP component of the project were (Warner and others, 1983):

— To strengthen and co-ordinate the rural piped-water programme with the MOH;
— To expose up to 202,000 rural villagers to health education relating to improved sanitation and hygiene practices;
— To focus health-education activities in sanitation and hygiene within each of the locations receiving rural piped water;
— To train Malawians in basic health and sanitation education.

The 1986 USAID project evaluation states that "ninety-two health surveillance assistants are deployed under HESP, each serving 10 villages. If the average population reached in each village is 300, then the total population reached is approximately 270,000." (Warner and others, 1986)

The HESP programme begins with the revitalization of existing village health committees, created in the wake of the 1974 cholera epidemic, or, in their absence, the creation of new ones. The committee members are trained in:

— The water/sanitation/health relationship;
— Excreta and waste disposal;
— Personal and environmental hygiene;
— Water storage;
— Intestinal worms and their treatment;
— Diarrhoeal, skin and eye diseases and their treatment.

The training is intended to modify committee members' habits and create the desire to change their behaviour. To facilitate changes in behaviour and to set an example for other villagers, committee members are encouraged to build latrines, bathing shelters, refuse pits and dish racks: the committee as a whole is encouraged to build a washing slab near the tap (see figure 15). The project supplies supervision and cement, while committee members supply other materials and labour.

Looking at the results of the programme in 1986, HESP staff evaluated 13 HESP areas as having 64 per cent of households with latrines, as compared to 35 per cent before the HESP programme and 55 per cent for the national average; however, a number of these collapsed during the rainy season. (Warner and others, 1986) In 1984, HESP workers evaluated all HESP areas as having dish-racks in 44 per cent of households; however, there is no pre-HESP or national statistic with which this finding can be compared. In 1986, 103 washing slabs had been constructed (Warner and others, 1986), whereas washing slabs did not previously exist in project areas. Based on these data, HESP has had a significant impact on construction of hygiene and sanitation infrastructure.

HESP is giving indications of long-term sustainability. The first indicator is that the morale and performance of HESP field staff is so much better than that of other staff that there is now a demand within MOH to spread HESP to new areas. Secondly, MOH is finding new sources of funding: 1985 saw the initiation of a $US92,000 WHO and UNICEF funded project, including the construction of washing slabs and 110 pilot VIP latrines in areas served by USAID- funded piped-water schemes. Also, in 1985, UNICEF funded a four-year project for training and supporting 50 HESP workers for areas served by groundwater programmes. (Warner and others, 1986)

2. Research projects

Research projects have been carried out, either to solve technical problems encountered in the field or to expose the relationships between improvements in water supply and sanitation and specific aspects of health, behaviour and social organization. On the technical side, excessive pipe breakages and corrosion in the Mulanje area were traced to unstable soils, poor AC-pipe manufacturing and, particularly, to chemically aggressive waters: researchers found that placing a layer of limestone rocks in screening and sedimentation tanks was sufficient to improve the pH from 6.4 to 7.2. (Warner and others, 1983) Problems with excessive siltation in the upper section of the mainline and sedimentation tanks of several schemes led to re-examination of the intake design: experiments produced an intake which both reduced the size of intake holes, thus admitting fewer particles, and increased the open surface area, thus reducing suction.

As previously mentioned, project planners are considering less favourable sites than those used to date. The main problem encountered is water quality, i.e., high turbidity and high bacteria counts. Experiments and pilot projects are running to develop a slow sand filter, to treat the bacteria, and a pre-filter, to reduce turbidity. Results from the

Mwanza pilot treatment works show waters of 350-400 NTU being reduced to 80 NTU by the prefilter and, then, to 20 NTU by the slow sand filter. (personal communication, Water Treatment Engineer) The coliform count is reduced one order of magnitude by the roughing filter and a further two orders of magnitude by the slow sand filter. (Warner and others, 1983) In response to questions raised on the bacteriological quality of water in existing schemes, a wet-season and dry-season analysis was carried out by the MOWS Water Quality Laboratory (see section VIII.A for results).

The rural water-supply programme in Malawi has provided fertile ground for research into the nature of water-supply, sanitation, health, behaviour, and social-organization relationships. Malawi has areas with both a piped-water scheme and HESP, other areas with a water scheme only and other areas with neither, each of which can be studied and contrasted. In addition, construction is still in progress, so that a given population can be evaluated before and after the introduction of improved water supply and/or sanitation. Studies have included:

(a) User participation in rural water supply (Msukwa, 1983);

(b) Water collection and use (Easton, 1985; Easton, 1985; Young and Joseph, 1986);

(c) Institution building for the maintenance of rural piped- water schemes (Msukwa, 1986);

(d) Relation of rural piped-water supply, HESP and breast- feeding on diarrhoeal disease (Linskog and Linskog, 1985; Young, 1986; Young and Briscoe, 1986).

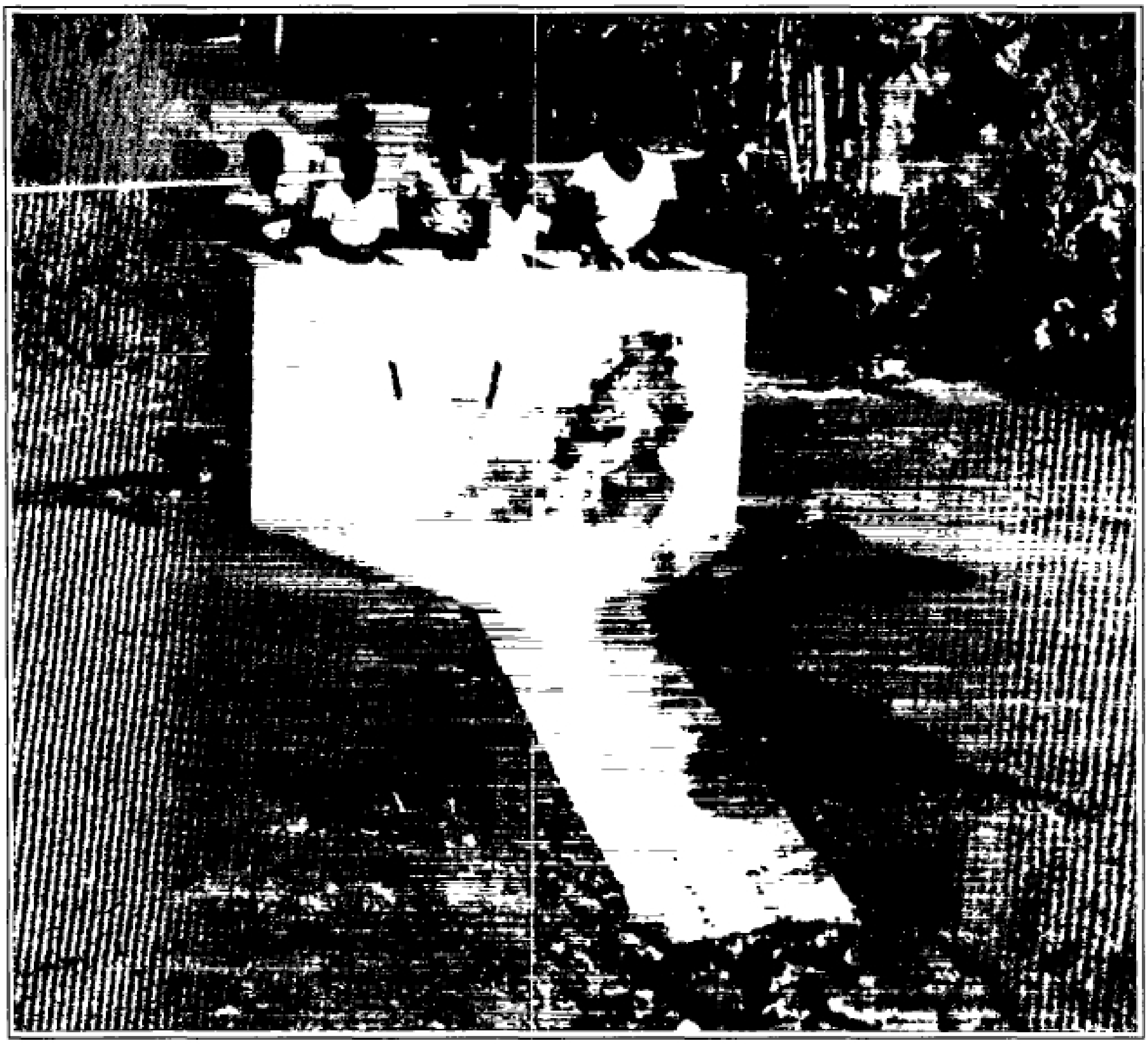


Figure 15 Users at clothes washing slab, drain and soakaway

IX. FACTORS CONTRIBUTING TO PROJECT SUCCESS

The Malawi Rural Water-supply Programme is a success, in that it consistently delivers sufficient high-quality water to meet users' needs: in addition, the Programme has had several positive impacts, including health improvements and, for some users, time saving. The reasons for this success are numerous. In the preceding sections, project strengths were highlighted through descriptions of the various aspects of the project: this section is a summary of the factors contributing to project success.

A. Guiding principles

There are certain principles or approaches on which the Section's programme has been built and which influence virtually every aspect of it. First, users need to be involved in every aspect of the programme to the maximum. It is this involvement which makes users feel that the system is truly their own, so that they take responsibility for construction and maintenance. Secondly, project staff members have the restricted role of adviser vis-à-vis users: the responsibility for organizing and supervising users lies exclusively with community leaders. When organization is required, staff members work with the leaders who, in turn, direct the people. When training is required, staff members rely on demonstrations, role-playing and other non- lecture techniques, so that users see for themselves rather than are dictated to. Thirdly, procedures are standardized wherever possible in design, planning, execution, monitoring and maintenance, so that the optimum procedure, based on total accumulated experience, is the one used on all current projects. This reduces the amount of supervision required by field staff and helps smooth the effects of high turnover in engineering staff. Fourthly, there are continual evaluation and improvement. The Section is forward-looking, anticipating and adapting to new situations as they arrive. The programme began as a one-off construction project, but senior staff members saw the potential of the rural population, created the Section as a permanent institution, hired, trained and retrained more than 90 staff members, developed appropriate maintenance, monitoring and research programmes, and began collaborating with HESP.

B. Geography

The numerous perennial streams with moderate flows from highland areas have the potential to serve 20 per cent of Malawi's total population without treatment or pumping.

C. Political will and organization

As policy, Malawi encourages rural development through self- help, thus providing the Section the necessary access to users. Members of Parliament recognize the need for water in rural areas and demand new schemes during parliamentary sessions. At the field level, the tradition of discipline within MCP and its roots that reach into every village make it an effective force in motivating and organizing users. The authority of MCP is fully recognized, so that, when party members participate in user- committee decisions and give directives, they are respected.

D. Personnel

Personnel of the Section have been one of the key factors to success. The dedication and team spirit manifested has elasticized the 40-hour work week, encouraged imaginative problem-solving and instilled enthusiasm in the community. Key factors contributing to the cohesiveness and competence of the field staff are the selection, training and promotion procedures described in chapter III.

A special mention must be made of the man who conceived the idea of gravity-fed piped-water schemes, designed and executed the first scheme (in part with his own labour), stayed on to lead the Section through 18 years of radical expansion and three Ministries and left behind an institution capable of functioning without him - Lindesay Robertson, Scottish missionary and military engineer.

E. Technical aspects

A prerequisite to project success is that the installation must work. All the community motivation and institutional/political support possible cannot compensate for a system which continually breaks down or supplies insufficient water for users' needs. Project design has started from the guiding principle of user-participation and added in the local conditions to fulfil the list of criteria in section V.B. All these criteria have contributed to the continuing flow of water, but the most critical requirement for user-participation in planning, execution, operation and maintenance is simplicity of design.

F. Planning and execution

Aspects of planning and execution which contribute significantly to overall project success are:

(a) Scheduling of execution activities around the annual subsistence farming activities takes advantage of user availability;

(b) Use of simple construction tools and techniques permits easy mastery of construction activities by self-help labourers, which can then be repeated when necessary during maintenance or repairs without further instruction;

(c) Use of local contractors keeps costs down, leaves the builder in the community in case of repair and, on a subtle level, makes villagers feel that tanks are an accessible technology because one of them built them.

G. Operation and maintenance

Factors in operation and maintenance which have helped keep water flowing include:

(a) Operation of the system is exceptionally easy - the turning of a tap;

(b) Routine maintenance is minimal, involving one person for one to two hours per day at the intake and one person for five minutes per day at each tap;

(c) Technical skills required to repair the majority of breakdowns (taps and PVC pipes) are well within the capacities of repair teams;

(d)Spare parts and materials are available;

(e) Monitoring assistants are well-known to the community and available when exceptional failures occur;

(f) A monitoring programme keeps a balanced presence of the monitoring assistant in all villages and prevents some failures.

H. User participation

User participation has already been mentioned as one of the guiding principles of the programme. However, its importance cannot be stressed enough. What should be noted about the Malawi programme are the range of activities in which users participate and the responsibility placed on their shoulders. These activities are listed in detail in annex III but, in short, they range from making an application for a project to choosing tap sites, organizing and supervising labour, labouring and participating in evaluations.

I. Other contributions

Although HESP has not directly contributed to the continuing flow of water, except through the reinforcement of community organization, it has been a critical factor in creating a health impact. Research activities, many of which were initiated in response to problems identified during maintenance, have been able to improve the design of and the materials used in schemes.

X. REPLICATION

Having looked over the various aspects of the Malawi Rural Water-supply Programme and the factors contributing to its success, the question arises: "How much of the Malawi programme is replicable in another setting?"

A. Guiding principles

The choice to make the most of users, adjusting technical design, timetabling, decision-making structures, construction technologies and maintenance routines to incorporate them, can be made for any project. However, the degree to which users can be incorporated varies with project design. Because of the wide- reaching implications, the decision to maximize user participation needs to be made early in project planning, and one of the results of this decision is the creation of user committees to make project decisions and organize labour. The idea of thousands of people forming their own committees and making their own decisions might not be supported by all governments. However, the incorporation of the existing political organization (e.g., MCP in Malawi) in the committees might surmount that obstacle and, in the long run, strengthen the water-supply project.

The degree to which committees are permitted to function and the degree to which construction and maintenance activities can be routinized control how directive field staff need to be. The more responsibility which can be taken by local leaders, the more staff can attend to specific problems and advise. Regardless of the community organization, demonstration and role-playing can be used in most training situations.

The standardization of procedures is possible and desirable in any situation where an activity is going to be repeated several times. It can be applied to virtually any activity - design, approval, strategies etc. - but is particularly helpful for user activities, e.g., trench digging, PVC-pipe fitting, tap and surround cleaning, and tank cleaning because it reduces confusion. Routine procedures are best developed after the activity has been done a few times and should be modified as new information comes in.

B. Geography

Unfortunately, geography is not transferrable. If the surface water available is not of acceptable quality, treatment will be necessary. Malawi is already several years into slow sand filter and prefilter research but has yet to prove sustainability in terms of user maintenance. If the surface water is insufficient in quantity or does not flow from highlands, changes from the Malawi design, i.e., dams and/or pumping, will be required. The success of this adaptation will depend on the ability of the new-type scheme to meet the design criteria in section V.B. which create the conditions for user operation and maintenance.

C. Political will and organization

Political will, even if not initially supportive, can usually be influenced over the long term. Keeping local politicians and district administrators abreast of project activities and incorporating them in decision-making create a oneness of purpose which might eventually work its way up the hierarchical ladder to the most influential persons. Also, as time goes on and the project produces increasing numbers of waterpoints and increasing numbers of satisfied villagers, politicians will want to be associated. Disciplined political organization at the field level might or might not be present. Organizational skills gained on the project might improve local political organization, but, for a rural water-supply project intentionally to create a political organization, may, in most cases, be unnecessary.

D. Institutions

In some cases, planners are able to choose to start the project in a community development/social affairs oriented ministry, so that the time, effort and funds spent on users will be accepted. Collaboration with the water ministry can then be obtained for necessary technical inputs. The addition of an HESP project, in collaboration with the health ministry, is usually dependent only on funding. The funds to be spent can be justified by the fact that a water-supply project can only attain health impacts by the association of an HESP project.

E. Personnel

The Section staff cannot be transferred to another project; however, the procedures used to select, train, motivate and maintain staff can be transferred (to the degree that nepotism and corruption are absent), thereby creating a similar work environment. To the extent that careful selection and a similar work environment affect personnel performance, the Section team spirit can be reproduced.

F. Technical aspects (design)

It is unlikely that the Malawi design is the best design for any other country, because of differences in geography and availability and cost of materials. Adaptations or completely different concepts of water-supply systems must meet the scheme criteria, in order to maximize user-participation in long-term operation and maintenance.

Reviewing section V.B., the criteria are conceptual simplicity; ease of installation, operation, maintenance and repair; durability; availability and transportability of materials; and low cost. The key to the Malawi scheme's simplicity and, therefore, design success is that it operates by gravity. Designs using this feature have an advantage over designs with working parts, e.g., pumps.

G. Planning and execution

The whole phase of project planning is reproducible on any project, including project initiation, project selection and, particularly, project timetabling. During execution, the choice to go with maximum user-participation dictates the use of simple tools and construction technology, which is possible on many projects but is dependent on project design which, in turn, is a function of geography.

The time required to work through user-committees, construct by hand, train users etc. might be much longer than if the project were executed with state-of-the-art equipment; but, in fact, the time staff spends day after day in the company of the users is actually an advantage, because it builds up a trust in the staff and a solid knowledge of the construction (and, therefore, repair) technology. For a project of similar design to that of Malawi, the time lost is more than compensated for by the benefits of user execution. Staff and local leaders in any project can be trained to maintain high standards of quality control.

H. Operation and maintenance

By the time a project reaches the operational and maintenance stage, most of the activities have already been determined by project design and skill of execution. As with the Malawi project, a project can place the responsibility for maintenance on the users, provided that the users receive necessary training during construction and periodic recycling thereafter, are given the necessary tools, have access to spares both physically and financially, and have a continuing staff presence to maintain technical and moral support. The degree to which any one or more of these factors is absent creates a corresponding need to increase the presence of staff to ensure operation and maintenance.

I. Summary and conclusions

Of the factors contributing to project success, it is the guiding principles which are most easily reproduced, because they are essentially decisions on how the project will approach the problem of rural water supply. The most critical of the principles is that the users need to be involved, as much as possible, in the planning, execution, operation and maintenance of their water-supply system. The important factor of staff dedication and competence can be controlled to some extent, but there is always an element of chance in who is available at the time of recruitment. Factors contributing to success which cannot be replicated are geography, political organization and stability, lack of corruption, and availability and cost of materials. These factors must be accepted as they are and the project designed around them in accordance with the guiding principles.

Annex I

RURAL PIPED-WATER PROJECTS - COMPLETED

Project	District	Region	Population involved	Length of piping (km)	Number of taps	Cost of material (Mk)*	Date completed
1. Chingale	Zomba	South	5,000	40	60	6,000	1969
2. Chambe	Mulanje	South	30,000	96	180	64,000	1970
3. Migowi	Mulanje	South	6,000	24	45	12,000	1971
4. Chilinga	Mulanje	South	2,000	10	14	4,000	1972
5. Ng'Onga	Rumphi	North	2,000	17	20	6,000	1972
6. Muhuju	Rumphi	North	1,000	19	21	7,000	1973
7. Chinkwezulu	Machinga	South	700	2	9	1,000	1974
8. Ighembe	Karonga	North	4,000	17	36	7,000	1974
9. Mulanje W.	Mulanje	South	90,000	237	460	170,000	1975
10. Luzi	Mzimba/ Rumphi	North	8,000	59	44	24,000	1975
11. Chinunkha	Chitipa	North	4,000	25	51	12,000	1975
12. Chilumba	Karonga	North	4,000	17	29	8,000	1975
13. Chilombwe	Ntcheu	Central	1,200	6	14	2,000	1975
14. Phalombe	Mulanje	South	140,000	400	660	500,000	1977
15. Dedza	Dedza	Central	1,400	8	10	5,000	1976
16. Mchinji	Mchinji	Central	20,000	136	215	52,000	1976
17. Chagwa	Machinga	South	7,000	80	110	15,000	1976
18. Kalitsilo	Ntcheu	Central	1,000	6	13	3,000	1977
19. Lifani	Zomba/ Machinga	South	20,000	100	152	72,000	1977
20. Hewe	Rumphi	North	8,000	42	42	30,000	1977
21. Nkhamanga	Rumphi	North	12,000	75	120	134,000	1978
22. Luzulu	Ntcheu	Central	6,000	24	34	20,000	1978
23. Namitambo	Chiradzulu/ Mulanje	South	60,000	290	360	480,000	1979

Project	District	Region	Population involved	Length of piping (km)	Number of taps	Cost of material (MK)*	Date completed
24. Sombani Mulanje	South	40,000	184	300	240,000	1979	
25. Ntonda	Ntcheu	Central	25,000	120	194	120,000	1980
26. Lingamasa	Mangochi	South	12,000	43	118	50,000	1981
27. Zomba	Zomba (Domasi)	South	100,000	448	813	711,000	1981
28. Luwazi	Mzimba	North	8,000	80	54	79,400	1981
29. Nalipiri	Mulanje	South	9,000	27	55	40,000	1980
30. Muloza E.	Mulanje	South	32,000	150	180	120,000	1980
31. Luchenya/ Muloza	Mulanje	South	46,000	168	270	180,000	1982
32. Karonga	Karonga	North	30,000	195	250	290,300	1983
33. Kawinga	Machinga	South	70,000	571	450	926,600	1983
34. Nthalire	Chitipa	North	3,000	21	46	66,500	1983
35. Liwonde	Machinga	South	23,000	110	130	198,000	1983
36. Kasinje	Ntcheu	Central	14,000	32	95	60,000	1983
37. Nanyangu	Ntcheu	Central	20,000	53	131	150,000	1983
38. Iponga	Karonga	North	5,600	24	35	40,000	1983
39. Nuloza S.	Mulanje	South	8,000	22	45	40,000	1983
40. Dombole	Ntcheu	Central	22,000	107	140	286,700	1984
41. Champira	N.Mzimba	North	24,000	167	154	236,000	1984
42. Mwansambo/ Kasakula	Nkhotakota/ Nchisi	Central	25,000	60	145	157,300	1984
43. Misuku	Chitipa	North	3,700	17	70	40,900	1984
44. Sumulu	Machinga	South	23,500	80	100	261,000	1984
45. LivingstoniaRumphi	North	3,000	15	21	9,600	1984	
46. Mirala	Machinga	South	13,000	56	81	108,000	1985
47. Makwawa	Zomba	South	16,000	68	101	93,000	1985
			1,009,100	4,556	6,685	6,148,900	

*MK 1 = $US2.30, August 1987.

Annex II:
Rural Piped-Water Projects - Under Construction 1987

	Project	District	Region	Population involved	Length of piping (km)	Number of taps	Cost (MK)*
1.	Chitipa + extension projects	Chitipa	North	46,000	323	300	303,400
2.	Mwanza	Chikwawa	South	40,000	218	400	1,079,400
3.	Chimaliro	S.Mzimba	North	32,000	221	200	512,400
4.	Zomba W.	Zomba	South	60,000	340	353	690,800
5.	Msaka	Mzimba	North	3,000	37	35	58,200
6.	Lifutazi	Nkhata Bay	North	6,000	40	43	33,800
7.	Mwanzambo/ Mwadzama	Nkhota -Kota	Central	18,000	50	100	60,800
8.	Mulanje	S. W. Mulanje	South	24,000	117	140	708,000
9.	Mpira/ Balaka	Machinga (rural)	South	260,000	15,000	1,850	?
				489,000	16,346	3,421	3,444,000+

*MK 1 = US$2.30, August 1987.

Annex III

USER PARTICIPATION

Planning

— initiate request
— make formal application
— prepare annual programme based on users' availability

Design

— identify water source
— delimit project areas, to follow Traditional Authority areas
— approve groupings of users by branch line, to ensure their compatibility
— select tap sites

Execution

— designate Traditional Authority to take responsibility for construction
— create and run main, section, branch and village committees
— plan detailed work programme
— divide user labour to fulfil the programme
— ensure attendance
— supervise labour and control quality
— dig trenches, excavate tank sites, build access roads, load and unload deliveries, transport tools and materials
— collect sand and gravel, load and unload
— supply hoes for digging

Operation

— turn the taps

Maintenance

— designate Traditional Authority to take responsibility for maintenance
— create and run tap committees, review main committee
— initiate and repair all PVC and AC pipes, and taps
— plan and supervise labour
— dig up and backfill broken pipes, clean tanks, clean aprons, drains and soakaways
— hire, supervise and pay an intake caretaker
— buy taps
— stock spare parts and tools
— promote correct use of the tap
— promote hygienic collection, transport, storage and use of water

Evaluation

— participate in project evaluations

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UNITED NATIONS CENTRE FOR HUMAN SETTLEMENTS (Habitat)
PO Box 30030, Nairobi