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# MAINTENANCE SYSTEMS FOR RURAL WATER SUPPLIES

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# PREFACE

The number of water supply systems in developing countries is expanding. Operation and maintenance of these systems is unfortunately lagging behind and is now recognized as a major bottle neck for long term success. Despite of the efforts made sofar the number of systems which are not functioning remains discouragingly high.

Review of existing experience and available literature on maintenance of water supply systems was therefore considered of great importance to establish a basis for further developments and improvements. The preparation was financially supported by the NGO, Education and Research Department, Section for Research and Appropriate Technology of the Ministry of Foreign Affairs.

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## SUMMARY

This report, which is based on available literature and interviews with project staff, reviews current thinking on maintenance of rural water supply systems. Many rural water supply systems are still being constructed without due consideration to a maintenance system and most maintenance systems are not efficient. The review indicated that maintenance is often not successfully organized in projects because poor project formulation, lack of resources, and lack of systematic involvement of users and local authorities. Maintenance of rural water supplies has lagged behind but there is growing recognition of the need for satisfactory maintenance.
Three main approaches have been distinguished:

- technical approach
- organizational approach
- systematic approach

The first two, technical and organizational approaches, have been shown to meet with difficulties; the comprehensive systematic approach appears to be most viable.

Factors affecting maintenance in donor supported projects are outlined including formulation of projects, planning of projects, definition of responsibilities for maintenance, assessment of costs and potential contributions, involvement of users and local authorities, role of women in user organizations, and evaluation of projects. Key factors in the development of suitable maintenance systems are identified: technology choice; institutional arrangements and legislation; logistics; financial viability; manpower development; and monitoring and control.

Towards the importance of maintenance systems four recommendations are made regarding:

- systematic evaluation of maintenance practices;
- systematic analysis of maintenance requirements;
- development of community based management systems;
- project assessment and preparation.

A checklist for maintenance-oriented project preparation and assessment has been drawn up.

## 1. INTRODUCTION

The purpose of the present study is to identify key factors and conditions to be considered in establishing maintenance systems for rural water supplies.

On the basis of a preliminary literature survey of project documentation and evaluation reports, a checklist was prepared as a guideline for interviews and discussions with professional staff involved in rural water supply projects in developing countries. Many of the projects discussed are being financed by the Dutch bilateral aid programme and non-government organizations in the Netherlands. These projects are located in Africa and Asia and one in Latin America. The objective of the interviews was to collect information on individual projects in order to identify problems related to maintenance taking into account prevailing conditions in countries and regions concerned. From the information obtained and a study of additional literature, key considerations for appropriate maintenance systems were identified.

In recent years and within the framework of the International Drinking Water Supply and Sanitation Decade (1981-1990), national governments and donor organizations have tended to concentrate on providing facilities for as many people as possible. However development of maintenance systems has lagged behind because of limited financial resources, as well as manpower and institutional constraints. Many sources report that facilities are not functioning because of lack of maintenance. (Van Ommen, 1982, Bannerman, 1986, Projet Volta Noire, 1985, WASH, 1984).

Often project staff are well aware of the need for an adequate maintenance system but they have tended to deal with immediate short-term problems related largely to the technical aspects of maintenance rather than to develop the financial and organizational aspects which form the basis of long-term maintenance systems. Very often emphasis is placed on what should be done rather than what could be done with the available resources. In many cases a comprehensive view or concept of maintenance has not been developed. Proposed actions tend to emphasize technical or logistic aspects.

As a framework for the present study the following definition of maintenance has been formulated. A maintenance system for rural water supplies is a semi- autonomous organizational and financial structure in an appropriate institutional framework. The system has to ensure and monitor performance of water supply systems in a clearly defined geographic area on the basis of agreed standards. The system needs to have the autonomy to generate and to manage its own financial, material and human resources, and clearly define the duties and responsibilities of those involved. There should be sufficient flexibility within the system to allow for economic, social and demographic development.

In Chapter 2, information obtained from available literature including documentation and evaluation reports about maintenance systems is summarized. In Chapter 3, problems relating to maintenance in projects are described. Chapter 4 discusses key factors which need to be considered in order to create suitable conditions for maintenance. In Chapter 5, general conclusions and recommendations are presented. It also includes a checklist for maintenance oriented project preparation and assessment.

## 2. CURRENT THINKING ON MAINTENANCE

Since the early 1970s investments in rural water supplies have greatly increased, but many of the facilities provided have broken down shortly after construction, because they were not maintained. Experiences in Africa and in Asia show a variety in maintenance problems which differ in nature according to various local factors. (Sundaresan et al, 1982, Benamour, 1985, Van Wijk, 1983). National governments and donor agencies have become increasingly aware of these maintenance problems (WHO/CWS, 1986, CILSS, 1980) and have made efforts to overcome some of them. At present, these agencies put great emphasis on the financing of recurrent costs of rural water supplies, and local maintenance (OECD, 1985).

### 2.1 Maintenance problems

Maintenance problems are reported to have occurred in many handpump programmes (Hessing et al, 1984, Baldwin, 1984, UNICEF, 1985, Hofkes, 1982, Bannerman, 1986). Maintenance was also reported as a major problem in small gravity water supply programmes (Strauss, 1983, WASH, 1983), and other rural water supply systems (WASH, 1981, WHO, 1983, Sundaresan et al, 1982). Most reports point at lack of maintenance capacities and lack of finance as major causes of maintenance problems. Other general problems mentioned are, lack of responsibility on the part of the users; lack of spare parts and materials; lack of capable manpower; poor financial management by local bodies; lack of monitoring, feed-back, control, poor operation; lack of water during dry periods; inadequate communication; lack of transport; insufficient revenues. Many problems have occurred due to poorly constructed wells, boreholes, standposts and storage reservoirs. In pumped water supply systems, operation and maintenance of diesel engines is frequently reported to be hampered by lack of fuel and spare parts. For electrically pumped schemes, power failures have been a major cause of breakdowns (see Table 1).

Table 1: Summary of maintenance problems in existing rural water supply systems

**Dug wells without hand pumps**

- poor construction resulting in collapsing of well lining
- insufficient recharge due to clogging or insufficient depth
- formal responsibility for maintenance and repair not defined because it is often not envisaged

**Drilled wells with hand pumps**

- poor borehole construction resulting in sand intrusion in the well
- inadequate pump selection
- lack of preventive maintenance
- lack of repair capacities and spare parts particularly in the long run
- poor organizational structure
- no revenue collection

**Piped gravity systems with public standposts**

- insufficient spring protection
- poor quality control and adequate construction leading to leaking spring boxes, pipes and reservoirs
- insufficient monitoring and control
- maintenance organizations not legally established
- inadequate revenue collection systems

**Pumped schemes with diesel or electric pumps**

- unsecure fuel supply
- intermittent power supply
- variation in power output of electrical system
- inadequate institutional structures
- lack of preventive maintenance and monitoring
- lack of spare parts and repair capacity
- inadequate revenue collection systems

## 2.2 Assessment of attempts to improve maintenance

Attempts to develop viable maintenance concepts have been mostly linked to the implementation of hand pump programmes, for example in India (WSOB, Tamil Nadu 1977), Bangladesh (MIDAS, 1984) and West Africa (Diluca, 1983). Attempts related to maintenance of piped gravity systems have been more recent, for example in Nepal (Ministry of Panchayat, 1982) and in Rwanda (BCEOM-SAUR, 1985). Most of these attempts focus on two or three-tier maintenance systems, financed by government, and under responsibility of district agencies or local bodies. Gradually, however, the emphasis is shifting towards more community based approaches.

The long term results of attempts to organize maintenance and to identify maintenance tasks are often difficult to assess, because monitoring data are rarely available and do not allow systematic comparison, as is shown by the following example.

In December 1984, a survey was carried out to assess the functioning of the three-tier hand pump maintenance system in four Indian States. In this system a village volunteer is responsible for day-to-day maintenance. At the second tier in the system, a trained mechanic is responsible for the minor repairs for all villages in one block. Major repairs are carried out by a mobile team responsible for several or all blocks in one district. The survey team reported that 75-98% of installed hand pumps were in working order at an estimated cost of maintenance of US$ 37 to 67 per pump per year. Even though it was found that no preventive maintenance is carried out, the system is considered to be successful. However, other sources estimate the maintenance cost to be US$ 200 per pump per year, mainly because of high administrative cost, and suggest that many pumps are not functioning well (Baldwin, 1984, World Water, 1983).

This three-tier maintenance system was strongly criticized and compared with a one-tier community based maintenance system in Rajasthan State (Roy, 1984). Under the one-tier system, all repair work is done privately by a trained villager, who combines the tasks of caretaker, block mechanic and the district level maintenance unit of the three-tier system. For the same Mark II hand pump, annual maintenance costs were estimated to be about US$ 40 per pump in the three-tier system and about

US$ 12 in the one-tier system. Again, other sources (Operations Research Group, 1984) indicate, that the one-tier system does not function well, because the private mechanics leave their job for other occupations.

These differences in assessment are sometimes due to a certain bias in the reports, but often they arise from the fact that different factors are considered. These include cost of repair, cost of total maintenance system, breakdown period, and users satisfaction. Sometimes, they also arise because the difference in the scale of maintenance systems prevents realistic comparison. For example, the above findings cannot be conclusive because a large-scale three tier system run by government is compared with a maintenance system for relatively few pumps organized by a non-governmental agency in one particular area.

## 2.3 Maintenance approaches

From the review of the literature, three main approaches to maintenance can be identified:

- the technical approach
- the organizational approach
- the systematic approach

### 2.3.1 Technical approach

At first, attempts to ensure the long-term functioning of rural water supply systems were based on the understanding that maintenance problems could be prevented by installing very sturdy and robust systems. For instance, many hand pump programmes concentrated on the development of"maintenance-free" pumps (DHV, 1978, Trietsch, 1984, Blankwaardt, 1984). The research carried out has contributed to improved pump design and pump reliability, but feedback from the field has shown that even the very sturdy and often costly pumps broke down and needed regular maintenance. Similar experience with public standposts, water treatment systems, and other components of rural piped water supply systems (Darwawan, 1985, Schramm & Guring, 1981, Sundaresan et al, 1982) indicate, that technology improvements are not sufficient to ensure the reliable functioning of rural water supply systems.

In 1974, Farrar and Pacey rejected the concept of maintenance-free pumps, and have argued that the selected technology was too complicated and therefore not appropriate. In their view a technology needed to be developed which allows for village-level maintenance, that is pumps which can be maintained and repaired by local caretakers with occasional support from agency staff. This shift in emphasis can also be observed in the UNDP/World Bank Rural Water Supply Handpumps Project (Arlosoroff, 1986). This project was designed to test and evaluate hand pumps, and to promote the development of a new generation of hand pumps (World Bank, 1985). While the initial objectives remained at the core of the project, the focus has widened considerably as it became clear that hand pump technology was only one of the factors involved. The project has concentrated increasingly on the promotion of village-level operation and maintenance (VLOM). This approach is considered suitable to reduce maintenance cost which may represent up to 85% of the lifetime cost of handpump installations (World Bank, 1983). However, available documentation does not provide sufficient data to estimate to what extent these costs will actually be reduced. The project has developed a computer programme which shows the potential and financial feasibility of VLOM and it is assumed that field studies will underscore these findings.

Intermediate results of the project indicate, that successful introduction of VLOM pumps greatly depends on higher level support, ongoing promotional activities and on the motivation of users to accept the main responsibility for their water supply facilities. For example, in the Malawi Upper Livulezi Project, timely maintenance carried out by (female) caretakers has helped to prevent breakdown of the pumps. However, it will be sometime before the real effectiveness of this maintenance becomes apparent because of the low number of users per pump, but no breakdowns have been reported since 1982 (World Bank, 1985). Unsatisfactory maintenance as a result of frequent absence of male caretakers has led to the training of women with children in two pilot villages in Thailand. It was considered, that mothers normally spend much time near home. The improvement in maintenance has led to the decision to train more female caretakers.

These examples show that even technology, which can be easily maintained at village level, needs to be properly introduced by involving the users from the beginning. The need to involve users and give them some control is also stressed by van Wijk-Sijbesma, (1983). A case is cited of the performance of local caretakers being very much improved after being put under the control of both the government and village council. She also indicates that involving the community, and particularly the women, in all stages of a project could be the key to improve operation and maintenance of water supply systems.

In Burkina Faso, the regular monitoring in the World Bank test programme has resulted in improved functioning of pumps. Pump breakdowns were reported by the monitoring team and subsequently repaired by the water agency. In Ghana, a similar improvement was observed in this test programme; pumps inside the pilot-test area, being better monitored and receiving higher level support, showed a 50% lower failure rate.

These examples indicate that village level maintenance is more successful with continuing support from outside. Activities in this UNDP/World Bank project are now concentrating on a combination of field tests, training of caretakers, and try-outs of village level operation and maintenance systems (World Bank, 1985). The shift from a technical approach to community-based maintenance can also be observed in community piped water supply projects in Sri Lanka, Indonesia, Zambia and Malawi (Darmawan, 1985, Yun, 1985) and in a gravity piped water supply programme in Nepal (Williamson, 1983). In Nepal, project staff constructed the schemes initially without involving villagers, but because of operational problems, this approach was changed and the communities were involved in construction, operation and maintenance. As maintenance was not carried out adequately, the approach was further adapted and much of the decision making concerning construction and maintenance is now left to the community. Whether this re-orientation is successful has yet not been reported.

### 2.3.2 Organizational approach

The high failure rate of hand pumps has forced implementing organizations to set up maintenance systems. At first, ad hoc repairs were mostly carried out by installation teams. Later on, some organizations started to train maintenance teams and to establish maintenance systems. Often these systems were rather independent of existing structures or governmental agencies, but several organizations have tried to develop a maintenance organization as part of a governmental body, for example the three-tier hand pump maintenance system developed in Tamil Nadu in India (Water Supply and Drainage Board, 1977), the two-tier system in the north and north-east of Guinea Bissau (Stepanistchev, 1981), and the three-tier system for piped supplies in Nepal (Ministry of Panchayat and Local Government, 1982).

In this organizational approach, responsibilities are shared by local communities and relevant government agencies in a decentralized maintenance system. The success greatly depends on technical management of human and material resources (Donaldson, 1984). Decentralization of certain responsibilities reduces maintenance costs (Hofkes, 1982), but requires technology which can be operated and maintained at community level. Further, back-up services for the village caretaker, and supply of spare parts need to be ensured.

Frequency and location of maintenance tasks to be carried out, should be identified before implementing a programme (WHO, 1983). To ensure the availability of sufficient resources including equipment, stores, spare parts, workshops and transport, for preventive maintenance and repairs, agreement needs to be reached on village contributions, support services, and government subsidies prior to implementation.

An analysis of existing or planned hand pump maintenance systems as summarized by Hofkes (1982) indicates that most of the systems seem to have been set up with emphasis on repairs to be carried out, and to a lesser degree on preventive maintenance (Table 2). In general, the central or regional government is responsible for the overall management, including organizational set-up and payment of staff, and users and local authorities do not have a say in or control over maintenance. Mostly maintenance is financed completely by the government. In a few cases there are revenue collection systems but mainly for the purchase of spare parts for minor repairs. In about half of the cases, no clear responsibility is set for manpower development and training, and for distribution and purchase of spare parts. In 75% of cases, no formal provisions have been made to monitor the functioning of the system, and this explains the limited data available on maintenance system performance.

Over the years the organizational approach to maintenance has developed and now includes a wide range of essential elements, but often too little emphasis has been placed on local environmental conditions, local resources for maintenance, and affordability of technology. The choice of technology should be related to these local conditions which determine the maintainability of rural water supply systems. Thus, often the organizational approach has not been successful because of inappropriate technology, and insufficient user involvement.

Table 2: Allocation of responsibilities in maintenance systems in 12 countries* in 1982

| EXECUTIVE AGENTS | Management | Revenue collection | Manpower development (Training) | Supplies (Distribution & purchase | Preventive maintainance minor repairs | Major repairs inspection | Monitoring |
|---|---|---|---|---|---|---|---|
| Central Government Administation | 1,9,12 | | 3,9 | 1.3.9 | | | 9 |
| Regional or District authorities | 2,3,6,7,8<br>10,11,12 | 7,8 | 8<br>3,9,10 | 1,3,6,8,<br>9,10 | 5,6,8 | 1,2,4,<br>5,6,8,<br>9, 10,<br>11, 12 | 8,9,10 |
| Local authorities or sub-districts | 4 | 1,4 | 1 | 1,3 | 1,2,3,7,9 | 3,4,7,<br>9 | - |
| Users | | 4,11,12 | 9,11 | | 1,2,4,7,9,<br>10,11,12 | 3 | - |
| Private sector | - | - | - | 11 | | 12 | - |
| Responsibility not clearly allocated in maintenance system | 5 | 2,3,5,6<br>9,10 | 2,4,5,6,<br>7,12 | 2,4,5,7,<br>12 | | | 1,2,3<br>4,5,6<br>7,11,12 |

* The 12 countries are:

1. Bangladesh
2. India
3. Indonesia
4. Sri Lanka
5. Thailand
6. Ghana
7. Kenya
8. Ivory coast
9. Malawi
10. Tanzania
11. Togo
12. Burkina Faso

### 2.3.3 Systematic approach

This approach to maintenance combines both the technical and organizational concepts but also takes into account environmental conditions, affordability and users involvement. Pacey concluded in 1977 that experience of donor agencies in Bangladesh, India and East Africa showed that the greatest effort was put into technology development.Other aspects of the maintenance problem, such as the social and human aspects were often neglected. Many water projects were implemented as crash programmes, whereas they should be part of a development approach which takes into account the local situation. In an attempt to apply systems theory to rural water supply, Pacey outlines maintenance systems for three situations distinguished mainly by the degree of community involvement as follows:

- total community self-reliance in the manufacture and maintenance of pumps;
- partial self-reliance, with factory-made pumps and villagers partly responsible for maintenance;
- no community involvement, sturdy pumps are provided and maintained by the government.

For each of these situations he addresses technology choice and maintenance organization, the level of training, local production potential, and quality control. Pacey's ideas form the basis for the systematic approach to maintenance, but do not sufficiently address aspects, such as finance, spare parts supply and management organization. These aspects received more attention from Shawcross (1978), who stressed the relationship between the local conditions for maintenance, the organizational set-up of a maintenance system, technology selection and financial resources. He proposed a step-wise decision-making process which includes two main stages:

- selection of a general maintenance strategy (comparable with the three 'typical' situations outlined by Pacey);
- definition of the most suitable organizational set-up on the basis of available governmental capacities and local resources for maintenance.

In the first stage, six key factors are considered: type of hand pump feasible in view of prevailing geohydrological conditions, population density, government structure, technological level of the local society, existing maintenance systems, and socio-economic conditions at community level. Shawcross does not show clearly how the results of this first stage in the process can be used to determine the most suitable organizational set-up, and how users can be involved in the decision-making process.

Field experiences show that local factors are best taken into account by involving users in decision-making. For example, the Yatenga-Comoe village water supply project in Burkina Faso, 24% of the villages preferred open wells to boreholes with hand pumps (BURGEAP, 1986). In some districts in Benin, 60% of the communities refused improvements to their water supply facilities, when their responsibilities were made clear to them. In other districts, where drinking water was scarce, almost 100% of the villages accepted fully these responsibilities and contributed towards maintenance. Experience in other African countries (Diluca, 1983) indicate that early user involvement and clear agreement on responsibilities may lead to lower maintenance costs and more reliable functioning of facilities.

In various African and Asian countries, systematic national approaches are beginning to emerge in piped water supply demonstration projects (Yun, 1985). In these projects, community level financial management and bottom-up planning are considered as key conditions for the sustainability of the systems (IRC, 1986).

Considering, the growing success of these, and similar efforts, the systematic approach seems to be the most viable approach to maintenance. Therefore this approach is used to identify the key factors to be considered in maintenance, which are set out in Chapter 4.

## 2.4 Cost of maintenance

Few suitable cost data on the construction and maintenance of water supply systems are available, and the data available show wide variation. For example, in 1984 the Asian Development Bank, published figures of the per capita investment cost of various types of water supply systems in 19 countries (Appendix I). For dug wells with handpumps per capita investment cost ranged from US$ 5 to 80 being on average

US$ 30. For a water supply system which includes treatment and distribution the range is US$ 60 to 550, being on average US$ 185. Annual operation and maintenance costs of completed schemes were not provided but were estimated to range from 3 to 8% of the construction cost (ADB, 1984). This wide range indicates that it is not possible to use general cost data for a realistic cost estimation. Such general data can only be used for an overall comparison of different service levels and to estimate the economy of scale (World Bank, 1976).

In Thailand various types of systems for 750 and 2000 consumers were compared (see Appendix II). The total annual per capita cost was found to be 35 to 60% lower, and the per capita operation and maintenance cost 30 to 50% lower for the larger system (2000 consumers). The total annual per capita cost of public standpost systems was almost half of that of a system with house connections.

Different cost elements need to be considered for realistic comparison of maintenance costs (see Table 3). Cost data presented in the literature are not only difficult to compare because they are based on different economic conditions, but also because very often it is not clearly stated what costs have been included. For example, full costs of transport, staff and support organization are often not included. Also, these costs are difficult to assess and may not exclude costs resulting from inefficiency in the functioning of the system. For instance, the West African Development Bank (BOAD) financed in 1979 and 1980 maintenance programmes in two projects in West Africa, for 100 and 150 boreholes with hand pumps. Annual maintenance costs were estimated at about US$ 180 for the first and about US$ 90 per borehole in the second project. In spite of these high costs, 30% of the installations do not function (BOAD, 1986). At present the BOAD estimates the maintenance costs (including depreciation of hand pumps, but not boreholes) at about US$ 170 for a village based maintenance system, and about US$ 210 for a governmental decentralized maintenance system. Considering that no costs for government support are included in the village-based system, these estimates indicate no conclusive evidence that village-based systems are cheaper than government maintenance systems.

Table 3: Possible cost elements for operation and maintenance

**Local Level**

- salary costs for caretaker(s) and village mechanic(s)
- spare parts, if locally purchased
- fuel and grease
- material for repair of system (e.g. cement, gravel, etc.)
- upkeep of tools and repair equipment
- cost of revenue collection
- cost of major repairs by private sector (if possible)

**Regular higher level support**

- cost of monitoring including salary costs, transport, data analysis and overhead
- salary of repair team (if available) including overhead and administration
- transport of repair team
- cost of spare part distribution system
- cost of workshop for maintenance and repair of pumps equipment and vehicles
- cost of offices
- training

**Irregular higher level support**

- replacement of major components including salaries, transport and overhead
- cost of external support (often carried by donor organizations)

An overview of annual recurrent costs in Sahel countries (CILSS, 1980) indicates that the recurrent costs of dug wells are about US$ 125. These costs do not include major repairs and improvement of captation systems. For hand pump systems, the same study indicates the average annual maintenance cost to be about US$150-175. However, these costs are only for pump maintenance and do not include borehole maintenance. These type of cost estimates do not provide a reliable basis for cost comparison, unless systematic information is provided on maintenance standards, service level and coverage (see Chapter 4).

In many countries, maintenance costs are shared to varying extents by government, users and donor agencies. In Indonesia, it is government policy to cover operation and maintenance costs from revenue collection by the responsible regional water enterprises. However, the water tariff set by the government seems to be too low and government subsidies or continuous donor support is required. In Burkina Faso, activities in the water sector are carried out by various government and non-government organizations and receive support from a large number of donors. A study in 1981 (DHER, 1981) estimated that to maintain or replace the 5000 existing pumps and wells, about US$ 1 million would be required annually which was 70 to 80 times the available budget for maintenance in 1979. In Malawi, the construction of piped water supply systems in rural areas started in 1968, and has continued with financial and technical assistance from many donors. Communities are involved in the construction of the schemes, each scheme serving a large number of communities. Maintenance and repairs of older schemes are carried out by teams working on new donor supported schemes. To date this has worked well, but when donor support is reduced additional financial arrangements will be required. It is not yet decided how this problem can be solved.

Other countries consider water supply a basic need which has to be supplied free of charge, that is at the expense of the government, but many countries no longer can afford the ever increasing maintenance costs. According to the World Development Report 1984, the number of people in low income and lower middle groups in developing countries is expected to increase by about 50 million per year. Assuming a per capita investment of US$ 20-60 (see Appendix II), the investment required to keep pace with demographic growth would be about US$ 1 to 3 billion per year. If the annual costs of water supplies are estimated to be US$ 3-5 per capita, the annual budget required for rural water supply investments and running costs would be about US$ 12 to 15 billion. During the first half of the 1980s, external funding has been maintained at about US$ 2 billion annually (WHO, 1984, UNDP, 1985). These figures indicate that US$ 10 to 13 billion needs to be paid annually in addition to donor finance. This would consume a considerable part of the budget of governments in developing countries, but distributed over the consumers, the amount is acceptable, provided that revenue collection can be organized.

A World Bank study (1976) states that in general people are willing to spend about 3% of their cash income on water supply. The Gross National Product per capita in the countries concerned is in the range of US $ 200 to 1600 per year, the average being US$ 400 per year. This means that per capita, US$ 6 to 50 could be made available yearly for water supply systems. Another rule of thumb has also been suggested, that the construction costs of water supply projects should not exceed 10% of the average annual household cash income (WASH, 1984). Both rules give only an indication and should be used carefully in view of the considerable range in income levels.

Using the high estimate for maintenance of 8% of the construction cost (ADB, 1984) and the cost data presented in Appendix I, it seems that consumers can pay for maintenance and sometimes also for the construction of water supply systems, although not for the same service level for everyone. This is confirmed by field experience. For instance, in the Kita region, Mali, it was concluded that poor villages could make an annual contribution of US$ 80 per pump, and pay US$ 50 per year in kind to remunerate rural mechanics. Some, but not all, villages were also expected to contribute to the recovery of capital costs (unidentified author, 1984). Donors increasingly stress the need for users to pay at least the maintenance costs (OECD, 1985, WHO/CWS, 1986, PAHO, 1986). However, national governments and donors have to co-ordinate their efforts to establish revenue collection systems. Particularly in rural areas, the average income will be lower which sometimes means that either a lower service level will have to be adopted or a cross-subsidy be given to make the system affordable for the consumers. Suitable community based financial management systems, for example as used in Burkina Faso (Diluca, 1986), will be required which take into account the variation and range in income over the year and within the community.

## 3. FACTORS AFFECTING MAINTENANCE IN DONOR SUPPORTED PROJECTS

This chapter is based on information obtained from interviews with professional staff involved in 22 rural water supply projects and programmes. Most of the projects have received or are receiving financial support from the Netherlands Government or Dutch non-governmental organizations. These projects include 10 piped supply projects, 7 hand pump projects, 2 well construction projects and 3 rural development projects.

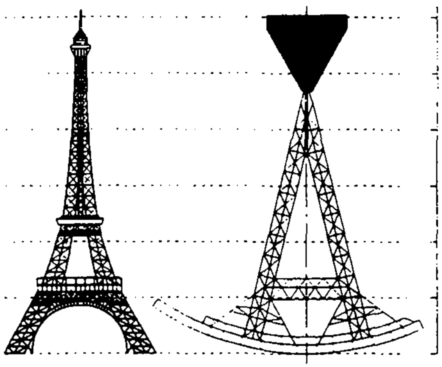
From the interviews, it became apparant that maintenance is generally not very successful. To solve the problem of systems being out of order, projects have started research activities, although mostly these activities are not part of project objectives. Mainly, this research has focussed on technical improvements and the development of "maintenance-free" technology. Other projects trained part of their staff to carry out maintenance tasks, but in general efforts to solve the maintenance problem have been scattered and did only partly address the most important aspects.

### 3.1 Formulation of projects

Formulation of projects seems to receive too little attention. Particularly the long-term effects of a project are not explored, but are said to be the responsibility of the country concerned. General funding criteria set out by donor agencies are formally met but the actual conditions under which the project is carried out are often not checked.

Projects do not properly establish planning criteria (coverage number of users per system, priority villages), service levels (discharge rate, walking distance, water distribution system) and technology levels (improved traditional wells, lined wells, hand pumps, different types of piped water supplies). If criteria were defined, these were not based on sufficient analysis of the sustainability of spare parts provision, institutional and financial requirements for maintenance, and availability of managerial capacity.

* *Het Keringhuis is toegankelijk voor rolstoelen.*
* *Er is een restaurant aanwezig.*
* *Het is mogelijk om na overleg aan te meren met een boot (rondleiding wel verplicht).*
* *Ruime parkeergelegenheid aanwezig.*

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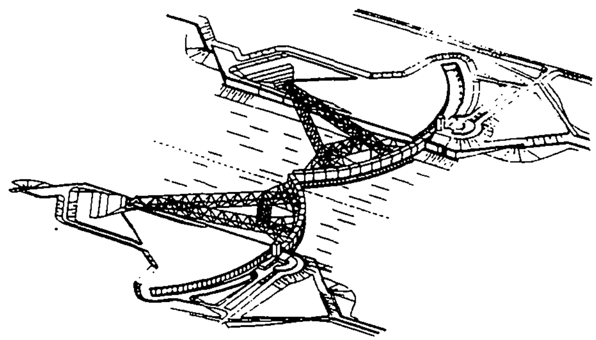
# het Keringhuis

informatiecentrum Maeslantkering

## PRAKTISCHE INFORMATIE



**Openingstijden Keringhuis**

Maandag t/m vrijdag: 10.00 tot 16.00 uur
Zaterdag en zondag: 11.00 tot 17.00 uur

## Rondleidingen voor groepen

Het Keringhuis verzorgt rondleidingen op afspraak voor verschillende groepen (o.a. algemeen, technisch, scholen).

Maandag t/m vrijdag 09.30 - 11.00 - 13.30 - 15.00 uur

| | |
|---|---|
| Kosten: | 8 ~~75~~,- per 50 personen |
| Reserveren: | telefonisch, per fax of in het Keringhuis zelf |
| Duur: | ca. 90 minuten |
| Talen: | Nederlands, Engels, Duits |
| Programma: | * film<br>* uitleg in het Keringhuis<br>* bezoek aan de bouwplaats van de stormvloedkering |

De groep kan gebruik maken van de voorzieningen van het restaurant.

**Scholen**

Het is mogelijk om met een klas een speciale rondleiding te volgen. Max. 35 leerlingen, tot 16 jaar

| | |
|---|---|
| Kosten: | 35,- per klas |
| Reserveren: | telefonisch, per fax of in het Keringhuis zelf |
| Duur: | ca. 60 minuten |
| Talen: | Nederlands (andere taal in overleg) |
| Programma: | * film<br>* uitleg in het Keringhuis<br>* puzzeltocht, beroepenuitleg of uitleg bij uitzichtpunten (<u>niet</u> op de bouwplaats) |

**Symposia en Lezingen**

Het is mogelijk om in combinatie met een rondleiding voor een dagdeel een zaal te huren voor een lezing of klein symposium (neem voor meer informatie contact op met Patricia de Vries).

**Rondleiding particulieren**

In het weekend zijn er gratis rondleidingen in het Keringhuis (11.30 - 12.30 - 13.30 - 14.30 - 15.30 uur). Deze rondleidingen gaan <u>niet</u> over de bouwplaats.

# RESTAURANT HET KERINGHUIS

Vanuit Restaurant het Keringhuis heeft u een uniek uitzicht op de Maeslantkering en de Nieuwe Waterweg. Onder het genot van een hapje en een drankje kunt u de stormvloedkering van heel dichtbij bekijken en de drukke scheepvaart volgen. Bij Restaurant het Keringhuis zijn ook speciale arrangementen in combinatie met een rondleiding voor groepen mogelijk.

## Groepsarrangementen

* Koffie/thee
* Koffie/thee met gebak, koek of saucijzenbroodje
* Diverse lunches
* Warme en koude buffetten
* Diverse dranken en borrelgarnituur

## Lunch aanbiedingen

<u>Koffietafel A</u>

| | |
|---|---|
| *soep van de dag* | *1 x thee of koffie* |
| *5 soorten brood* | *1 x melk of karnemelk* |
| *5 soorten beleg* | |

<u>Koffietafel B</u>

| | |
|---|---|
| *soep van de dag* | *1 x thee of koffie* |
| *vleeskroket* | *1 x melk of karnemelk* |
| *5 soorten brood* | *5 soorten beleg* |

<u>Koffietafel C</u>

| | |
|---|---|
| *soep van de dag* | *1 x thee of koffie* |
| *gevulde paprika* | *1 x melk of karnemelk* |
| *5 soorten brood* | *salade* |
| *5 soorten beleg* | *fruit* |

**Neem voor nadere informatie en speciale wensen contact met ons op!**

Most reviewed projects have emphasized the construction of water supply facilities to increase coverage. The following procedure is often followed: A general inventory of existing facilities is compared with population figures for villages and districts in the project area. The maximum number of users per facility is derived from the assumed output of the proposed water system, and minimum daily per capita water consumption. A list of villages to be covered is composed with the highest priority to villages with the lowest per capita daily water consumption. This list is used to plan the construction activities.

This procedure does not include community participation as a main step in project preparation. As a result the selected technology often was too costly and did not comply with the needs and the technical capabilities at the local level.

Other inadequacies in project formulation have had consequences for maintenance. For example, in arid countries, mainly in the Sahel where water is needed urgently, thorough physical and geological surveys are often required to assess whether water is available during dry periods. Yet in response to the severe water shortages, many projects have been implemented without due attention to general hydrological, geological and environmental conditions.

In most water projects, public health and sanitation related activities are not formulated at the start, but introduced at a later stage for example, to motivate people to carry out maintenance. Only in the project in Latin America, health and sanitation were promoted together with water supply before implementation. Nevertheless, maintenance problems have occurred in this project because of lack of follow-up and back-up support by the government.

### 3.2 Planning of projects

Projects have faced serious management problems as a result of too rapid build-up of construction capacities. Planning of activities is normally based on fairly high quantitative targets, which do not allow sufficient flexibility in project implementation. Very rarely, projects start with pilot phase to test the technology and the planned procedures for implementation. Lack of job-specific preparation of technical assistance staff and time consuming selection procedures have caused expatriate staff to become effective too late. Local counterpart staff is often not well trained, or is transferred too often. These management problems urge projects to deal with daily problems associated with the construction programme and leave them little time to develop maintenance structures and procedures.

### 3.3 Definition of responsibilities

Projects financed by bilateral or multilateral organizations are generally implemented by the government. Ad hoc project units are set up with technical assistance from the donor and sometimes with the idea to be integrated in a government agency. However, these units, which often have assumed certain maintenance tasks, disappear when projects are terminated.

In general, projects have been formulated and implemented by the central government, mostly the Ministry of Public Works and maintenance and replacement is assumed to be the responsibility of local authorities and/or communities. Often, communities are expected to carry out some day-to-day maintenance. As a result, construction and maintenance are thought of as separate operations to be carried out by different agencies. Generally, it is the responsibility of the Ministry of Home Affairs to supervise local authorities. This ministry, the local authorities and the users may or may not be able to accept responsibility for maintenance, unless this and a clear definition of tasks are agreed upon before the project is implemented. For instance, in most of the reviewed cases, responsible agencies did not have the capacity to maintain the new systems and did not have the competence to introduce water charges or tax systems. In NGO financed projects, tasks are often more clearly emerging. Usually, these projects are carried out directly with users and by-pass existing administrative systems. Maintenance of facilities provided by these NGO-projects is often fully in the hands of, or strongly stimulated by motivated and properly trained individuals, such as missionaries who can guarantee long-term external support for local level maintenance activities. However, this concerns mainly small scale projects.

### 3.4 Assessment of costs and potential contributions

Total annual costs for construction and maintenance have ultimately to be paid by the users and the national government. Thus, these costs should be related to the income of the users and available resources because governments can only subsidize a small percentage of the total annual costs.

According to the interviews, the main local resource used in the projects has been labour. Several projects based technology selection to some extent on a general assessment of local skills in view of maintenance, but did not analyse local financial resources in detail. In North Yemen the capacity of villagers to contribute to construction and to pay for maintenance was underestimated. More villages requested water supply systems, even when they had to pay 40% of the construction costs and pay for maintenance themselves. However other experiences indicate that Yemen is a special case, because many people work abroad and send money to their families, and consequently sophisticated systems with high service levels are affordable (Dop, 1985).

Various projects have found that users are able to keep systems running by replacing major components (such as pump/motors) at their own expense, because they have had sufficient funds to buy these components on the local market. However, there is no preventive maintenance and systems are not operated as planned.

In a number of projects there has been virtually no counterpart contribution in the project costs. In others, a counterpart contribution was budgeted, but did not materialize, except for payment of local counterpart staff. In general, projects were started before definite arrangements had been made about financial management, and payment for construction and maintenance costs. Further, the relationship between rural household incomes and the annual cost of maintenance has not been recognized clearly.

In the projects considered, very few realistic cost figures have been produced. Figures on maintenance are mostly lacking altogether. Data on rural incomes have not been collected, and estimated maintenance costs, based on rules of the thumb, are not verified and do not seem to be realistic. Most cost data available concern construction only and show a wide variation. The price of simple dug wells with technical assistance by volunteers varied from US$ 1000 to 2500 per well; the price of drilled wells with pumps constructed by bilateral donor projects between US$ 5000 and 10 000 per well or borehole in African countries. Assuming 500 users per facility, the per capita construction costs are between US$ 2 for improved traditional wells to about US$ 20 for concrete open wells and boreholes with hand pumps. Maintenance cost data were not available from these projects. These costs are comparable with the Buba Tombali estimates (Visscher & Hofkes, 1982). For small gravity supplies with standposts estimated per capita construction costs varied between US$ 10 and 60. In two of these projects direct maintenance costs were estimated at about US$ 3 per capita year.

In practice, these cost data only provide global indication of per capita costs, because the real number of users per well, pump or standpipe was not known. Donor support to the projects concentrated on construction of new systems and in general donor agencies were reluctant to finance maintenance. Nevertheless they indirectly finance bad maintenance practices by providing funds for rehabilitation or replacement of existing facilities.

## 3.5 Involvement of users and local authorities

In a few cases the involvement of the users is seen as a way to obtain cheap "self-help" labour. While creation of water committees suggests that users are involved in decision-making, this practice is often limited to the organization of village labour and the appointment of a caretaker. In most cases both users and local authorities are involved only on an ad hoc basis and do not really influence decisions concerning technology choice, planning and organization. In only one out of 22 projects local authorities were systematically involved in decision making. Users were involved more often, but only three of 22 projects had involved them in decision making in the three main stages (preparation, implementation and follow-up) (Table 4).

Table 4: Involvement of users and local authorities in rural water supply projects*

| DEGREE OF INVOLVEMENT / MAIN PHASES OF PROJECTS | Project preparation and planning | Project implementation | Follow-up | Involvement in each of the three phases |
|---|---|---|---|---|
| **INVOLVEMENT OF USERS** | | | | |
| Users are being informed and asked for their opinion. | 9 | 10 | 4 | 4 |
| Users have a degree of decision making power. | 4 | 4 | 2 | 3 |
| Users are taking up responsibility and are contributing. | 1 | 5 | 4 | - |
| Users not involved | 8 | 3 | 12 | 15 |
| **INVOLVEMENT OF LOCAL AUTHORITIES (regional, district, municipal)** | | | | |
| Local authorities are being informed and asked for their opinion. | 12 | 6 | 1 | - |
| Local authorities have a degree of decision making power. | 3 | 1 | 4 | 1 |
| Local authorities are accepting tasks and responsibilities | - | 1 | 1 | - |
| Local authorities are not involved. | 7 | 14 | 16 | 21 |

* Based on interviews with project staff in 22 Dutch assisted projects. The figures in the table show how many projects are concerned in each case.

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SANITATION (IRC)

Communities are required to maintain their water supply systems but there is no clear institutional and legal basis on which to base this approach. In most cases, a government support organization for user or community based maintenance needs to be developed. For example, formal agreements with village authorities, including financial institutional and organizational arrangements for the division of tasks and responsibilities between the users, government, local authority and others were made in Ruwanda. In the project concerned, the water agency reaches a formal agreement with the 'commune' which is the local administrative level and with tap committees before a system is constructed.

From the interviews it would seem that local capacities for maintenance have not been the decisive factor in technology selection. The main factor in the selection of gravity supply systems has been the topography. The need to construct many systems in a short period of time has led to the installation of more hand pumps, and less open wells, in particular in the Sahel. Improved pumps were introduced as a result of corrosion of underground components in different parts of Africa. Combined water and sanitation units were used in Indonesia for technical and financial reasons. The level of education and technical ability of villagers to carry out maintenance tasks has not greatly affected technology selection. Training of caretakers was considered mostly after the construction of a number of facilities.

Mostly caretakers are given only basic instruction. They are often selected from among those villagers, who participated in construction work. In a project in Sudan, selected villagers were given training of several weeks, but the intended maintenance system could not be developed because the project was terminated abruptly as a result of the outbreak of civil war. Sometimes users have been demotivated as a result of poor co-ordination among agencies involved in rural water supply. An example was cited of a missionary who had motivated villagers to repair their handpump. The villagers had great difficulty in finding spare parts but finally by the time they had succeeded in doing so, a new handpump tube well was constructed for them by another project without consultation and without having to make a contribution.

## 3.6 Role of women in user organizations

None of the projects had originally developed activities specifically oriented to the role of women in water supply, but in some projects women's participation proved essential for maintenance of facilities. The Ruwanda project succeeded in convincing the government that water supplies can be managed by user associations, covering several villages in some cases, which could run the small piped supply systems provided on a cost recovery basis. This system can be considered to be semi-private, as it is institutionally linked to the village government, and supervised by the regional government. It is being developed with increased involvement of women in the water organization in particular in revenue collection by tap committees. In Malawi, men decided that women could provide self-help labour for digging trenches. These women were motivated to maintain branch lines because they had an interest in the functioning of the facilities. This is in accordance with the findings of the UNDP/World Bank Rural Hand Pump Testing Project, and analysis by Van Wijk (1985).

## 3.7 Evaluation of projects

Project achievements are often evaluated on the basis of quantitative project objectives. This means that achievements in terms of user satisfaction, the quality of facilities and their long-term functioning, and the final impact are not taken into account sufficiently. For example, it is taken for granted that a high percentage of the facilities will not function. An average of 20% water points (taps, pumps) being out of order is often considered acceptable. Evaluation missions have adopted similar attitudes and considered maintenance successful when a high percentage of installed systems was functioning during project implementation or shortly afterwards. None of the projects has developed maintenance standards, although these are essential for any maintenance system as they provide a yard stick for measuring the functioning of the system. The viability of project based maintenance systems is generally evaluated without sufficient information on available national and local resources for maintenance. As a result projects have continued to invest in maintenance without creating an adequate institutional and financial basis, both at the user level and the government support level.

These deficiencies illustrate the ad hoc character of many projects, which is also pointed out in a report issued in 1983 by the Netherlands Ministry of Foreign Affairs based on inspection missions to bilateral water projects (Ministry of Foreign Affairs, 1983). The report states that accurate determination of both policy objectives and detailed project targets rarely occurs.

## 4. KEY ASPECTS TO DEVELOP SUITABLE MAINTENANCE SYSTEMS

The interviews with several experts confirm that in the systematic approach to maintenance, the following main factors need to be examined to develop the most suitable maintenance system:

- technology choice
- institutional arrangements and legislation
- logistics
- financial viability of the maintenance system
- manpower development
- monitoring and control

These factors are interrelated and need to be examined from a development perspective. Concentrating on one issue, for instance affordability as a basis for the technology choice, does not lead to better maintenance; all issues need to be systematically addressed. A maintenance system requires flexibility to allow for adaptation to changes in the situation, such as population growth, increase in water demand and number of systems to be maintained. If after some years a large number of facilities is installed, the private sector for example may become interested in maintaining them, and taking over certain responsibilities, which were originally assumed by the government or the users.

### 4.1 Technology choice

The technology choice for water supply systems should primarily be based on the maintenance capacities. It is necessary to select a level of technology, of which the maintenance requirements are affordable and technically feasible for the users and their government. Technology choice has also to take into account the existing type of systems and their quality. This may permit standardization to facilitate maintenance. Involvement of users in decision-making about the service level and type of technology may lead to higher coverage and better use of facilities. Users may be willing to contribute more in cash and kind for a higher service level. If it is technically feasible and acceptable for users or trained individuals from the community to maintain the facilities, fewer visits by outside teams will be required. This may lead to considerable savings for the government because at present cost of transport is a major component of maintenance costs.

4.1.1 Affordability

It may not be expected that governments and users together can maintain a technology which they cannot afford. Donor support may be obtained, but this will increase their dependency. However, sometimes, even the simplest technology may be too costly for a particular country. The consequence of long-term support for maintenance is then inevitable and should be seen in terms of cross subsidization on an international scale.

Realistic assessment of local, regional and national resources is required to determine whether the technology is affordable. A preliminary indication can be obtained from the Gross National Product. However, differences within the country concerned may require adoption of a range of technology levels or the introduction of cross subsidies. Willingness to pay often depends on the service level provided, but also on the existence of appropriate financial procedures properly controlled by independent authorities to avoid misuse of funds.

4.1.2 Technical feasibility

Whether the choice of a technology is technically feasible for a certain location depends mainly on:

- level of expertise available or which can be developed, particularly at local and regional level;
- technical quality of the system and its components;
- availability of spare parts and tools;
- resources available (fuel, cement, sand, etc);
- environmental and hydrogeological conditions.

Sometimes a technology can be selected which can be maintained at the local level. For example, a local blacksmith may be able to maintain simple pumps or a rope and bucket system, if only spare parts and some financial resources are made available. Then the maintenance system can be restricted to this local level with only back-up support for the supply of spare parts.

The maintenance of a higher level of technology, for example a deep well handpump or a diesel pump, will not only require simple daily tasks which the community can and may be willing to carry out, but also involves more complicated tasks. When these tasks are beyond the capacities of the user communities, a more complicated and more costly maintenance system will be required. This may include the formation of maintenance and repair teams, supply of spare parts and workshops. Only when the long-term functioning of such a system can be guaranteed is a higher technology level acceptable.

### 4.1.3 Standardization

Standardization is an important factor in the technology choice and particularly when a range of service levels is provided. For example, limiting the number of types of pumps also limits the number of spare parts and reduces the need for training. However, some caution is needed as standardization should not lead to dependence on a single supplier, who may be able to control the market. An example of simple standardization is to use the same base plate for different types of pumps (CIEH, 1985).

## 4.2 Institutional arrangements and legislation

Main areas of responsibility involved in maintenance include overall management, preventive maintenance, repairs, spare part supply, revenue collection, training, and monitoring. Prior to implementation a detailed analysis is required for realistic division of responsibilities.
The degree to which the users can assume certain responsibilities will vary according to available resources and capacities. Devolving tasks, responsibilities and risks to local institutions needs to be authorized formally and reflected in the legislation which may be a rather time-consuming process. However, an institutional setting with full involvement of users and local authorities as formal partners will allow for better control of maintenance which may improve greatly the functioning of the system.

## 4.3 Logistics

### 4.3.1 Supply of spare parts

The required spare part supply will depend on the type of technology selected. It is an exception where spare parts are readily available in the local community. In almost all cases the supply and the distribution of spare parts will have to be organized. Sometimes local industry can produce the required parts and in other cases these may have to be imported.

However, in both cases an appropriate distribution system will be required. This may be linked to the government or left to the private sector. Careful monitoring and control is needed to ensure that good quality spare parts are available in the required places.

### 4.3.2 Infrastructure and transport

In countries with a less developed infrastructure, transport is difficult. Bad road conditions will not only reduce the lifetime of cars, bikes and equipment but also lead to long travel times. It is not uncommon that some sites become inaccessible for several months during the rainy season. Under such circumstances the following need to be considered:

- selection of a technology which can be maintained at village level, after adequate training is provided;
- provision of more systems, for example hand pumps, to reduce the risk that some people are left without water because not all systems will break down at the same time. This will require approval of the community to ensure that all groups in the community have access to another system if their system breaks down;
- appointment and training of caretakers to have responsibility for repairs of a number of systems in their region, and provision of appropriate tools and transport for caretakers.

An interesting story in this respect is the caretaker who was very enthusiastic when he was provided with a motor bike. After two days he returned and asked whether he could exchange the motor bike for two donkeys who could do a much better job in the mountaineous area in which he lived.

### 4.3.3 Workshops

Often major repairs cannot be carried out adequately in the field. Some components are better replaced with new or overhauled components and the broken parts repaired in a workshop. In this way quality control can be better guaranteed, repairs may last much longer and even older systems will remain reliable.

Workshops may also be required to maintain equipment and transport for maintenance teams. If these workshops could be integrated in an independent maintenance organization, probably as a special department of a water agency, priority could be given to maintenance without a risk of being overruled by the construction department.

## 4.4 Financial viability

The annual maintenance cost will greatly depend on the type of water supply system, the type of technology and the selected maintenance organization. The financial implications of the introduction of a technology and provision for maintenance requires careful and realistic assessment. A water supply system will only continue to function if maintenance can be paid for. When users have to contribute directly to the cost of maintenance, an appropriate system for revenue collection needs to be established. Experience shows that such systems need to be developed prior to construction and in close consultation with the community and with responsible authorities at local, regional and national level. Long term financial viability should include arrangements for replacement, reconstruction or rehabilitation of new systems. Differences in income level of users may make it difficult to adopt a communal system. When this is the case, alternatives may have to be sought, such as the introduction of a differential tariff system, provision of different service levels (for example, a system with a mixture of house connections and public standposts).

An independent and well defined budget for the maintenance organization is important to ensure that full attention is given to maintenance. Adequate control of expenses at local and regional level by independent authorities increases the reliability of the organization and may improve efficiency.

## 4.5 Manpower development and training

People will have to be trained to carry out their tasks, which may include technical repairs, book keeping, management and stock-keeping. Those trained will do a better job if they are motivated, and therefore in addition to training, a reward system will be required. This may concentrate on compensation in cash or kind for the work but ideally needs to be put into the wider framework of personnel management. When staff over the years can get better or more rewarding jobs within the organization, it is more likely that they will remain with the organization. Training is of little use if the organizational structure does not provide opportunity for the newly acquired knowledge and skills to be used.

At village level opportunities for job rotation and promotion are limited. This may require other solutions, such as the selection and training of users as caretakers, the creations of side jobs (for example bike mechanic), or the provision of a piece of land which can be used to grow vegetables. This may reduce the risk of caretakers leaving their village to find better jobs.

In selection of trainees, their attitude is very important. For example caretakers who assume the role of owner of the system are likely to fail to gain the support of the community. Members of the community are often in the best position to select trainees from among themselves.

## 4.6 Monitoring and control

Monitoring of a maintenance system involves the formulation of maintenance standards and the collection, processing and interpretation of data on functioning and use of facilities and equipment.

It is essential to set objective standards according to which a system should function. Items on which standards need to be set are indicated in Table 5.

Table 5: Items for maintenance standards

- quality of installed facilities
- water consumption/provision per water point
- maximum number of users per water point
- acceptable water quality
- water pressure at water point
- acceptable number of breakdowns
- acceptable breakdown period
- quality of spare parts and repairs
- level of preventive maintenance
- cost of maintenance
- revenue collection
- users satisfaction

The data collected in the monitoring process need to be compared with standards and action needs to be taken in case of sub-standard functioning of the system. Whenever possible the collected information should be used to improve the performance of the systems, the agency staff and the responsible community members. Careful monitoring will also enable timely modifications of the water supply or the maintenance system, in order to meet the agreed standards on a continuous basis.

Quality control is also important and should include regular checks on the technical equipment installed, which sometimes could be carried out at the factory. Manufacturers may be given a contract to provide equipment provided they are prepared to accept or carry out regular quality checks. Also, the quality of the installation and repair of equipment needs to be monitored. When maintenance is left to the private sector a contract could be awarded to those prepared to provide quality service. Quality control is only possible when standards are agreed upon and linked to formal contracts indicating the rights and obligations of users, suppliers and responsible agencies.

## 5. CONCLUSIONS AND RECOMMENDATIONS

Even though maintenance of rural water supply systems is increasingly being recognized as a major problem (WHO, 1986), many systems are still being constructed without due consideration to maintenance. This is strengthened by the fact that donor agencies are prepared to finance the construction of water supply systems but are themselves not committed to long-term support to the maintenance of these facilities.

Project objectives and results are often expressed in terms of installed facilities and not in terms of long-term functioning of these facilities. Therefore, project staff tend to concentrate on construction and pay less attention to maintenance requirements of new facilities and to development of maintenance skills. Project preparation on the basis of systematic assessment of the local and national situation in relation to future maintenance is required.

The first maintenance systems emerged in response to unexpected breakdowns of rural water supply facilities (mostly hand pumps) and were directly linked to and paid for by externally financed projects. In various countries, governmental agencies became involved and gradually assumed to varying extents the tasks and responsibilities involved. However, because maintenance was not planned and maintenance requirements not taken into account, inappropriate types of technology and types of maintenance system have been selected. Although little information is available, it appears that most maintenance systems functioning at present are not efficient and are too costly to be effective in the long term.

Because of the lack of financial resources and efforts to reduce cost, governments expect users to take a share in the maintenance tasks, or take over the facilities, very often without adequate higher level support. In general, these users are not involved in decision-making and mostly it is not clear whether they are willing, able or can afford to maintain the facilities, and as a result rural water supply facilities are often not maintained.

The review of the literature indicates the unsystematic approach to maintenance which is followed by most projects, but also indicates that gradually more attention is paid to integration of technical and organizational aspects. Current thinking on maintenance is developing towards a more systematic approach which takes into account environmental conditions, affordability and users involvement. This approach aims to develop a maintenance system for a technology which is suitable, affordable and culturally acceptable in the specific situation of the region or country concerned. Key factors which need to be examined in order to develop the most suitable maintenance system include: technology choice, institutional arrangements and legislation, logistics, financial viability of the maintenance system, manpower development, and monitoring and control. The involvement of users and local governments in decision making about the level of service, the type of technology and the maintenance system is a basic condition for successful maintenance. Concensus on these points and formal agreements need to be reached before new facilities are implemented.

## 5.1 Systematic evaluation of maintenance practices

Despite increased awareness at the international level, national governments do not give sufficient priority to maintenance. This is to a great extent due to the lack of country-level information on functioning of rural water supply facilities and cost of existing maintenance practices. A review and systematic evaluation of current maintenance practices at national level is an essential starting point to create greater commitment and to stimulate awareness of the need for suitable maintenance systems. Preferably, these studies should be carried out by national staff with support from donor agencies. Recommendations are likely to be more acceptable if similar studies are carried out in several countries at the same time and are discussed and reviewed by specialists in regional meetings.

## 5.2 Systematic analysis of maintenance requirements

A systematic overview of the maintenance requirements of different types of rural water supply systems is urgently required. This overview will facilitate better preparation of projects in view of long-term maintenance requirements. It will be of direct use in the selection of the most suitable technology or can form the basis to set up a pilot programme to test some of the options in combination with a suitable maintenance system. It also provides a basis for discussions with users, local and other authorities who are expected to take up tasks and responsibilities in maintenance and play a role in the choice of technology. This overview should include main technology options, such as bucket wells, hand pumps, gravity systems, and simple treatment. It would allow more realistic identification of specific maintenance requirements under local circumstances.

## 5.3 Development of community-based management systems

In many countries users will be made directly responsible for their water supply. This requires suitable community based management systems which need to build on local structures and to fit into the overall organizational and institutional setting of the water agency. Further experiments with suitable options for communities to manage their water supply systems are very important. Particularly in rural areas collection of water charges is complicated and suitable financial systems are required. An overview of such financial management systems for piped supplies is presently under preparation within IRC's public standpost water supply project. This overview could provide a basis for pilot studies concerning the development of community-based financial management in the broader framework of the outlined systematic approach to maintenance.

## 5.4 Project assessment and preparation

In project assessment and preparation much more attention must be paid to the sustainability of rural water supply systems. In view of this, key considerations, and key issues for maintenance oriented project preparation and assessment are summarized in the following checklist.

Checklist for maintenance oriented project preparation and assessment

| Key considerations | Key issues |
|---|---|
| **1. Technology choice** | |
| Technology selection must be primarily based on identified maintenance requirements and local resources. Users involvement in technology choice and selection of service level increases the possibility of adequate maintenance and better use of the facilities. | Service level, technology type, maintenance tasks, caretaker training, community organization, finance, control. |
| Technology has to be affordable, which means, that maintenance and possibly construction costs can be paid for by the users. Alternatively a system of cross subsidies must be adopted. | Total annual costs, per capita costs, annual maintenance costs, cross-subsidies, service level, technology level, willingness to pay, control of funds. |
| Technology must be technically feasible which means that the quality of the system must be acceptable and suit the local conditions | Level of available expertise, quality of systems and components, availability of spare parts, tools and materials, environmental and geo-hydrological conditions. |
| Standardization of technology simplifies maintenance. It facilitates developing national and regional capacities for maintenance, and the introduction of quality standards. | Choice of suppliers, manpower development & training, local production of spare parts, workshop management, price control, quality control. |
| **2. Institutional arrangements and legislation** | |
| The maintenance system needs to be formalized. Tasks, responsibilities and rights of all parties have to be clearly identified, agreed upon and authorized | Task analysis, control powers, sanctions, legislation, contracts, overall management, preventive maintenance, repairs, spare parts supply, revenue collection, personnel management & training, monitoring. |
| **3. Logistics** | |
| The supply and distribution of spare parts should be quaranteed and organized before project implementation starts. Short term solutions do not suffice. | Import regulations, local production, distribution system, prices, competition, role of private sector, quality control, stock keeping, monitoring, standardization. |

| Key considerations | Key topics |
|---|---|
| Immediate repair of facilities is essential. In case local conditions prevent maintenance teams to travel, alternatives are required such as VLOM options or installing additional facilities. | Access roads, transport (regional and local), transport costs, local storage of spares, caretaker selection & training, community organization. |
| Replacement of system components combined with repair in well equipped workshops, will allow for better quality control and improve reliability of repairs. | System components, workshop equipment manpower, transport quality control. |
| 4. Financial viability | |
| Financial assessment should include all costs, and all available revenues, including taxation by local governments. | Direct maintenance costs, total system costs, depreciation, revenues, service level, subsidies. |
| Revenue collection mechanisms need to be developed and agreed upon prior to construction. | Tariffs, community based financial management, budgetting for maintenance, control, training, bookkeeping. |
| 5. Manpower development and training | |
| Training efforts need to be based on careful assessment of required skills and long term manpower requirements. Acquired knowledge should also be applied. | Task analysis, manpower planning (decentralized) training, selection of trainees formal status, operational working relations. |
| Job satisfaction is very important to keep staff and villagers motivated. This requires flexible organizations and personnel management. | Salary, income generation personnel management, career planning, job rotation fringe benefits, side jobs, accountability, sanctions. |
| 6. Monitoring and control | |
| Monitoring on the basis of selected information is a basic requirement for management of available resources. | Monitoring criteria, indicators, procedures, data collection, records, standards (number of users, waterconsumption, break-downs, costs), user satisfaction feed-back, corrective measures. |
| Control of the quality of equipment that installed and spare parts that are provided is needed and should meet agreed standards. | Standards, legislation, local manufacture, sanctions, quality codes. |

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APPENDIX 1: EXAMPLES OF OPTIONS FOR VILLAGE LEVEL [illegible]

| TYPE OF ORGANIZATION | KEY REQUIREMENTS | | | | COST | |
|---|---|---|---|---|---|---|
| | Construction | Operation and Maintenance | Access | Motivation of Manager(s) | To Authority | To User |
| Water authority with water rate | Direct employment or contract: construction may be efficient, but expensive | Routine maintenance possible at a cost | Open to the public by right | Bureaucratic | High cost, but offset against the prospect of recurrent income | User faces recurrent charges that will be substantial in the case of small supplies |
| Water authority with some management delegated to local individual or committee | Community participation in fund-raising and in construction can be organized | Some local maintenance or 'first aid' repair can be institutionalized, but responsibility rests with water authority | Open to the public by right | Local managers receive some kind of reward either financial or from derived status and local influence | Initial cost may be reduced but recurrent costs must be met | User pays through participation in construction thereafter only indirectly through taxation |
| Private supply institution supply with access to public | Private; no administrative involvement | Private; no administrative involvement | Access by payment (per container or per month) | Interests of owner/user plus possible profit in some cases | Some subsidy may be necessary to secure standards access for the public | Commercial fee unless there is private or public subsidy |
| Water users' association | Association constructs with some technical assistance | Association responsible for maintenance | Access to members only | Corporate interests of members plus token share of dues and local influence | Initial capital grants and supervision costs | Routine payments of dues to cover costs of operation and maintenance |
| Local authority or commune | Water supplies constructed as a communal facility | A routine activity for a work team or department | By right of commune - its membership | Water management one of several functions from which derive power, influence and income | Grants and supervision costs | Costs met out of of local tax or in a commune, production profits |

SOURCE: IRC Technical Paper Series No. 15

APPENDIX I. WATER SUPPLY PROJECTS INVESTMENT COST PER CAPITA [illegible]
(1984 prices)

| TYPE OF SYSTEM: | Dug well with hand-pump | Shallow drilled well with hand-pump | Deep borehole well with distribution system and un-treated water | Deep borehole well with distribution system and treated water | Surface water with gravity feed distribution and treated water | Surface water with pumped distri-bution system and treated water |
|---|---|---|---|---|---|---|
| Bangladesh | 10 - 30 | 20 - 40 | 40 - 90 | 90 - 110 | 100 - 120 | 100 - 200 |
| Bhutan | 20 - 50 | 40 - 80 | 50 - 150 | 80 - 150 | 80 - 150 | 100 - 200 |
| Burma | 5 - 20 | 15 - 40 | 30 - 60 | 60 - 100 | 80 - 120 | 100 - 150 |
| Hong Kong | 40 - 80 | 60 - 110 | 90 - 150 | 100 - 160 | 100 - 200 | 150 - 550 |
| India | 10 - 25 | 15 - 35 | 40 - 80 | 40 - 80 | 50 - 130 | 60 - 150 |
| Indonesia | 5 - 15 | 15 - 30 | 30 - 60 | 60 - 100 | 70 - 120 | 120 - 300 |
| Korea | 15 - 30 | 20 - 50 | 40 - 80 | 70 - 100 | 90 - 200 | 100 - 350 |
| Laos | 10 - 30 | 15 - 30 | 30 - 60 | 60 - 100 | 80 - 120 | 100 - 200 |
| Malaysia | 20 - 40 | 30 - 80 | 50 - 100 | 70 - 120 | 80 - 200 | 80 - 350 |
| Maldives | 5 - 20 | 20 - 40 | 30 - 60 | 60 - 100 | 60 - 120 | 60 - 150 |
| Nepal | 20 - 50 | 40 - 70 | 60 - 100 | 70 - 120 | 80 - 150 | 100 - 200 |
| Pakistan | 10 - 30 | 20 - 60 | 50 - 100 | 80 - 110 | 100 - 140 | 100 - 200 |
| Papua New Guinea | 20 - 50 | 40 - 70 | 60 - 100 | 80 - 120 | 100 - 180 | 150 - 400 |
| Philippines | 30 - 60 | 40 - 80 | 60 - 110 | 90 - 130 | 110 - 200 | 120 - 450 |
| Singapore | 30 - 80 | 50 - 100 | 80 - 150 | 100 - 150 | 100 - 200 | 150 - 400 |
| Salamon Islands | 15 - 30 | 20 - 50 | 40 - 100 | 60 - 100 | 80 - 120 | 110 - 250 |
| Sri Lanka | 10 - 20 | 20 - 80 | 50 - 150 | 50 - 150 | 80 - 200 | 100 - 250 |
| Thailand | 10 - 20 | 20 - 40 | 40 - 60 | 50 - 100 | 70 - 120 | 90 - 250 |
| Vietnam | 20 - 50 | 30 - 50 | 30 - 90 | 60 - 130 | 70 - 110 | 100 - 200 |
| Average range | 20 - 40 | 30 - 60 | 50 - 100 | 70 - 120 | 80 - 150 | 110 - 260 |

SOURCE: Asian Development Bank (27)

APPENDIX II: COST COMPARISONS IN THAILAND
(All costs in Bahts x 1000 - 1 US$ = 20 Bahts)

| System type: | CONVENTIONAL | | | | BARANGAY III A | | | | SHARED CONNECTION | | | | PUBLIC STANDPIPES | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Source type: | SURFACE | | GROUND | | SURFACE | | GROUND | | SURFACE | | GROUND | | SURFACE | | GROUND | |
| Population (No.): | 2000 | 750 | 2000 | 750 | 2000 | 750 | 2000 | 750 | 2000 | 750 | 2000 | 750 | 2000 | 750 | 2000 | 750 |
| Capital cost/$m^3$ | 4,5 | 6,1 | 4,2 | 5,8 | 3,5 | 5,0 | 3,2 | 4,7 | 6,0 | 8,7 | 5,9 | 8,8 | 7,6 | 11,0 | 7,3 | 11,2 |
| Annual capital cost/capita | 107,7 | 151,3 | 98,4 | 143,2 | 86,7 | 126,3 | 77,4 | 118,2 | 73,3 | 114,5 | 71,3 | 116,1 | 63,9 | 91,4 | 60,9 | 93,4 |
| Operation and maintenance cost $m^3$ | 1,8 | 2,3 | 1,8 | 2,4 | 1,2 | 1,8 | 1,2 | 1,9 | 1,7 | 2,8 | 1,8 | 2,8 | 1,9 | 4,0 | 2,0 | 4,1 |
| Annual operation and maintenance cost per capita | 51,8 | 67,5 | 51,8 | 68,9 | 35,1 | 53,6 | 35,7 | 54,9 | 25,2 | 44,9 | 25,8 | 46,0 | 21,3 | 39,3 | 21,8 | 40,1 |
| Total cost/$m^3$ | 6,3 | 8,4 | 6,0 | 8,2 | 4,7 | 6,8 | 4,4 | 6,6 | 7,7 | 11,5 | 7,7 | 11,6 | 9,5 | 15,0 | 9,3 | 15,3 |
| Total annual cost/capita | 159,5 | 218,8 | 150,2 | 212,1 | 121,8 | 179,9 | 113,1 | 173,1 | 98,5 | 159,4 | 97,1 | 162,1 | 85,1 | 130,7 | 82,7 | 133,5 |

SOURCE: WASH Field Report No. 19, 1981 (22)

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