Operation and maintenance of urban water supply and sanitation systems

A guide for managers

World Health Organization
Geneva

The World Health Organization is a specialized agency of the United Nations with primary responsibility for international health matters and public health. Through this organization, which was created in 1948, the health professions of some 190 countries exchange their knowledge and experience with the aim of making possible the attainment by all citizens of the world by the year 2000 of a level of health that will permit them to lead a socially and economically productive life.

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Preface

The International Drinking Water Supply and Sanitation Decade 1981–90 (IDWSSD) had the objective of providing safe and adequate drinking-water and appropriate sanitation for as many people as possible. The decade stimulated governments, communities and external support agencies to release resources for the development of water supplies and sanitation. Such development is acknowledged as essential for the good health on which personal well-being and national productivity and wealth depend. For these benefits to be fully realized, however, the water and sanitation facilities provided must function continuously, efficiently and to their full capacity. Unfortunately, there is ample evidence to show that this has not always been the case, mainly because resources have largely been utilized for the planning, design and construction of facilities while operation, maintenance and project evaluation have often been neglected. As a result, some water and sanitation facilities are failing before their projected lifespan is over. Others are operating in an inefficient and costly manner. Benefits are not being fully obtained and scarce resources are being wasted.

Poor management coupled with inadequate operation and maintenance has led to more than half the water supply being unaccounted for in many large cities in developing countries. In the parts of these cities served by public supplies, wastage is high and tariffs are often subsidized. By contrast, residents of fringe areas remain largely unserved by public supplies and are forced to pay the market price for insufficient and unsafe water from private vendors. The price is often 10 to 20 times higher than that charged to users connected to the public water supply.

This situation has been a growing concern to governments and external support agencies. Recommendations from many IDWSSD consultations have called for increased attention and support to be given to the area of operation and maintenance. A number of external support agencies are now providing resources for operation and maintenance projects. The World Health Organization, in its Eighth General Programme of Work (1990–95), emphasizes the importance of improving the effectiveness of operation and maintenance to improve institutional performance in community water supply and sanitation. This publication is a sign of WHO's concern. Operation and maintenance are complementary processes essential to the efficient provision of water supplies and sanitation at all levels. These two processes are indeed so closely related that the term "operation and maintenance", often referred to simply by the initial letters O & M, has become a common expression among water and sanitation specialists.

This publication has been prepared to provide managers and other key personnel dealing with planning, organization and finance in water supply and

sanitation agencies with guidance in formulating programmes and implementing activities aimed at improving the efficiency and effectiveness of operation and maintenance practices. Because different countries, regions and agencies encounter a variety of different problems, the guidance offered here cannot be exhaustive. Some readers may find it useful, or even necessary, to use complementary material to help them formulate solutions that suit their particular situation. A list of publications that may be helpful is found on pages 101–102.

Acknowledgements

This publication is based on an earlier one by WHO's Regional Office for the Americas.[1] The earlier text has been revised, updated and adapted to the requirements of water supply and sanitation services worldwide. The present publication is the result of cooperation between WHO and the Water Supply and Sanitation Collaborative Council, as well as that council's Working Group on Operation and Maintenance.

Acknowledgement should be made of the participation of Alberto Gonima, Horst Otterstetter, José A. Hueb, J.C.B. Berenhauser, José Pérez and Luis C.R. Soares in the preparation of the first Spanish version of this publication. This Spanish version was revised as a result of a review meeting attended by the following: Guillermo H. Dávila, Roger Gamboa, Julio R. Jiménez, Janet Khoddami, Luis A. Leal, Dante Muñoz, Juan Olmedo and José Pérez (all of the Pan American Health Organization, Washington, DC, USA); Eduardo Arbeláez, Colombia; Manuel Becerra, Mexico; Jaime Castaño, Colombia; Rodrigo Castrillon, Colombia; Julieta González, Colombia; Edgar Llanos, Colombia; Marco F. Martínez, Colombia; Gastón Mendoza, Mexico; lldefonso Nuñez, Colombia; Enrique Palacios, Colombia; Antonio C. Parlatore, Brazil; Luis H. Pierotti, Colombia; Emiliano Rodríguez, Mexico; Osias Rojas, Colombia; and Ramón Villa, Mexico.

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[1] *Modelo de gerencia de operación y mantenimiento de sistemas de agua potable y saneamiento.* Washington, DC, Pan American Health Organization, 1986.

Introduction

Adequate and safe drinking-water supplies and appropriate sanitation facilities form a sound basis for improvement in community health. Maximum health benefits will be achieved, however, only when the water supply and sanitation facilities operate continuously and to full capacity in conformity with acceptable standards of quantity and quality. Accordingly, operation and maintenance tasks must be carried out effectively and efficiently. In many instances this has not been so. Despite progress made during the International Drinking Water Supply and Sanitation Decade 1981-90 (IDWSSD), a number of problems have arisen:

- Many people still do not have access to drinking-water and sanitation services.
- Water supplies are often intermittent and of inadequate quality.
- Defective sanitation services and discharge of substandard effluent cause pollution.
- Unacceptably large quantities of water are unaccounted for.
- Staff morale, efficiency and productivity are low.
- Operating costs (for chemicals, energy, manpower, defective equipment, spare parts and tool inventory procedures) are high.
- Repair and replacement costs are excessive as a result of inadequate preventive maintenance.

Additionally, the technical options chosen for water supply and sanitation development projects are not always those best suited to the technical, social or financial environment in which they are to operate. Shortsightedness, lack of trained staff and inadequate financial resources combine to make the funding and standards of operation and maintenance a low priority.

Lack of effective management is the factor with the greatest negative impact on water supply and sanitation services. This is particularly evident when there are no clearly defined objectives, no long-term planning and no short-term programming or budgeting. Other typical failings are:

- There is a lack of operational and management tools for programming, performance evaluation and control of activities.
- There is a lack of information to guide the formulation of operation and maintenance plans and to identify staffing profiles and training needs

(essential information includes basic manuals, inventories of equipment, layout drawings, construction plans and maps showing locations of other underground utilities).

- There is a lack of consideration of operation and maintenance requirements during project planning, design and construction (essential requirements include definition of institutional, technical and financial responsibility for operation and maintenance, recruitment and training of operation and maintenance staff, provision of equipment for operation and maintenance — such as tools, transport and stores — and definition of standards).
- There is a lack of effective preventive maintenance procedures to minimize breakdowns and prolong the operational life of the service.

These and other factors all contribute to poor performance by water supply and sanitation agencies. The prime factor responsible for poor operation and maintenance is a lack of operational and management control combined with limited leadership and directorial skills and aggravated by poor information systems on which to base sound decisions.

Objective of this publication

This publication describes one approach to management theory and practice in the operation and maintenance of drinking-water supply and sanitation services. It is intended to serve as a guide to strengthening the technical, operational and managerial capabilities required to operate and maintain water and sanitation services according to acceptable norms of quality, continuity, reliability and cost. This publication is intended primarily for managers in charge of the operation and maintenance of urban drinking-water and sanitation agencies. The ultimate objective is to provide the consumer with the best quality service at the lowest cost. The publication contains five parts, as outlined here.

Part 1. The systems approach to management

The first part describes the use of the management systems approach to analyse the functions of drinking-water and sanitation agencies and to solve operation and maintenance problems. It explains what an operational system is, how it works and what subsystems it includes.

Part 2. Management of operation and maintenance

The second part describes the operation and maintenance functions of different management levels, activities and factors so as to help agencies formulate personnel requirements and profiles.

Part 3. Planning and control of operation and maintenance

This section defines the programmes and projects that should be the priority responsibilities of operation and maintenance managers.

Part 4. Information systems

The section on information systems describes the conceptual framework, methodology, centres of decision and basic indicators for the development of management information systems and decision support systems for operation and maintenance. It further suggests techniques for measuring effectiveness of programmes by using performance indicators.

Part 5. Implementation

The final part outlines actions to be carried out and stages to be completed in order to implement the procedures described in this publication.

How to use this publication

The procedures proposed in this publication are intended to be a guide for developing management capability in operating and maintaining drinking-water supply and sanitation facilities. The publication is not exhaustive but should serve as a reference source and conceptual framework for agencies formulating development programmes. Concepts and procedures should be adjusted as appropriate to tackle the specific problems of each agency and each country.

The publication should be used to supplement but not replace existing manuals describing management procedures and techniques for operation and maintenance.

Programmes and projects related to operation and maintenance should also be formulated on the basis of an exhaustive assessment of the water supply and sanitation services under review.

PART 1

The systems approach to management

CHAPTER 1

Organizational systems

The systems approach to management enables managers to describe and reorganize the service framework of a water supply and sanitation agency and to allocate resources so that targets can be achieved efficiently. According to this approach, each water supply and sanitation agency can be described as an overall agency system within which is a range of organizational systems.

An organizational system is characterized by areas of specific action (operation, administration and so on) within the agency and therefore represents groups of specific functions. Thinking in terms of organizational systems allows managers to study relationships between the various parts of the agency. The systems approach to management facilitates detailed analysis of the agency, even in complex situations, without obscuring the overall picture.

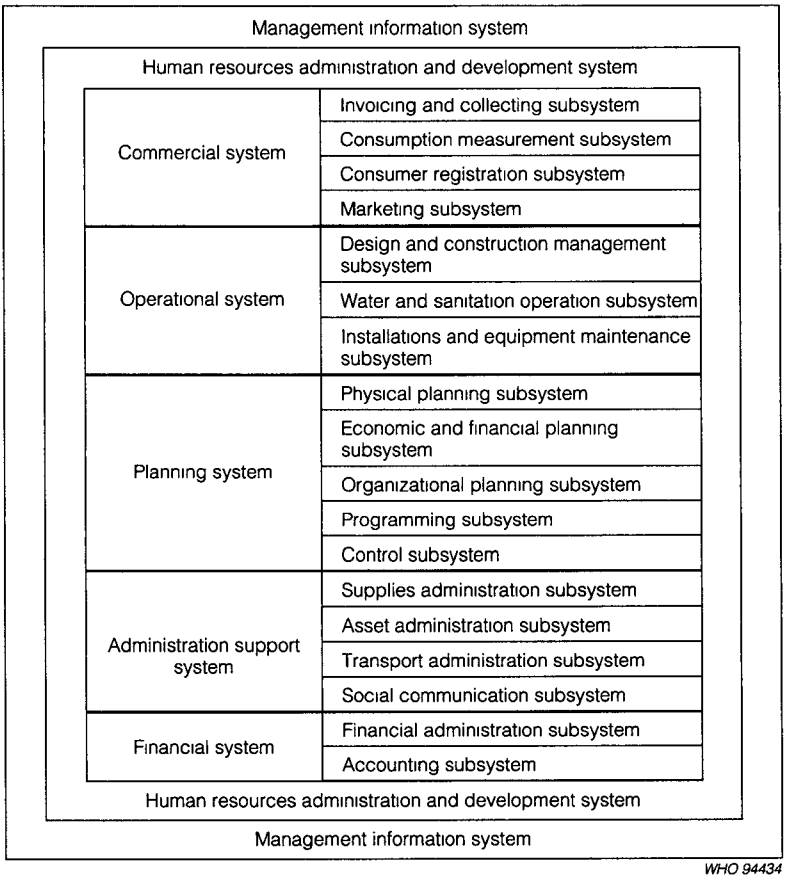
Just as the overall agency system comprises a set of organizational systems, so each organizational system comprises a set of subsystems that carry out the functions of the organizational system to which they belong. The organizational systems outlined in this publication are commercial, operational, planning, administrative support, financial, human resources and management information. These organizational systems and their corresponding subsytems are shown in Fig. 1. The administration support system comprises functions of different kinds, including those that facilitate the operation of other systems (transport, supplies, etc.).

The subsystems that make up each organizational system are grouped by function, as shown in Fig. 1 and described in Table 1, so as to facilitate their analysis. It is important to note, however, that they do not necessarily correspond to an organizational structure. Indeed, since each subsystem carries out activities corresponding to one function, the subsystems can be grouped by functions to fit a variety of organizational structures so long as due account is taken of differences in decision-making and information processes, inputs, outputs, interactions and interconnections.

The processing of information, together with senior management activities, is the basis for determining targets, priorities, schedules, responsibilities, distribution of resources and the entire decision-making process.[1] This can serve as the link between systems and subsystems at the initial stage of agency development until the knowledge needed to measure results, take corrective action, formulate new parameters and distribute new resources has been established as a basis for management control.

[1]See Eaton JW. *Institution building and development*. Beverly Hills, CA, Sage Publications.

Fig. 1
Organizational systems



As the systems approach to management becomes established in an agency and the organizational systems are identified and refined, the working of the subsystems should be monitored and data collected. At this stage, outlines of management action and results forseen on the basis of the planning system must already be available in order to identify and investigate discrepancies and provide corrective action.

An agency must define the instruments it needs for management as well as the corresponding information needs. Analysis of data supplied by different levels of the agency, planned so that the information generated serves as a basis for the agency's operation, administration and decision-making, constitutes the agency's information system. When functions in addition to the routine processing of data are added, this becomes the management information system[1] (see Part 4).

[1]See Davis GB. *Management information systems.* Tokyo, McGraw Hill Kogakusha Ltd, 1974.

Table 1
Description of organizational systems

System	Description
Planning system	This system begins with analysis of the problem and its solution by comparing the agency's current service with targets set according to social, economic, environmental and regulatory policies within which the agency must function. Using this frame of reference, the planning system must aim at effective accomplishment of the objectives of the agency in the long, medium and short term The planning system must make sure all parts of the agency work efficiently to meet targets so that the agency delivers the services (safe drinking-water or adequate sanitation) required by the community. This system generates physical expansion and institutional development programmes. Supported by the management information system, it establishes feasibility of the objectives, plans and programmes of the agency and controls their implementation. The agency carries out these activities through its subsystems for physical planning, economic and financial planning, organizational planning, programming and control.
Operational system	The operational system consists of the resources and activities necessary for the preparation of designs, the construction of works, the operation of water supply and sanitation, and the maintenance of installations and equipment. The operational system functions through its subsystems for design and construction management, water and sewerage operation, and installations and equipment maintenance.
Commercial system	The commercial system is a strategic element for attaining the objectives of the agency (meeting drinking-water and sanitation demands within regulatory requirements). It is a tool for the promotion and sale of services and for recovery of the cost of delivering those services to the users. This enables the agency to be financially self-sufficient. The agency performs its function according to policies, standards and plans established in the light of consumer demands and official regulations. The commercial system includes subsystems related to consumption measurement (for water supply), discharge (effluent) estimation (for sanitation), invoicing and collection, consumer registration and marketing.
Financial system	This includes all policies and standards established by the agency to carry out its financial tasks, together with the procedures used for recording and evaluating financial operations and reporting on their results. These activities are found in the financial administration and accounting subsystems.

Table 1 (continued)

System	Description
Human resources administration and development system	This comprises all policies, standards and procedures which ensure that the agency has the personnel it needs and that the personnel are appropriately trained. To this end, a plan of human resources demand and supply should be drawn up The following activities should be carried out: technical activities through the subsystems of post classification and grading, staff selection and recruitment, evaluation of underutilization and training, control activities through the subsystem for staff administrative control, and human relations activities through the subsystems for social welfare, industrial safety and workers' health.
Administration support system	The administration support system includes four subsystems – for supplies administration, asset administration, transport administration and social communication Each of these is a virtual system within itself and is made up of a variety of smaller subsystems *The supplies administration subsystem* is the agency's set of policies, standards and procedures, together with goods and services, for the construction, operation and maintenance of water supply and sanitation systems It functions through stock management and control, procurement administration, and storage and distribution of materials (tools, spares, chemicals, etc.). *The asset administration subsystem* takes care of the inventory, custody and control of the property assets of the agency *The transport administration subsystem* is responsible for the management, operation and maintenance of the vehicles used by the agency. *The social communication subsystem* comprises the agency's activities at different levels aimed at giving the community an appropriate image of the agency in line with senior management policy External activities include enlisting the support and participation of the community in the preparation and execution of the agency's plans, while internal activities include maintaining good relations with and between the employees. Important aspects of the communication subsystem include its influence on decision-makers and on the general public. Decision-makers and politicians need to be aware of the importance of supporting financially the operation and maintenance of drinking-water supply and sanitation Many employees of water and sanitation agencies interact directly or indirectly with the public so they are also responsible for the public image of the agency The professionalism, behaviour and effectiveness of the people who work for these agencies help form the public's image of the agencies. The public also needs to realize that people who work for water supply and sanitation agencies play a vital role in the health of the community.
Management information system	Chapter 10 contains a description of the objectives, structure and components of an information system to support decision-making processes in the management of operation and maintenance

CHAPTER 2

The operational system

In order to show more clearly the functions related to the operation and maintenance of drinking-water and sanitation services, we here describe the operational system and its respective subsystems in a water supply and sanitation agency. In order for the operational system to contribute to the attainment of the agency's objectives, it must receive inputs from the other organizational systems as described in Chapter 1. This calls for harmonious organizational development. Efforts to develop the operational system without substantially developing the related organizational systems will not lead to sustainable improvements in the agency.

The simultaneous development of all organizational systems may not be feasible. For this reason, we look at the constraints found in most water and sanitation agencies in developing countries and propose the implementation of priority activities as part of a long-term process of agency development.

Definition

The operational system of an agency providing drinking-water and sanitation services comprises all resources and activities necessary for the preparation of designs, the execution of construction work, the operation of the water and sanitation installations, and the maintenance of these facilities and their equipment.

Objectives

The objectives of an agency's operational system are as follows:

- to supply plans and designs for the construction work necessary for provision of the agency's services, in line with technical, social and financial requirements;
- to ensure that construction work complies with the plans and designs of the agency and is appropriate to the needs of the community with regard to health, quality, functioning, timing and cost;
- to establish standards for the delivery of services that are satisfactory in respect of quantity, quality, continuity, coverage and cost;
- to maintain the installations and equipment in a condition that will ensure they can be operated satisfactorily, function efficiently and continuously, and last as long as possible at lowest cost;

- to produce information on the water supply and sanitation installations and their component units, with specific reference to their functioning and their adequacy to meet the needs of users, thus enabling the agency to evaluate how well the installations work and how effective its services are.

Component elements

To attain its objectives, and in line with the policies and standards of the agency, the operational system must carry out a series of processes through its own subsystems or through other subsystems functionally linked with the operational system. In implementing the plans and carrying out the programmes of the agency, the operational system must constantly interact with the other organizational systems and take into account the local situation.

The processes of the operational system must be grouped and interrelated so that they complement each other. These processes include the following:

- Management of the design and construction of facilities (preparation of studies and designs, construction, programming and control of projects).
- Operation of water supply and sanitation installations, along with their component elements (collection, transmission, treatment, storage and distribution of water and/or collection, treatment and re-use or disposal of sewage), including support to community groups in the area served by the agency.
- Maintenance of installations and equipment.

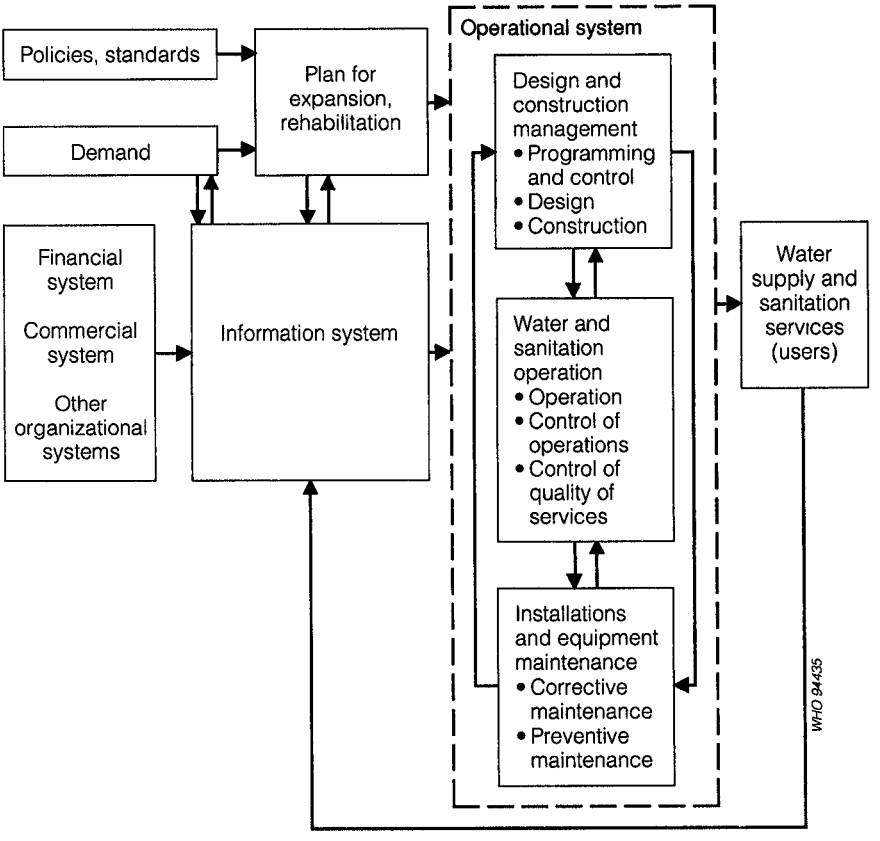
These processes of the operational system are carried out through three subsystems: the design and construction management subsystem, the water and sanitation operation subsystem, and the installations and equipment maintenance subsystem.

Other elements are also essential to the functioning of the operational system: human and material resources, procedures, a functional organizational structure, communications and the management information system which supplies data for decision-making. All of these interact within the operational system, undergoing change and adjustment as part of a dynamic process in order to attain their objectives.

It is important that each subsystem should develop its own objectives and should be provided with the necessary resources to achieve these objectives.

Fig. 2 shows the internal activities of the operational system as a link between the policies, objectives and plans of the agency and the demand for its services (safe drinking-water, adequate sanitation) in the community.

Fig. 2
Operational system



CHAPTER 3

Subsystems of the operational system

Design and construction management subsystem

Definition

The design and construction management subsystem comprises all resources and activities necessary to ensure the preparation of designs and the construction of new works needed for the delivery of the drinking-water and sanitation services.

Objectives

The overall objective of the design and construction management subsystem is to administer the resources required to realize the agency's plans for investment in design and construction by technically appropriate and cost-effective means. The specific objectives of the subsystem are:

- to administer efficiently the procurement, distribution and utilization of personnel and technical resources, both within and outside the agency, for preparing plans and designs and for carrying out construction work for the agency;
- to evaluate different means of construction, to select the most appropriate and to contribute to decisions about the most efficient procurement, distribution and use of the required resources;
- to supervise the agency's investment in facilities so that those facilities ensure constant high quality services that are both acceptable to the community and facilitate operation and maintenance;
- to ensure that the agency carries out its work by means of technology and activities that are within its capacity, are appropriate to user groups in the community and take full advantage of available natural resources;
- to obtain, maintain and supply up-to-date information needed for the design and construction of facilities.

Basic activities

The design and construction management subsystem has three groups of interacting elements that form the basic activities necessary to attain its objectives:

— preparing plans and designs;

— scheduling and supervising design preparation and construction work;

— carrying out construction work.

How the subsystem works

In order to prepare designs and build facilities to meet the agency's targets, the design and construction management subsystem includes technical and managerial activities at various levels in line with plans and programmes prepared by the agency's planning system.

First, design and construction schedules should be drawn up. Design and construction work should be planned in such a way that information about progress is continuously updated. On the basis of that information, progress of the work should be monitored and evaluated and, if necessary, there should be adjustments, corrections or even complete rescheduling.

Following the schedule, preliminary studies are carried out in order to assess the technical and financial feasibility of different designs. As the agency makes choices about what kind of facilities to invest in, the design and construction management subsystem must consider technical (engineering), cost (construction, operation and maintenance) and social (acceptance by potential users) aspects. In coordination with the planning system, possible types of facility will be evaluated so as to set priorities and reach conclusions about the benefits, costs, advantages and limitations of each type.

The process of designing projects to establish, expand or improve a water supply or sanitation system has three distinct phases:

- The preliminary study determines how to meet a community's demand for services in line with health, technical, social and economic requirements.
- The preliminary design describes all the elements of a water supply or sanitation installation and why it is needed (including analysis of the feasibility of different types of installation), with due consideration for its proper operation, maintenance and administration.
- The final comprehensive design, based on the conclusions and recommendations of the preliminary study and preliminary design, includes all the inputs needed to carry out the work.

Among the processes of the design and construction management subsystem is the awarding of contracts for design and construction work (including administrative procedures for registration and classification of consultants and contractors, preparation of terms of reference and invitations to tender, and the actual award of contracts). It is essential that the agency should have regulations that are clear and objective and that define, both for the agency and for contractors, the criteria and procedures to be applied in selecting and awarding contracts for the preparation of designs and execution of construction work.

To control costs and to ensure the quality, continuity, safety and correct functioning of the installations once they begin operation, it is essential that the work of construction, like that of design, is done according to a schedule and

monitored through to completion. This will include supervision of design preparation and inspection or audit of construction work. For this means of control to provide the required guarantees of quality, quantity and performance, its effectiveness must be checked before use — with the subsystems for water and sanitation operation and for installations and equipment maintenance — and changed if necessary.

Fig. 3 shows how the processes of the design and construction management subsystem relate to the other subsystems of the operational system.

Water and sanitation operation subsystem

Definition

The water and sanitation operation subsystem is the second of the three subsystems of the operational system. It comprises all activities required for operating the water supply and sanitation facilities and equipment, for monitoring their functioning and for monitoring the quality of the agency's services (water supply and sanitation).

Objectives

The overall objective of the water and sanitation operation subsystem is to produce drinking-water, ensuring sufficient quality, quantity and continuity, and provide an adequate sanitation service. The specific objectives of the subsystem are:

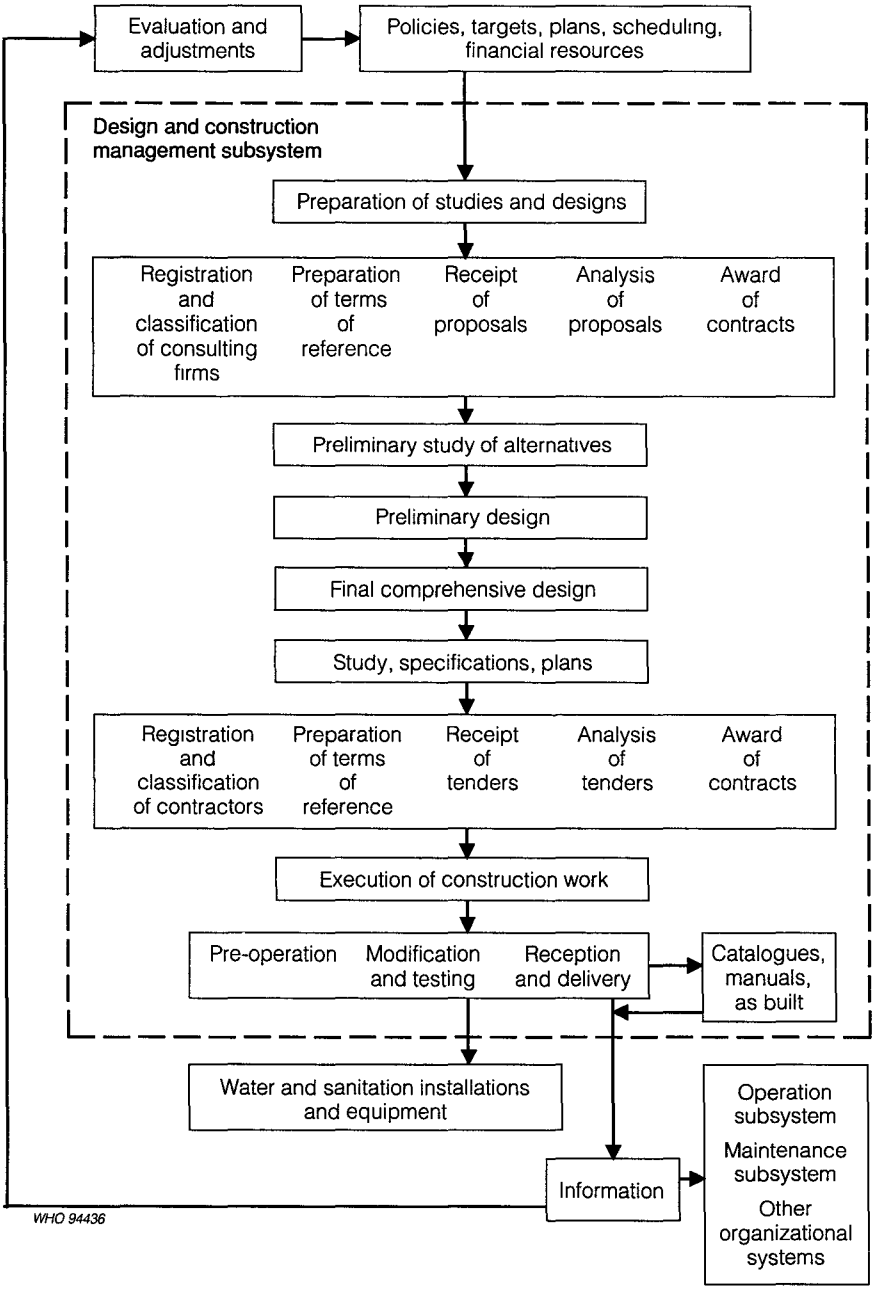
- to operate the facilities and carry out the processes necessary to deliver drinking-water and sanitation services with the greatest efficiency, safety and economy;
- to ensure the quality of the water (potability) and of the services delivered (quantity, pressure, continuity);
- to protect public health and the environment by monitoring the quality and quantity of sewage effluent discharges;
- to monitor the water supply and sanitation installations in general, and their components in particular, in terms of how well they function and how well they meet requirements, so that their effectiveness can be evaluated.

The water and sanitation operation subsystem bears the major responsibility for ensuring that the agency accomplishes its most important objective, i.e. providing water and sanitation services in sufficient quality and quantity to meet the needs of the community and to protect public health and the environment.

Basic activities

The water and sanitation operation subsystem comprises a wide range of activities at different levels of the agency. Activities vary according to the type of facilities

Fig. 3
Design and construction management subsystem



and equipment the agency has, but can be grouped according to three functions of the subsystem:

- Installations and equipment will be operated in order to carry out the production and distribution of drinking-water and the collection, treatment and disposal of wastewater.
- There will be monitoring of the operations and facilities that play a part in water production (collection, transmission and treatment), storage and distribution, sanitation (collection, treatment, re-use and disposal of sewage) and other elements of the subsystem (drainage basins, water sources, receiving bodies, etc.).
- The agency's services will also be monitored (quality and quantity of water, continuity and coverage of water supply and drainage, quality and coverage of the sanitation service).

The scheduling, implementation and monitoring of these operations depend on sufficient reliable data being available. Consequently the timely collection, recording and processing of information are essential to the efficient working of the subsystem.

How the subsystem works

The water and sanitation operation subsystem carries out activities of a technical and managerial nature at all levels of the agency. These activities must be in accordance with specific procedures and with the established plan of operations, in order to ensure that requirements for quality, quantity and continuity are met.

Prior to the installations and equipment coming into service, the water and sanitation operation subsystem begins activities in conjunction with the design and construction management subsystem to prepare technical maps and records of piping, structural components, equipment and so on. This facilitates monitoring and evaluation of the equipment and installations once they are in operation.

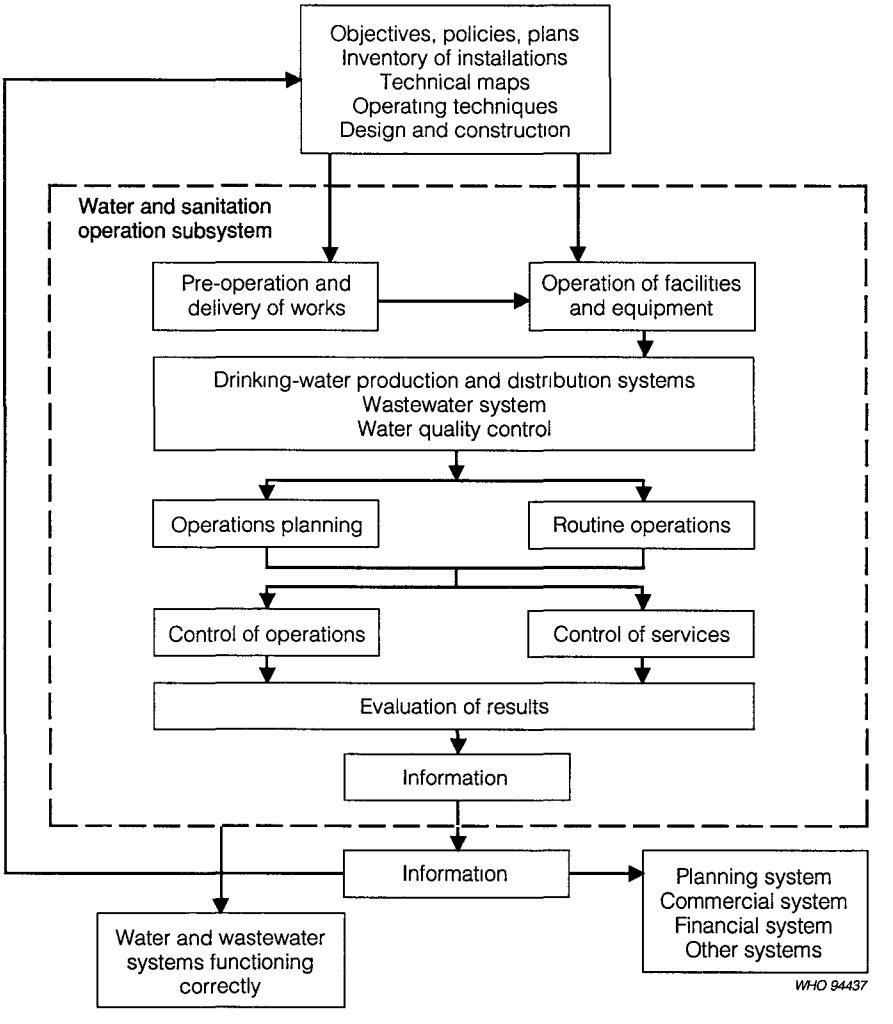
The agency's installations are operated in accordance with operational plans (as described in Part 3) containing all the elements necessary for maximum efficiency, economy of operation and the delivery of services appropriate to the requirements of the community. These elements include performance targets, programmes of operation, standards, procedures, technical maps, information, channels of communication and special instructions.

Data must be obtained and recorded about the operation of the installations. These data form the basis for control of operations. Operational control has three aims: to ensure that operational performance meets established targets and standards, to correct deviations and shortcomings, and to evaluate the results so that installations can be maintained in operation in accordance with the agency's objectives and plans. Information on the operation of installations must also be supplied to the other organizational systems of the agency – especially the planning, financial and commercial systems. This enables the agency to determine

such things as cost of operation in relation to the total costs of the agency and the ability of installations to meet demand.

The efficient functioning of the subsystem is critical because of the need to carry out numerous activities and processes, sometimes with inadequate resources to provide services that are basic to the health and well-being of the community. The initial responsibility of managers and operation supervisors must be for the monitoring of operations, the quality of services provided and the satisfaction of the users. It will thus be possible to reach the targets of the agency and of its operational plans, monitoring operations and evaluating results to determine if

Fig. 4
Water and sanitation operation subsystem



they meet requirements and, when necessary, correcting the operations or standards as appropriate.

Fig. 4 shows how the processes of the water and sanitation operation subsystem relate to the other subsystems of the operational system.

Installations and equipment maintenance subsystem

Definition

The installations and equipment maintenance subsystem is the third subsystem of the operational system as defined in Fig. 1. The subsystem comprises the activities required to prevent or remedy failures in the installations and equipment of a water supply and sanitation agency.

Objectives

The overall objective of the installations and equipment maintenance subsystem is to maintain water and sanitation installations so that they can function efficiently, continuously and safely, keeping them in working condition and maximizing their useful life. The specific objectives of the subsystem are:

- to carry out maintenance activities efficiently, safely and economically;
- to monitor performance of equipment, with regard to the need for maintenance, and to evaluate its quality and the results of its use.

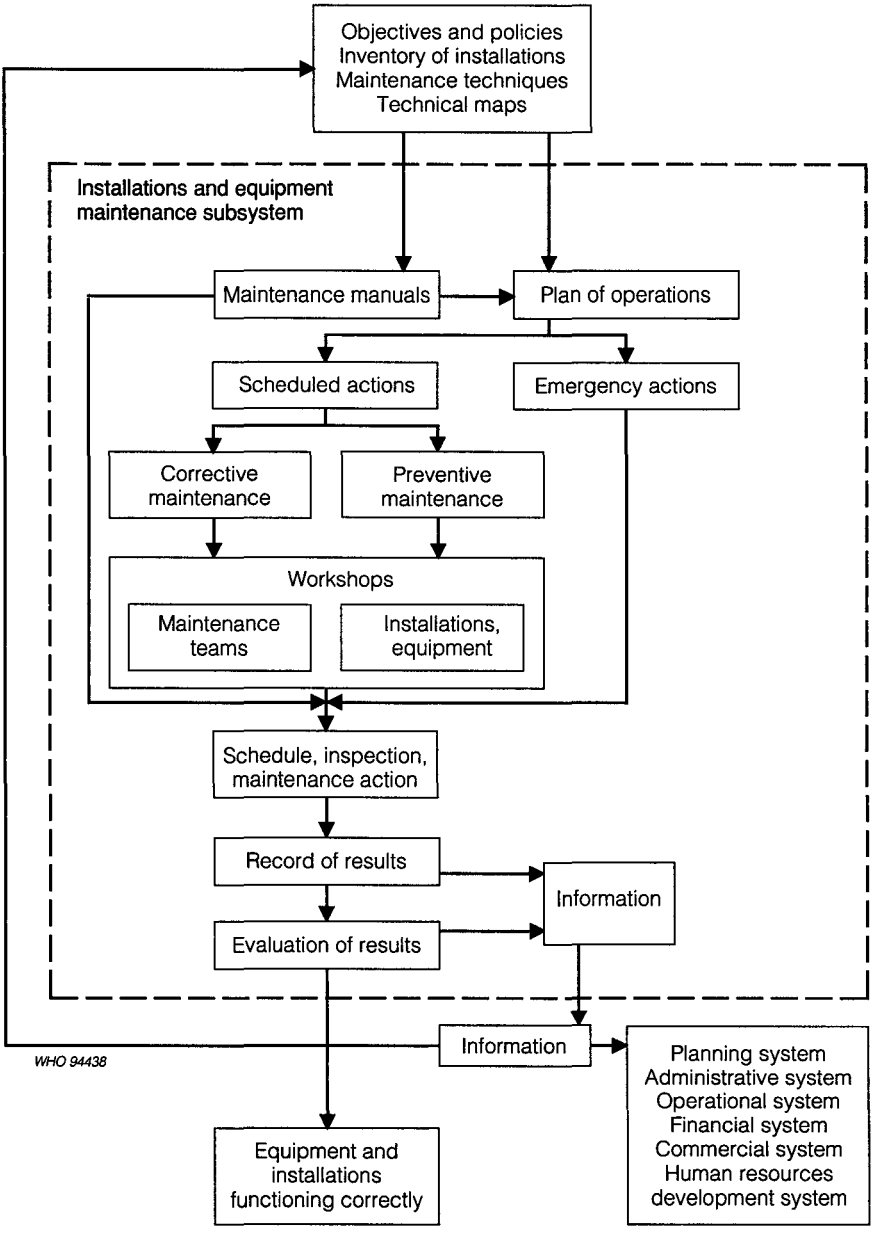
Basic activities

The activities of the installations and equipment maintenance subsystem are performed at different levels of the agency upon the constituent parts of the installations. They are aimed at meeting the need for continuity in delivering services, and have two basic functions: preventive maintenance and corrective maintenance.

In carrying out preventive and corrective maintenance, the subsystem's activities – whether managerial or operational – fulfil the following tasks:

- Actions are performed on the components and equipment of the agency's installations to ensure their cost-effective operation.
- Maintenance work performed on the installations and equipment is monitored for quality and timeliness.
- Maintenance is controlled and monitored in order to measure the performance of equipment and installations, estimate their useful life and provide for their replacement when indicated by cost-benefit studies or other technical considerations.
- Reliable, adequate and up-to-date information is collected, recorded and processed for the planning and proper execution of preventive and corrective maintenance activities.

Fig. 5
Installations and equipment maintenance subsystem



How the subsystem works

The installations and equipment maintenance subsystem carries out its functions of preventive and corrective maintenance according to defined procedures and techniques.

The subsystem's operational plan is formulated on the basis of three elements: the objectives and standards laid down for the subsystem in the plans of action of the operational system, the maintenance techniques, and the part of the installation or piece of equipment to be maintained. The operational plans must include (as indicated in Part 3) objectives, activities, procedures for technical and administrative work, productivity and other functional standards, timetables for maintenance, channels of communication and types of resources to be used.

The programme of preventive maintenance and the actions for corrective maintenance depend on well-equipped workshops and maintenance teams to do the work needed. Information on maintenance activities, the results of maintenance and the condition of installations and equipment after maintenance must be recorded for monitoring and evaluation. This information should also be communicated to the other subsystems of the operational system and to the other organizational systems, particularly the financial system and the planning system.

Maintenance information will be used for making relevant changes in technical maps and records (such as changes in the characteristics or condition of installations and equipment), for pointing out potential problems (weakness of structure, reliability, obsolete equipment, etc.) and for determining how long the facilities can function usefully. Accurate and up-to-date technical maps are important to avoid damage to underground installations by workers from other public service agencies.

Information obtained from maintenance records should be compared with the objectives and standards laid down for the subsystem. This comparison may reveal a need to reformulate maintenance objectives and standards so that maintenance activities yield maximum benefit at minimum cost.

Fig. 5 shows how the processes of the installations and equipment maintenance subsystem relate to the other subsystems of the operational system.

PART 2

Management of operation and maintenance

To attain the objectives of the operational system as indicated in Part 1, there must be efficient administration of the processes necessary for providing drinking-water supply and sanitation services. The management of the agency uses the productive capacity of the agency's staff to obtain results that have the desired impact both on the environment and on the health of those who receive the agency's services. The managerial staff are responsible for influencing how the agency is organized in order to attain its objectives.

CHAPTER 4

Management levels

The key functions of the management of operation and maintenance are carried out at the various levels of the agency,[1] as shown in Fig. 6 and described below. The numbers of the functions and responsibilities listed here correspond to the numbers in Fig. 6.

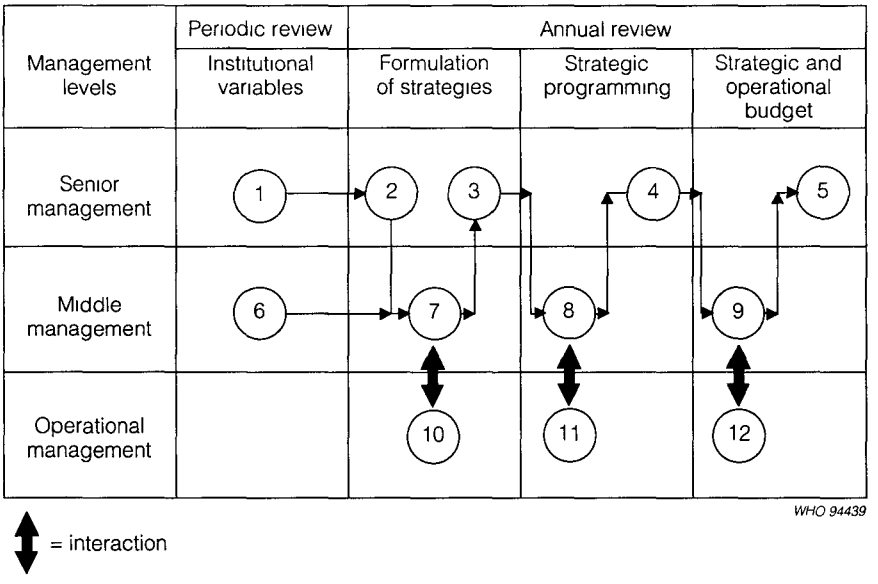
Senior management

Function 1. As part of its task of defining the agency's role and its strategies for achieving long-term objectives, senior management must be in close contact with relevant external bodies. There must be coordination with government and private bodies in areas such as planning, design, construction, operation and maintenance, evaluation, and general administration. Senior management has responsibilities in several areas:

- Objectives must be established for delivery of drinking-water and sanitation services to all population groups, priorities must be determined and areas for expansion of coverage defined (e.g. poor urban areas).
- Decisions must be made about the types of service to be provided (water supply system, sewerage, rainwater drainage, sanitary excreta disposal, sewage treatment and disposal, education and other services to users) and the corresponding objectives.
- Administration of personnel matters (staffing structure, conditions of service, salary scales, post descriptions, performance standards, procedures for staff training and promotion) should be carried out efficiently.
- There must be efficient use of funds and control of construction and operating costs per unit of water (marginal cost).
- Targets must be set (for quality, quantity, continuity, cost, price to be charged for drinking-water and sanitation services) in accordance with public health criteria, social equity and the agency's need for financial self-sufficiency.

[1]The levels of management and assignment of functions will vary from agency to agency depending on situation and staff. Too many levels can hamper the flow of information between the different systems and subsystems with negative consequences on efficiency and effectiveness.

Fig. 6
Management functions in relation to operation and maintenance



- Action must be taken to promote dissemination, acceptance and support of the agency's plans by public and private bodies.
- Action must be taken to promote better use of water at all levels, including re-use of treated sewage.
- It is necessary to work with an advisory board (including representatives of agriculture, industry, drinking-water suppliers and the public) for the allocation of water resources.

Function 2. In the formulation of strategies and plans for operation and maintenance, senior management has a variety of responsibilities:

- There must be situation analysis, both external (natural resources, technological capacity, government policies, sources of funding, etc.) and internal (physical inventory of the agency's installations and equipment). There must be forecasting of the agency's ability to provide services in response to demand and in line with plans for development. And there must be definition of projects with lowest marginal cost and which allow the extension of coverage at lowest cost, having regard to relevant public health, technical and social factors.
- Best results must be achieved from facilities for the collection, treatment, storage and distribution of drinking-water, from facilities for the collection, treatment and disposal of sewage and from other methods of sanitary

excreta disposal that are the agency's responsibility (emptying of septic tanks, etc.).

- Strategies must be devised for improving the availability of services (increasing capacity of supply installations, reducing amount of water wasted or not accounted for, instituting water conservation practices).
- Design criteria, construction methods and the use of appropriate technologies should be applied using strategies that will minimize costs of operation and maintenance.
- Strategies must be devised for improving quality control in the purchase and installation of materials and equipment, and for prolonging the useful life of materials and equipment through adequate preventive maintenance.
- Strategies are needed to ensure that the costs of operation and maintenance are taken into account when selecting tenders for the provision of goods and services.
- Strategies and plans are required for raising productivity of the agency's workforce.
- The best safety procedures must be ensured and necessary safety equipment must be provided.
- Strategies and plans must be drawn up for exploring, exploiting and managing water resources in coordination with the appropriate authorities.
- Strategies and plans are required to prevent and control pollution in coordination with the appropriate authorities (standards for discharge of effluent and re-use of sewage, guidelines for the disposal of sewage and waterworks sludge).
- Strategies and plans are also needed for monitoring the content of wastewater (from industrial connections, etc.) to obviate damage to the agency's installations and the environment.

Function 3. Senior management should also consolidate the programmes formulated by middle and operational management into a long-term plan for operation and maintenance by setting specific targets for each organizational system, in terms of coverage, output, productivity and cost. Senior management will determine the technical, economic and organizational feasibility of the operation and maintenance plan in relation to the overall plan of the agency, making adjustments and carrying out cost-benefit, socioeconomic or other studies as necessary. The operation and maintenance plan should be shared with other agencies and authorities as well as with the public.

Function 4. Following approval of the long-term operation and maintenance plan there must be corresponding programmes of investment and implementation. Senior management must allocate resources for the long-term plan in accordance with pre-established priorities. They must set intermediate targets and indicators for the managerial control entrusted to the agency's middle management. Senior

management will periodically monitor progress and evaluate results, making appropriate adjustments and reallocating resources as necessary to ensure the attainment of long-term and medium-term objectives in operation and maintenance.

Function 5. Each programme reaches its operation and maintenance targets by means of projects. Senior management must establish the budget for each programme and project annually on the basis of physical targets and in light of long-term objectives. This procedure must be coordinated with the activities and inputs (services and goods) of other organizational systems of the agency, or of other agencies, which are necessary to carry out operation and maintenance functions. In the short term this will provide senior management with a tool for coordinating the activities of the different organizational systems of the agency. In the long term it will allow adjustments to be made to targets, strategies and plans in light of both the agency's performance and the dominant forces that will determine future trends.

In addition to the above regular programmes, senior management should encourage programmes of a strategic nature that have potential for research, development and adaptation of new technologies and organizational approaches for the operation and maintenance of the agency's services. Such programmes will lay the foundation for continuous adaptation of the agency to technical, regulatory and political changes.

In zones at high risk of recurrent disasters, the vulnerability of the water supply and sanitation services must be analysed and contingency plans formulated for the continued delivery of services in emergency situations.

Middle management

While the activities of senior and middle management complement each other they must also interact. Middle management should contribute to the formulation of strategies and plans for operation and maintenance, as well as to programmes and projects for expanding the organization's facilities and making them more effective. To do this, it should:

- obtain data for the selection of design and construction criteria and methods that meet technical standards and social needs in the most cost-effective way;
- formulate and implement programmes to increase productivity;
- formulate and implement programmes and projects for the exploration, exploitation and management of water resources;
- provide data for the formulation and implementation of pollution control programmes.

Function 6. Middle management is responsible for defining objectives by type of service to be delivered (drinking-water treatment, storage, water distribution, rainwater drainage, sewage collection, treatment, re-use and disposal, sanitary

excreta disposal, etc.). In each case there should be indications of the coverage to be achieved. Increase in output should be measured in terms of capacity for treatment, storage and distribution of water, capacity for collection, treatment, re-use and final disposal of sewage, or capacity for the provision of other excreta disposal facilities.

Function 7. The middle management tasks also include formulating, evaluating and supervising medium-term programmes for operation and maintenance, including procurement and distribution of resources. This should be done on the basis of proposals drawn up with operational management. Medium-term programmes should aim at:

- expanding coverage of services;
- making best use of existing physical, financial and human resources;
- improving the quality of the services provided;
- reducing and controlling water loss;
- reducing and controlling infiltration into and exfiltration from sewage collection systems;
- rehabilitating — preferably as part of a preventive maintenance programme — component parts of the water and sanitation installations and equipment with a view to extending their useful life;
- reducing costs and raising productivity in the agency's operation and maintenance programmes;
- controlling the production and quality of drinking-water and the quality and discharge of sewage effluent;
- supervising the operation and maintenance of sanitation and drinking-water services;
- monitoring pollution of water sources and receiving bodies;
- promoting awareness of and educating users about the proper use of drinking-water and sanitation services.

Function 8. The long-term operation and maintenance plan should be evaluated by middle management in the light of technical, economic and organizational feasibility studies. Middle management should determine priorities and methods for developing and implementing the plan.

Function 9. Short-term programmes and projects formulated by operational management should be consolidated by middle management who will set the targets for each programme, calculate what funds are needed and propose the budget allocation for the agency's units. The consolidated short-term plan for operation and maintenance is submitted to senior management to make sure it is compatible with the agency's long-term plan and that it complements other programmes. In the light of senior management's comments, middle management adjusts and repeats the process until final approval is obtained.

Operational management

The operational management of an agency is responsible for short-term planning. It also participates in formulating, implementing, evaluating and controlling long-term and medium-term plans and programmes. In line with the objectives of the operational system, operational management has several responsibilities in the execution of planning, design and construction work as well as in the operation and maintenance of the agency's installations and equipment.

Function 10. Operational management proposes medium-term activities and programmes to provide services (drinking-water, collection of sewage, rainwater drainage, sanitary excreta disposal and other related services) for which the agency is responsible. The operational level of management also participates with middle management in defining objectives, strategies and resources both to extend the coverage of services and to ensure full use of them.

Function 11. Another operational management task is to evaluate the feasibility of medium-term investment and programmes for the operation and maintenance of drinking-water and sanitation systems.

Function 12. In line with the medium-term programmes, operational management should formulate short-term objectives, targets and programmes. This includes calculating which resources are needed and allocating them to the operational units, as well as monitoring and evaluating their performance in a number of areas:

- Studies and designs are needed for the rehabilitation of installations or the expansion of water and sanitation services.
- Construction work must be carried out to install or expand water and sanitation services.
- Operational units must be maintained so that they work efficiently and last as long as possible.
- Measurement of water flow rates, pressures and levels (macrometering) should be introduced or developed.
- Diagnostic processes should be introduced, based on models that show the hydraulic configuration of the water distribution network under real or simulated conditions.
- Processes for reducing and controlling leaks in the water supply network should be introduced or adapted.
- Technical maps of the drinking-water distribution and sewage collection networks should be drawn or updated.
- Processes for improvement of house connections and domestic plumbing should be introduced or revised.
- Processes for the production and quality control of drinking-water should be introduced or adapted.

Table 2
Management functions dealing with institutional objectives

Management level	Management function
Senior management	Objectives for provision of services Types of services to be provided Efficiency in personnel administration Targets for quality, quantity, continuity, cost and price Interaction with external agencies
Middle management	Objectives by type of service provided Definition of increase in output in terms of capacity for treatment, storage and distribution of water and capacity for collection, treatment and disposal of wastewater
Operational management	—

Table 3
Management functions related to formulation of strategies

Management level	Management function
Senior management	Situation diagnosis Ensuring best use of equipment and installations Improving availability of services Design and construction criteria, appropriate technology Improving quality control Selection of tenders for procurement of goods and services Improving productivity of personnel Ensuring safety procedures for workers Management of water resources Quality control of wastewater Consolidation of programmes formulated by middle and operational management Feasibility studies Long-term operation and maintenance plan
Middle management	Formulation, evaluation and supervision of medium-term programmes Expansion of coverage Best use of resources Improvement of quality of services Reduction of water loss Rehabilitation Improvement of cost/productivity ratio Control of production and quality Control of pollution of water sources and receiving bodies Education of users
Operational management	Proposal of medium-term programmes and activities

Table 4
Management functions relating to strategic programming

Management level	Management function
Senior management	Approval of long-term programme Allocation of resources Monitoring, evaluation, adjustments
Middle management	Evaluation of long-term plan for operation and maintenance Determining priorities Establishing methodology for implementing the long-term plan
Operational management	Evaluation of feasibility of medium-term investment and operational programmes

Table 5
Managerial functions related to strategic and operational budget

Management level	Management functions
Senior management	Approval of annual budget for each programme and its projects Encouragement of research, innovative approaches, special projects
Middle management	Setting targets for programmes Calculating need for financial resources and proposing budget allocation
Operational management	Studies, designs for expansion Construction of new works Rehabilitation Macrometering Network survey Leakage control Technical mapping Improvement of house connections Inventory of technical information Improvement of processes for production, quality control Revision of procedures for maintenance Definition of short-term objectives, targets, programmes, projects Definition of responsibilities regarding formulation, implementation, follow-up, monitoring and evaluation of projects Improvement of raw water quality, pollution control Improvement of efficiency, reduction of costs, increase in productivity

- Preventive maintenance programmes for the installations and equipment of water and sanitation systems should be introduced or revised.
- Medium-term programmes should be consolidated by defining short-term objectives, targets, programmes and projects.
- The responsibilities of each of the agency's units should be determined with regard to the formulation, implementation, follow-up, monitoring and evaluation of projects.
- Activities should be introduced to preserve or improve the quality of raw water and to control pollution.
- Activities should be introduced to improve efficiency, reduce costs and increase production of drinking-water and treatment of sewage.
- As front-line representatives of the agency, operational management should establish lines of communication with the community and foster good public relations.

Tables 2–5 summarize these key functions of the management of operation and maintenance.

Relationship between management levels and agency functions

The levels at which management functions are carried out in regard to operation and maintenance, and their relationship with the other functions of a water supply and sanitation agency (operation, human resources, financial, etc.), are shown in Fig. 7. For instance, senior managers responsible for long-term (strategic) planning have to take high-level decisions in each of the organizational systems (operational, financial, planning, etc.). The middle managers responsible for medium-term planning will carry out the management functions relating to their level of decision and will also provide inputs to decisions and action at senior management level. This is shown in Fig. 7 by the overlapping of the horizontal rectangle. Managers must realize the importance of establishing clearly the different management levels and management functions to be performed at each level, as well as the procedures for interaction and exchange of information between them.

Using Fig. 7 we can identify in detail exactly who performs what type of management activity and in which organizational system. We can draw the profiles of the different management positions in the agency, regardless of its current organizational structure, thus facilitating the analysis, planning and development of human resources.

Table 6 uses the preceding methodology to indicate the profile of a middle manager within an agency's operational system. The table gives a description of the various management activities and the part they play at the tactical (middle management) level, with interactions at the strategic (senior management) and operational levels. Table 6 also shows the organizational functions (within the organizational systems), with emphasis on the operational system and its links with the other organizational systems of the agency.

Fig. 7
Areas of management activity according to management levels and organizational systems

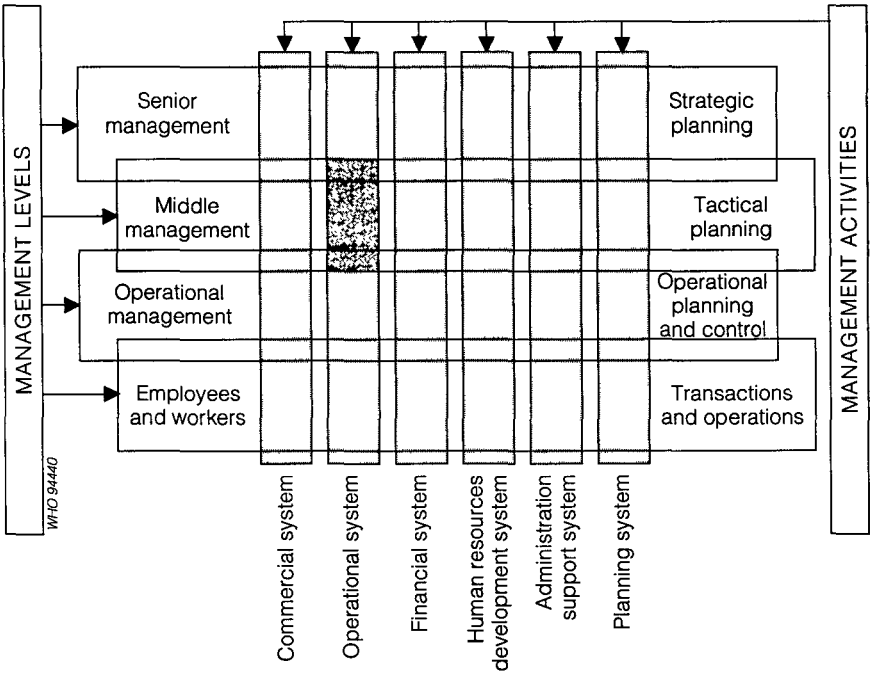


Table 6
Functional occupational profile: operational system, middle management level

Management activity	Areas of action (organizational function)	Interaction with different management levels
Planning	*Operational system*	Senior management
Definition of objectives, policies, strategies	Design and construction, operation, maintenance, other programmes (e g control of losses, infiltration, exfiltration)	Operational management
Fixing targets, units of measurement	*Planning system* Physical, economic, financial planning	Senior management Operational management
Programming of activities	*Commercial system* Programming of metering coverage, expansion plans	—
Organization	*Operational system*	
Classification of activities	Operation of drinking-water production and distribution, plus sewage collection, treatment, re-use, disposal	
Grouping of tasks by function and relationship with the agency	Electromechanical maintenance, instrumentation, construction work	
	Maintenance of collection, and distribution networks	
	Maintenance of sanitation facilities	
	Planning system Organizational functions (systems) organizational planning, organizational structure	—
Personnel	*Operational system*	
Selection of personnel, assignment of tasks	Objectives, functions Technology	
Definition of plans, development programme	*Human resources system* Staff development, training policies Methods, resources for training Occupational profiles Staff rules Personnel administration Post classification Incentives Performance standards	

Table 6 (continued)

Management activity	Areas of action (organizational function)	Interaction with different management levels
Coordination Sequential ordering of activities Communication of changes in priorities	*Operational system* Subsystems Loss control programme Infiltration, exfiltration control programme	Senior management Operational management
	Planning system Programming techniques Targets, programmes, budget	Senior management Operational management
	Commercial system Loss control programme Infiltration, exfiltration control programme	Senior management Operational management
	Social communication system (personnel and users)	Senior management Operational management
	Other systems Objectives, interrelationships	Senior management Operational management
Direction Group work (leadership) Incentives promotion (motivation) Decision	*Operational system* Decision models *Human resources system* Behaviour techniques Performance appraisal Classification, grading of positions Styles of communication	
	Management information system Evaluation, monitoring of management indicators	Senior management Operational management
Control Measurement of results Monitoring, evaluation Reformulation, adjustment of policies, strategies, programmes	*Operational system* Objectives, targets, management indicators, control of results	Senior management Operational management
	Planning system Internal control	Senior management Operational management
	Financial system Cost control, budget control	Senior management Operational management
	Human resources system Productivity Performance appraisal	Senior management Operational management
	Management information system Evaluation, monitoring	Senior management Operational management
	Commercial system Control of losses	Senior management Operational management
	Administrative support system Personnel control, administration	Senior management Operational management

PART 3

Planning and control of operation and maintenance

To carry out the functions of the operational system, and hence of operation and maintenance, managers must make appropriate plans and ensure that relevant programmes are carried out, as noted above. Some programmes that are normally important for water and sanitation agencies are described in the following pages, and their objectives and component projects are identified. The scope, objectives and content of each programme must be adjusted to the situation in which the agency operates and the types of service it provides to the community. The programmes described here are offered as general examples that must be adapted according to local conditions.

The procedures outlined can serve as a guide for preparing more detailed procedures and programmes for the operation and maintenance of facilities.

The following programmes are described:

- loss control (this important programme is given special emphasis and is therefore considered in more detail):
- control of production and quality of drinking-water;
- control of sewage collection, treatment, re-use and disposal.

These programmes call for concerted efforts and flexibility in support areas such as the development of human resources, management of material resources and implementation or improvement of information systems. These elements are included in this publication, though not with the same emphasis as the programmes themselves.

CHAPTER 5

Loss control programme

Reducing loss of water

A programme for control of water loss comprises those activities carried out by an agency to achieve and maintain the lowest possible level of loss (from leaks, overflows, illegal use of water, waste, operational consumption, special consumption, errors in metering or estimation).

Projects and activities aimed at the control of water loss extend to all the organizational systems of the agency, though most are concentrated in the operational and commercial systems. This section therefore emphasizes projects and activities in these two systems.

Control of water loss is a consequence of efficient management and helps the agency attain its objectives at the lowest cost. In order to be considered efficient and effective, an agency should be able to meet certain conditions:

- The water supply system should be capable of collecting, transmitting, treating and distributing volumes of water adequate to meet the domestic, commercial and industrial demands of the population (quantity).
- Drinking-water delivered to the population should meet recognized standards of potability (quality).[1]
- Water should be supplied to the population without interruption and at adequate pressure (continuity).
- The operating staff should be able to overcome the problems liable to affect the supply of water (reliability).
- The cost of achieving the above conditions must be kept as low as possible (cost).

Lack of efficient agency management leads to poor results from loss control projects. This will in turn lead to need for new installations or extension of existing facilities well before the planned time.

Decisions to expand the water supply facilities should not be motivated exclusively by shortcomings in the supply but should be based on reliable data and adequate planning studies. Failure to control losses is likely to lead to complaints from users, compounded by lack of financial resources to expand the supply

[1] See: *Guidelines for drinking-water quality*, 2nd ed. Vol. 1. *Recommendations*. Geneva, World Health Organization, 1993

network. Lack of information on the extent of loss and why it occurs can prevent effective management action to reduce it. This leaves the users to bear the costs of the agency's inefficiency. It is essential to use the existing water supply system to its fullest capacity before expanding a system that will continue to lose too much water.

A programme for control of loss must not only address faults, such as leaks and metering errors, but must also investigate their causes and, as far as possible, reduce or eliminate them. It is indispensable that a loss control programme should be concerned with planning, design, construction, supply of materials and equipment, operation, maintenance, marketing, organization and administration.

A loss control programme involves systems and persons both within and outside the agency since its activities may lead to the introduction of far-reaching changes that extend even to consultants, contractors and suppliers of materials and equipment.

Water loss can be represented by the following equation:

$$L = \frac{V_p - (V_m + V_e)}{V_p} \times 100\ \%$$

where:

L = loss (%),

V_p = volume of water produced (m^3),

V_m = volume of water metered (m^3),

V_e = volume of water estimated for invoicing purposes in house connections without meters (m^3).

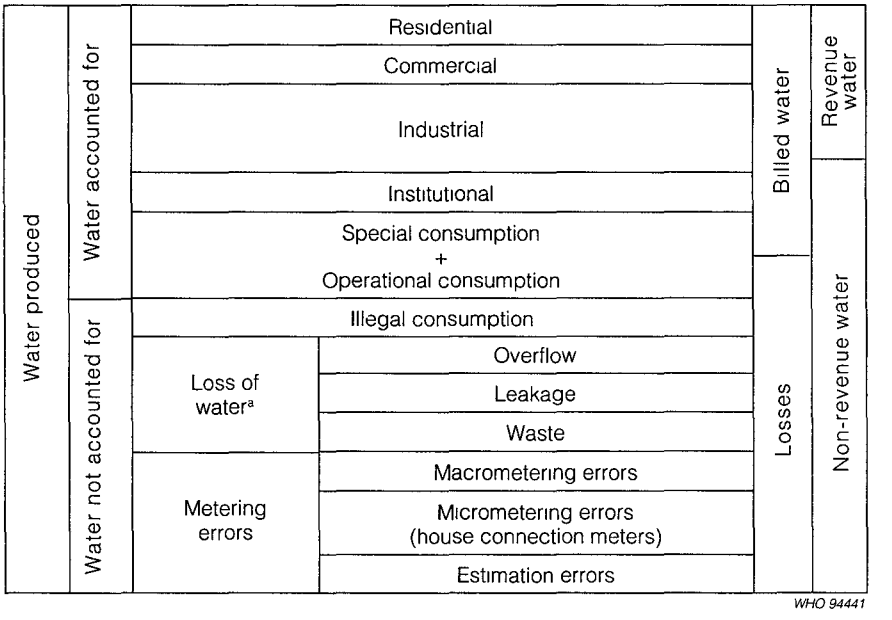
This loss is normally attributable to leakage, metering errors or non-recoverable uses of water (see Fig. 8).

- *Leakage* represents loss due to spillage of water from the overflow devices of service reservoirs and leakage from pipes or other parts of the distribution system, including house connections up to the meter. Leaks and overflows inside the properties where consumption is not metered are also included under this heading.

- *Metering errors* account for a substantial part of total losses and are caused by inaccuracy in the macrometering and metering equipment that measures flow. This category of loss is an indication of the efficiency of the metering system. It has to do with errors in the metered quantities of water rather than with actual loss of water.

- *Non-recoverable uses* represent losses from quantities of water that are not accounted for in the agency's invoices. This category includes operational consumption (washing and disinfection of pipes and service reservoirs), special consumption (fire-fighting and irrigation of public areas), illegal connections and legally allowed (or tolerated) services which are supplied free of charge.

Fig. 8
Volumes of water accounted for and producing revenue compared with water not accounted for and not producing revenue



[a] Leakage, overflow and waste occurring within a metered property are not included in the figures for loss of water (the user will be billed for metered water that is wasted).

At the level of production, losses represent the difference between the quantities of water collected at the sources and the quantities supplied for distribution. Since the complexity of water production varies from agency to agency, plans must be made to detect and control losses that occur during water production in order to minimize these to the extent that facilities allow.

Losses during water production should be measured and minimized through special programmes and activities carried out with this aim. Loss during water production is shown by the following equation:

$$L_p = \left(\frac{V_s - V_p}{V_s}\right) \times 100\ \%$$

where:

L_p = losses during water production (%),

V_s = volume of water collected at the intake,

V_p = volume of water produced.

Objectives of a loss control programme

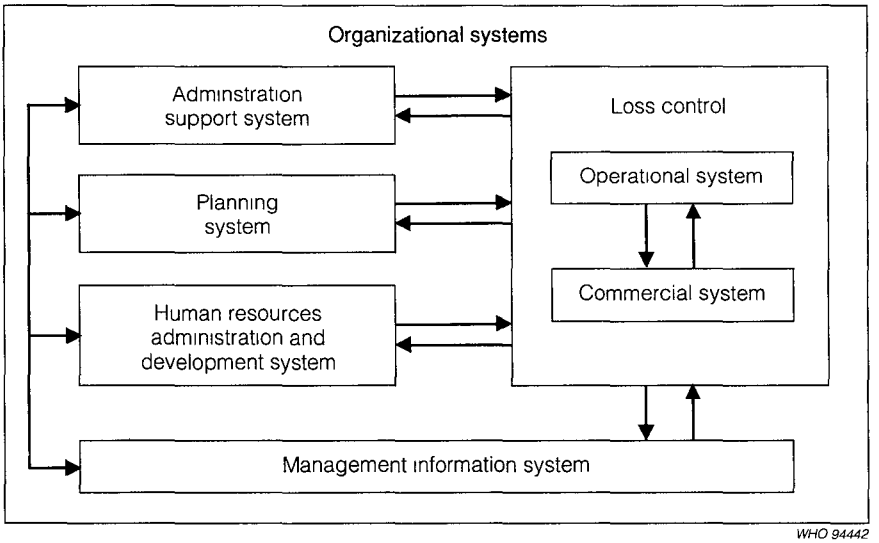
The overall objective of a programme to control water loss is to diagnose how loss is caused and to formulate and implement action to reduce it to a technically and economically acceptable minimum.

The activities of all who are part of the water supply process—including suppliers, consultants and contractors—must be coordinated so as to attain efficient performance.

A water loss control programme has the following objectives:

- to reduce losses to an acceptable minimum;
- to meet additional demands with water made available from reduced losses (usually with benefit to fringe areas);
- to ensure that the water supply system functions as efficiently as possible for as long as possible;
- to increase the useful life of the facilities;
- to distribute water to as many users as possible and ensure that costs are shared equitably among all users;
- to minimize the cost of production and distribution of water.

Fig. 9
A loss control programme focuses on the operational and commercial systems but should include priority projects of other organizational systems



Component projects

A programme of water loss control is made up of different projects that need to be implemented in an integrated manner. These projects constitute a range of measures to reduce loss and to improve the overall efficiency of the agency. They relate to several of the agency's organizational systems.

To be effective the water loss control programme should include priority projects of key organizational systems and should not concentrate only on those systems dealing directly with operation and maintenance (see Fig. 9). The following chapters describe water loss control projects in the agency's operational system, commercial system, human resources administration and development system, and administration support system.

CHAPTER 6

Water loss control projects of the operational system

Within the water loss control programme, a number of the agency's organizational systems have contributions to make. Nevertheless, it is in the operational system, which is responsible for operation and maintenance, that most of the projects are found.

Network survey

Objective

The objectives of a network survey are to obtain, process, analyse and disseminate operational data concerning water flows, pressures and levels, performing specific diagnoses of the operational units of water supply systems under real or simulated conditions.

Description

A network survey involves different performance tests in the various parts of the water supply system. The survey gives an accurate profile of the operational and hydraulic conditions of the system. The survey results can then be used as the basis for adopting measures that will improve the performance of the system under controlled conditions. The most common performance tests include the following:

- Measurement of flows and pressures in cross-sections of pressure mains.
- Measurement of flows and pressures over long periods (24 hours or 1 week) at hydraulically important points in the water supply system.
- Determination of the water-carrying capacity of pipes and checking for obstructions.
- Studies of per capita consumption.
- Determination of maximum hourly consumption and maximum daily consumption.
- Checking the accuracy of macrometering devices.
- Determination of the calibration curve of differential-pressure water-metering devices.
- Determination of characteristic curves of centrifugal pumps and evaluation of the performance of pumping stations.

- Sectorizing of pressure zones.
- Tests to evaluate the capacity of the distribution network to cope with new demands for water.
- Study of real and simulated water transmission operations and pressure zones in support of operation control management (see project for controlling the operation of the water supply network).
- Setting up and monitoring of metering districts for the control and reduction of water loss.
- Acceptance tests on new mains.
- Special tests to meet the particular requirements of a given water supply system.

Activities

The agency's managerial and technical staff should be convinced of the importance and scope of network survey services. Therefore before the project is implemented it should be promoted among managers and personnel involved in planning, operation, maintenance, construction, and metering/billing. In large agencies, it may be necessary to create decentralized network survey units to provide flexibility, efficiency and effectiveness in carrying out network survey services.

- Equipment should be selected for use in network survey operations. If possible, preference should be given to equipment manufactured within the country or to imported equipment for which the manufacturer can ensure a supply of spare parts and technical assistance.
- Professional staff should be selected, motivated and trained for network survey work. Staff should be given opportunities to receive basic and advanced training in other agencies where network survey services are in operation.
- Within the water supply network, points must be determined at which network survey stations will be installed.
- Mechanisms must be created for disseminating the results of studies by the network survey units and expediting the circulation of information.
- A programme of activities must be defined for a given project period. Tests should be done regularly although there may have to be some adjustment to schedules depending on local conditions and the agency's specific requirements and constraints. The recommended frequency of tests is as follows:
  - — determination of the water-carrying capacity of the mains: once every two years
  - — checking the accuracy of macrometering devices: every four months (or according to the reliability of the device)

— determination of the calibration curve of differential-pressure water-metering devices: once a year

— determination of the characteristic curves of centrifugal pumps and evaluation of the performance of the pumping station: every two years.

- Mechanisms must be established for follow-up, control and adjustment of the network survey project.

Macrometering

Objective

A macrometering project has as its objectives the installation of permanent measuring devices for the collection of routine operational data on water flows, pressures and levels, and the processing, analysis and dissemination of those data.

Description

Macrometering is an indispensable tool for guiding the operation of the water supply system and for obtaining statistics on the production and distribution of water. A macrometering project involves the following:

- Continuous evaluation of the hydraulic conditions of the water supply system.
- Determination of water volumes and flows at various points in the system and analysis of this information in relation to expected performance.
- Monitoring of changes in water pressure caused by changes in control or blocking valves, or in the functioning of pumping stations.
- Determination and analysis of pressures in pipes and water levels in reservoirs or wells to give guidance in routine operation of the network or in planning changes in its operation.
- Evaluation of trends in consumption, and forecasting possible excess of demand for water over the agency's capacity to supply it, on the basis of demographic, socioeconomic and cultural data.
- Constant monitoring of loss in the water distribution system.
- Periodic assessment of the factors causing loss, such as macrometering errors, micrometering errors, leaks and overflows, illegal connections, special consumption and operational consumption.
- Determination of consumption coefficients, such as per capita consumption, day and hour of highest consumption, consumption per network extension, consumption per house connection, and minimum night consumption.
- Determination of volume of drinking-water produced and fed into the distribution system.

- Determination of the volume of water used in the water treatment process.
- Determination of the volume of water lost at water treatment plants.
- Evaluation of existing systems of metering, including degree of suitability of house meters to the pattern of demand of the households, degree of accuracy and sensitivity of meters and equipment, efficiency of maintenance, planning for replacement of meters and the processing and analysis of data from meters.
- Planning for the installation of metering systems according to a list of priorities based on macrometering (see projects of the commercial system, page 55).
- Operational planning so that maintenance causes the least possible disturbance to the water distribution network.

Activities

The macrometering project should include the following activities:

- Development of a list of priority points of the water supply system for installation of meters to measure water flow, pressure or level.
- Preparation of an inventory of the macrometering devices in the water supply system, whether or not they are installed, functioning and accurate.
- Definition of degree of sophistication of devices used at each measuring point with regard to indication, integration, recording, transmission and reception of data.
- Choice and specification of the most suitable macrometering devices to be purchased for each water supply system, taking into account how the existing equipment is used.
- Preparation of detailed maps, showing location of each measuring point.
- Determination of mechanisms for collecting, processing, analysing and disseminating data.
- Obtaining manufacturers' manuals on the operation and maintenance of meters and introducing appropriate adjustments according to special needs.
- Training of staff to keep their knowledge and skills up to date.
- Preparation of a plan of action for implementation of the project.

Leakage control

Objective

The objective of a leakage control project is to reduce to a minimum the time that elapses between the occurrence of a leak and its repair.

Description

The volume of water lost through each leak should be reduced by taking whatever action is technically and economically feasible to ensure that the leak is repaired as quickly as possible.

To this end the agency needs procedures for identifying, reporting, repairing and accounting for visible leaks. These procedures should involve the active and conscious participation not only of staff members but also of the population served by the agency.

Activities

The project should have provision for the following activities:

- Establishment of procedures whereby the population served by the agency can notify the agency of visible leaks.
- Establishment of procedures for attending correctly and efficiently to the leaks identified in this way.
- Establishment of procedures for characterization and categorization of leaks.
- Establishment of procedures for prompt repair of leaks.
- Reporting by staff of visible leaks found while carrying out other work on the water supply system.
- Identification of critical areas where leaks often occur, and implementation of appropriate corrective measures.
- Organization of a service for detecting and locating non-visible leaks through processes compatible with the technological, operational and financial capability of the agency or agencies involved. The selection of the most appropriate process for detection and location of leaks must take cost-effectiveness into account.
- Procurement of equipment for detection and repair of leaks.
- Training of staff to keep their knowledge and skills up to date.
- Statistical processing of data on leaks in order to evaluate detection and location work and to provide a basis for management decisions regarding the overall problem of water loss.
- Action to reduce the occurrence of leaks in household plumbing by installing meters and setting up programmes to promote better maintenance.
- Reduction of water loss from leaks by controlling pressures in the water distribution network.

Mapping and inventory of pipes and fittings in the water supply system

Objective

This project has the twofold objective of instituting or updating the mapping and inventory of pipes and fittings (indispensable for operation and maintenance).

Description

The project should set up routine procedures for preparing and updating a map and inventory of pipes and fittings. It is recommended that a single mapping system be adopted and that it should be possible to exchange maps with other public or private utility services (electricity, telephone, etc.).

Activities

The project for mapping and inventory has the following activities:

- Establishment of cooperative action with the management of other public and private utilities.
- Definition of the characteristics of the maps (layout, scale, representation of pipes and fittings, etc.).
- Definition of the characteristics of layout of public road intersections and representation of underground installations.
- Establishment of processes for storage and retrieval of maps and inventory information.
- Setting up procedures for collecting map information in the field.
- Compiling instructions for updating survey maps and drawings of intersections.
- Verification of compliance of the design of "as-built" networks with results in the field.

Improvement of house connections

Objective

The objective of this project is to improve the condition of house connections, which are often responsible for leaks in the water distribution system.

Description

This project is aimed at developing a rational system for design, sizing, standardization, construction, inspection, acceptance and quality control of house connections. High priority should be given to this project because of its potential for reducing loss of water.

Activities

The activities of the project for improvement of house connections are as follows:

- Investigation of the reasons for leaks in house connections by reviewing procedures used in the purchase, acceptance, supply and installation of materials.
- Review of the criteria for specification, purchase, acceptance, supply and installation of the materials used in house connections.
- Implementation or improvement of the training and licensing of plumbers responsible for installing house connections.
- Identification of procedures, tools and materials that regularly result in leaks, followed by a programme for changing procedures and tools and for changing or reconditioning unsuitable materials.
- Introduction of appropriate administrative processes to authorize new house connections to the service. This will lead to better surveillance of the work carried out by plumbers or others.

Controlling the operation of the water supply system

Objectives

The objectives of this project are to introduce procedures to obtain, process and analyse the variables related to water flows, pressures and levels as well as the consequences of manipulating control devices (control or blocking valves and pumping stations) so that the hydraulic status of the system can be adjusted to match the demand for water.

Description

The efficiency and effectiveness of a water supply system depends on the operating personnel's knowledge of the variables that affect the continuity, reliability and amount of water supplied to consumers. The personnel should be able to influence the hydraulic configuration of the system by acting on those variables promptly and effectively.

The operation control project should include both routine operation and operation planning. Routine operation refers to activities for adjusting the configuration of the water supply system to match prevailing conditions. These activities are based on analysis of the variables communicated continually to the central operating unit.

Operational planning is the definition of criteria and options for operation under specific configurations of the water supply system. Criteria are determined on the basis of analysis of the effects of particular operations on the hydraulic configuration of the water supply system. These effects can be seen in simulated operating situations. For this purpose, mathematical simulation models can be developed from basic data about the network (length and size of pipelines,

characteristics of pumping stations, service reservoirs, valves, etc.). This approach can be very useful, particularly in the case of large and complex water supply systems.

Water demand

Objective

The objective of a water demand project is to develop a demand management programme to reduce the excessive use of water.

Description

This project should develop a water conservation policy and implement it among consumers.

Activities

The following activities should be considered when formulating a water demand project:

- Installation of accurate water metering and establishment of a realistic tariff structure to encourage water conservation.
- Introduction of restrictions on household fittings such as taps, showers and toilets.
- Introduction of poor-flush water-closets.
- Enforcement of restrictions on use of water for watering lawns, cooling, curing concrete and washing vehicles.
- Encouragement and/or enforcement of the re-use of water in industrial processes.
- Development and implementation of public education programmes to encourage water conservation.

Electromechanical maintenance and instrumentation

Objective

The objective of the electromechanical maintenance and instrumentation project is to improve performance and reliability by setting up a system of preventive and corrective maintenance of electromechanical installations, equipment and instruments.

Description

Equipment that is disabled or is working incorrectly in a water supply and sewerage system is a threat to the quality of the services rendered to consumers.

There is also a threat to public health if water supply systems do not function properly and if sewage is incorrectly connected, treated, re-used or disposed of. Repair costs for poorly maintained equipment usually exceed the cost of preventive maintenance. Preventive maintenance programmes help keep equipment operating satisfactorily and aid in detecting and correcting malfunctions before they develop into major problems.

This project should formulate and implement a programme of systematic preventive maintenance, if possible with the support of a computer, specifying a schedule for maintenance of each piece of equipment and describing the maintenance procedure. There should be a procedure for issuing a work order for the tasks to be performed, for listing the tasks not completed and for recording when tasks are completed. There should also be a means of generating information to evaluate the quality and reliability of the maintenance process and the decisions taken.

Activities

The electromechanical maintenance and instrumentation project should include the following activities:

- Development of maintenance procedures and techniques according to the standards of the water supply system and the recommendations of the manufacturers of the equipment.
- Reorganization of maintenance to new requirements arising from the introduction of network survey, macrometering, leakage control, operation control and other services.
- Establishment of programmes for preventive maintenance of equipment and operational units.
- Establishment of programmes for rehabilitation of operational units following studies of technical and financial feasibility.
- Preparation of maintenance manuals for equipment and operational units.
- Evaluation of preventive maintenance schedules. It is necessary to determine if maintenance is being carried out often enough, or too often, in terms of cost-effectiveness (by comparing frequency and cost of failures with costs of maintenance).

Implementation

Use of a computer will help implementation of a preventive maintenance service. The computer can be used to store, retrieve and analyse data, to schedule maintenance tasks and to record results when tasks are completed. The following are suggested steps in implementing a preventive maintenance service:

- An inventory of all equipment and facilities should be prepared.
- Data should be recorded for each piece of equipment, including name, address and telephone number of manufacturer.

- An equipment service card should be prepared for each piece of equipment. Each card should have the name of the piece of equipment on it, and should:

  — list each required maintenance operation with an item number;

  — list maintenance interventions in order of frequency;

  — describe each maintenance intervention in terms of work to be done.

  All necessary inspections and services should be listed on the card.

- A service record card should be prepared for each piece of equipment. The service record card is a record of each maintenance task performed on that particular piece of equipment. The card should list the date, the work done and the signature of the person who did it.

- Preventive maintenance work should be scheduled on a daily, weekly, monthly, quarterly or annual basis.

- An inventory should be prepared of existing equipment and spare parts, together with a list of items needed.

- Schedules for obtaining spare parts should be developed in advance of maintenance and overhaul activities.

- Prioritized lists of maintenance tasks should be developed.

- A means of obtaining lists of maintenance and repairs carried out should be developed in order to evaluate the performance of the equipment and to serve as a reference when ordering equipment in future.

- A list of uncompleted work and currently scheduled maintenance should be maintained.

- A procedure should be developed to obtain summaries of maintenance costs, including cost of materials, parts and labour.

- A procedure should be prepared for obtaining information on the status and condition of equipment.

- A schedule should be prepared for inspecting and testing safety equipment.

Maintenance of distribution networks

Objective

The objective of this project is to improve the level of maintenance of water distribution networks and house connections through improved coordination and planning of administrative and fieldwork and through the use of adequate techniques, equipment and materials for field maintenance.

Description

This project relates to the flexibility of maintenance scheduling and team action, types of vehicles used, tools, special spare parts and fittings, as well as coordination

of activities, quality control of services, and training of staff for better public relations with consumers.

Activities

The following activities should be considered in a project for maintenance of distribution networks:

- Establishment of procedures for setting up maintenance schedules and obtaining and processing the information provided both by the public and by the maintenance teams.
- Formation of maintenance teams (with provision for continuous training) for each type of service.
- Establishment of repair procedures for standard services.
- Specification of appropriate tools.
- Allocation of suitable means of transport, tools and equipment to each team.
- Establishment of expected time and other standards for each maintenance task and monitoring the productivity of each team.
- A preventive maintenance programme which schedules maintenance tasks, sets priorities, issues work orders for tasks to be performed, lists scheduled tasks that are not completed, records when tasks are completed and maintains a record of tools, materials, labour and costs required to complete each task.

Review of design and construction criteria

Objective

The objective of this project is to make adjustments in design and construction criteria so as to obtain best return on investment, control the costs of water distribution systems and facilitate the operation and maintenance of the water supply systems.

Description

The planning, design and construction of water distribution systems should include arrangements for layout of pipes and location of valves and washout valves to facilitate programmes of leakage control, metering of consumption, operation of the network and maintenance of pipes and fittings.

CHAPTER 7

Water loss control projects of other organizational systems

Projects of the commercial system

The commercial system is important for attaining the objectives of the agency since there is a need for financial mecahnisms to cover the costs of operation and maintenance as well as capital costs. The commercial system should aim to maintain a predetermined level of financial reserve, depending on the agency's economic and financial policies. The agency should be financially self-sufficient and should develop a target financial reserve for unexpected contingencies, emergencies, replacement and expansion.

Projects in the commercial system can contribute substantially to reducing loss, inasmuch as they increase revenue and reduce the cost of water that is not accounted for.

The commercial system is composed of the following subsystems (as shown in Fig. 1):

— invoicing and collection,

— consumption measurement,

— consumer registration,

— marketing.

Actions for loss control should be carried out through each of these subsystems.

Invoicing and collection

The invoicing and collection subsystem is responsible for establishing an account for each consumer. This account enables the agency to record the precise value and amount of the services delivered, to collect payment periodically, to record and check payments made, and to enforce legislation if payment is overdue. The invoicing and collection subsystem contributes to increasing revenue by effective billing and collecting of charges for water and sewerage services.

Consumption measurement

The objective of the consumption measurement subsystem is to ensure the best use of services, charging customers according to how much they use, and enabling the services to be equitably distributed to the largest number of users. This involves determination of metering policies (technical, social, economic and financial), methodologies and processes for the administration and maintenance of metering

systems, determination of consumption (reading of meters and scrutiny of readings) and analysis of trends in consumption and metering (by types of consumer).

Consumer registration

The consumer registration subsystem provides for registration of the consumers who form the market for the agency's services. Legitimate consumers are registered so that charges can be made for the services provided, but prospective and potential consumers should also be noted as a guide for planning and marketing the expansion of services. Illegally connected users should be identified in order to convert their use of the services to that of paying consumers.

Marketing

The marketing subsystem contributes to expanding and maintaining the consumer market so that the agency can provide the maximum service to the largest possible number of users. Through the activities of the marketing subsystem, charges for services will be fixed in accordance with criteria of economic efficiency, social equity and financial autonomy. Through programmes of education and promotion the subsystem contributes to efficient and equitable use of the agency's services and gives the largest possible number of people access to them.

Projects of the human resources administration and development system

The human resources administration and development system also contributes to the water loss control programme. For the activities of loss control projects to be formulated, implemented and controlled, the personnel involved must be prepared to cope with new procedures and the use of different technologies. Specifically, provision must be made for training activities that prepare staff to receive and provide information and to be agents for the technical, operational and managerial development of their respective units.

Projects of the administration support system

The administration support system also has projects that contribute to an agency's programme of water loss control. These projects relate to the quality of materials and equipment and effectiveness of transport used by the agency.

Quality of materials and equipment

This project is carried out through the supplies administration subsystem of the administration support system. It is aimed at ensuring the quality of materials and equipment used by the agency. The project's objective is to introduce technical and administrative procedures for improving the procurement, acceptance, transport, storage, installation, operation and maintenance of materials and equipment.

The materials and equipment quality project can be complex to formulate and implement because of the difficulties that arise when agencies ask manufacturers to modify their traditional manufacturing and supply procedures, thus resulting in change of traditional quality standards. Agencies should exchange information with other agencies to learn from their experiences.

Water distribution systems should be inspected and tested on a regular basis. Weak or badly deteriorated sections should be rehabilitated or replaced before they break down and the entire system fails.

Transport

The objective of a transport project is to improve the effectiveness and efficiency of the agency's vehicles through better management and appropriate use.

CHAPTER 8

Programme for the control of the production and quality of drinking-water

A water supply network should be capable of continuously gathering, producing and distributing water that is fit for human consumption at an economic cost using technology consistent with the local socioeconomic conditions and levels of development.

All aspects of the water loss control programme allow agency personnel to be alert for and to inspect for potential sources of drinking-water contamination. The network survey, metering projects, leakage control projects, mapping and inventory of pipes and fittings, improvement of house connections, maintenance projects, and review of design and construction criteria all provide opportunities for staff to search for existing and potential sources of degradation in the quality of drinking-water.

Definition

The programme for the control of production and quality of water for human consumption comprises elements and procedures aimed at identifying and controlling factors that directly and indirectly affect the quality and efficiency of the water supply.

Objectives

The programme for the control of the production and quality of drinking-water has the following objectives:

- to formulate and implement policies, strategies and activities that will ensure the best selection, use and protection of water sources;
- to control water production, storage and distribution in a way that will guarantee the physical, chemical and microbiological quality of the water produced (making the most of existing facilities by using technology that suits both the resources available and the socioeconomic situation of the population served);
- to formulate and implement policies, strategies and activities that will maintain the quality of the water stored and distributed (promoting joint action by consumers, health administrations and other sectors of the community, with special emphasis on education).

Projects

The programme for the control of the production and quality of drinking-water includes projects for the protection of water sources and for controlling production, storage and distribution of water. These projects need to be backed up by support activities in the areas of human resources, material resources and information systems.

Protection of water sources

A project for the protection of water sources is an effective means of coordinating and implementing a range of activities in this area. The overall programme should have the power to regulate land use in the drainage basin of the surface water or groundwater sources. Potential polluters can be prevented from establishing activities within the drainage basin, and the activities of current polluters (or established potential polluters) can be closely monitored and problems corrected. Well-head protection programmes protect groundwater from contaminants that originate from surface run-off or sub-surface leaching (including septic tanks).

Objective

The objective of a water source protection project is to preserve and protect water resources that are in use or are designated for future use. This objective requires efforts in two directions. Firstly there must be efforts to secure the legal basis that will enable agencies responsible for drinking-water supply to take priority over other demands. The agencies should also be able to enforce such preventive and corrective measures as are needed to maintain the quality of drinking-water. Secondly there must be care in selecting sources of water supply. Sources should be chosen on the basis of three criteria:

— the amount of water available to satisfy demand;

— the characteristics of the source;

— viability of use (i.e. technical and economic feasibility of ensuring potability by means compatible with resources available).

Activities

The activities of the water source protection project come into four categories: preventive, monitoring, corrective and interagency coordination.

The project includes three preventive activities.

- The responsible authorities should be requested to regulate and control all aspects of the use of drainage basins.
- Compliance with these regulations should be overseen and the drainage basins should be inspected for sources of contamination.
- The sources and risks of pollution (continuous or accidental) should be identified.

Monitoring is an essential part of the project and is accomplished in several ways:

- There must be coordination with relevant agencies for setting up meteorological and hydrological stations where none exist or there are too few.
- Information about surface and groundwater quality should be collected from other agencies and government institutions. Water quality should be monitored downstream from potential domestic, industrial and agricultural sources of pollution.
- Meteorological and hydrological data need to be recorded, processed and analysed.
- There must be routine sampling of raw water and analysis of data on its physical, chemical and microbiological quality.
- The pollution control activities and waste disposal practices of industries in drainage basins must be observed.

Water source protection clearly also involves corrective activities:

- There must be control and minimization of discharges and risks of pollution resulting from the operation of the water supply network.
- Appropriate plans of action should be implemented in abnormal situations.
- Discharges and risks of pollution from domestic, industrial and agricultural sources should be controlled and minimized.

The project must also include interagency coordination for preventive, corrective and support activities.

Control of water production, storage and distribution

This project is directed towards improving control of water production, storage and distribution, to ensure that public health is protected and that water of acceptable quality is delivered to consumers at all times.

Objectives

The objectives of this project are:

- to control the processes and installations for water production, storage and distribution;
- to control operation and maintenance in order to ensure the production and distribution of safe water.

Activities

The activities of this project are as follows:

- Establishment of quality standards for water supply on the basis of international criteria, the characteristics of the agency's installations, and the material and economic resources available.

- Production of water to be delivered to consumers according to established standards.
- Identification and characterization of the different facilities, chemicals, equipment and installations required for collecting, transporting, processing, storing and distributing water.
- Study of water treatment processes, components, connections and auxiliary installations to determine operational parameters and characteristics.
- Determination (using relevant materials) of the following:
  - —methods of operation under a range of conditions, i.e.
    - (i) normal and abnormal conditions,
    - (ii) special conditions (start-up, shutdown, alternative modes),
    - (iii) emergency conditions requiring preventive action (analysis of vulnerability, disaster relief activities), operation in situations of alert or actual disasters, or the emergency restoration of services;
  - —common operational problems (troubleshooting), their causes and possible solutions, followed by selection of a solution and evaluation of its effectiveness;
  - —functions, responsibilities, requirements, training and qualifications for staff at various levels (see Chapter 14).
- Introduction of methods for recording, generating and processing data as a basis for management decisions.
- Operation and monitoring of plant and installations, using the methodology described above, and setting up a schedule for successive improvements as resources become available.
- Establishment of a management information system that will get the best results from installations and processes (see Part 4).
- Design and implementation of programmes for collecting samples from the water source, treatment plant, storage facilities and distribution network. This includes description of parameters to be analysed, type of analysis to be carried out, frequency of sampling, sites of sampling, methods of collection and preservation of samples, labelling and transport of samples to laboratory. The design of sampling programmes should take into account the size of the installations, the population served, health hazards, water quality, problems, and cost and feasibility of implementation. Their aim is to ensure sustained quality control and identify the causes of poor quality water.
- Determination and introduction of methods of analysis, presentation of results, and preparation and use of information.
- Installation of laboratories and equipment.

- Improvement of the operation and maintenance of water storage facilities. Maintenance should include inspection of the facility, corrosion control, cleaning, application of protective coatings and disinfection.
- Improvement or implementation of procedures for identifying causes of water quality degradation (cross-connections, corrosion, biological growth and activity), and development of a strategy for correcting problems when they occur.
- Elimination of cross-connections, prevention of back-flows and back-siphonage, and the elimination of health hazards in public and private water facilities.

Support activities

The implementation of the projects described above will require the following support activities:

- Development of human resources, as part of the human resources administration and development system.
- Management of material resources, as part of the supplies administration subsystem of the administration support system.
- Information systems for the generation and dissemination of operational data.

CHAPTER 9

Programme for the operation and maintenance of sewage collection, treatment, re-use and disposal

The coverage levels of sanitation services in developing countries are generally low compared with those of drinking-water supply services. Although there are a number of low-cost alternatives for the sanitary disposal of excreta and wastewater (e.g. oxidation ponds, septic tanks, on-site latrines), many existing urban sanitation services are based on conventional high-cost sewerage systems which have been in use for many years. Low-cost on-site sanitation for use in dispersed housing areas was the subject of much research and development during the International Drinking Water Supply and Sanitation Decade (1981-1990), and provision of sanitation by this method has increased considerably during the past few years.[1]

The choice of sanitation service should be based on feasibility studies that take into consideration not only initial cost but also the cost of operation and maintenance and the capacity of the agency to keep the service in good operating condition. The introduction of on-site low-cost sanitation projects will in many cases require introductory projects to promote awareness of social and public health needs, involving technical cooperation between the local agencies responsible for these concerns.

Objective

The objective of this programme is to implement procedures for the operation and maintenance of sewage disposal services in such a way that the agency can provide the widest coverage, the biggest capacity for disposal and the best quality continuous service, with cost kept to a minimum.

Projects

The programme should be introduced through a series of projects to improve and control sewage collection, treatment, re-use and disposal. Apart from the usual technical and financial considerations that apply to project selection, full consideration must also be given to local social and cultural conditions. These may have overriding implications for the selection of an appropriate sewage disposal service. In many low-cost sanitation systems the responsibilities of the agency may be

[1] See. Franceys R et al. *A guide to the development of on-site sanitation.* Geneva, World Health Organization, 1992.

limited to giving advice, supplying construction materials, and providing back-up assistance for operation and maintenance (e.g. septic tank emptying).

Some of the projects described in relation to the water loss control programme are also relevant for the development of this programme, namely the project for revision of design and construction criteria (p. 54), the quality of materials and equipment project (p. 56), the projects of the commercial system (p. 55) and the human resources projects (p. 56).

In addition to the above, there are other projects, as described below, that are specific to this programme.

Monitoring the coverage of the sewage collection network

Objective

The objective of this project is to monitor the coverage of the sewage collection service in the agency's area of responsibility, so as to ensure that it is consistent with the coverage of the drinking-water supply system.

Description

Following the establishment of a sewage collection service, systematic action must be taken to expand the service throughout the designated project area.

Activities

The activities of the project to monitor coverage of the sewage collection network are as follows:

- Monitoring of existing dwellings in the area covered by the sewage collection network to ensure that they are being served by the network's facilities.
- Determination of the limits of the sewage collection network and identification of any technical limitations that affect service (e.g. high water table or areas of hard rock which would limit use of septic tanks, soakaways or pit latrines).
- Supply and receipt of information from the commercial system on dwellings connected to the water supply system and not served by the sewage collection network.
- Establishment of a programme for periodic inspection of household facilities to check if rainwater is being discharged to non-combined sewage facilities where these have been installed.
- Inspection of sewage collection networks to identify illegal connections.
- Inspection and testing of the sewage collection network for leaks (stormwater, surface inflow, groundwater infiltration, sewage exfiltration).
- Regular inspection of the sewage collection network to identify corroded, broken or cracked pipes and joint failures, and preparation of a rehabilitation schedule.

- Development of projects to extend coverage, in order to provide for regular growth of the network in coordination with expansion of the water supply network.
- Ensuring that all technically and socially acceptable means of providing sewage treatment, re-use and disposal, both public and private, are considered in projects dealing with the construction of a sanitation system.
- Where the provision of on-site treatment, re-use and disposal facilities is chosen, the following types of activities will be required: promotion, provision of technical advice and materials, development of local contractual capacity, coordination of responsible agencies, and provision of assistance and advice for the operation of completed facilities,
- Measures to ensure that the system is extended according to a master plan and not on the basis of isolated initiatives.

Mapping sewage collection facilities

Objective

The objective of this project is to set up procedures to provide maps of the sewage collection facilities as a back-up to operation and maintenance.

Description

In developing a mapping service of the sewage collection network, this project should take into consideration the need for exchange of mapping data with the water supply network as well as the need for information on the register of users invoiced for drinking-water services. The mapping service of the sewage collection network should liaise with the mapping services of rainwater drainage and public highways of the area, and with the respective telecommunications, electricity and other utility mapping services.

Activities

The project for mapping of sewage collection facilities involves the following activities:

- Determination of the information system to be adopted. This must include selection of data and forms to be used, definition of type of sketch-maps and drawings of intersections, collection of data, coding, storage, retrieval, updating and quality control.
- Correlation with the register of users invoiced for drinking-water services of the agency.
- Determination of the degree of consistency in mapping by comparing with maps of public roads and rainwater drainage, as well as with those of telecommunications, electricity and other utilities.
- Collection of field data.

- Preparation of sketch-maps and drawings of intersections.
- Identification and mapping of catchment areas in the locality to be served by the sewage collection network, and the location of elements such as rock or high water table that would affect the choice of sewage treatment, re-use and disposal facilities.
- Establishment of routine procedures for updating the maps of the sewage collection network and other critical information.

Operational control

Objectives

The project for operational control has three objectives:

- to improve or introduce procedures, mechanisms and equipment for the collection, treatment, re-use and disposal of sewage from the area covered by the network;
- to ensure the hygienic re-use, disposal or discharge of treatment effluent in designated places;
- to monitor the efficiency of operation of sewage collection, treatment, re-use and disposal.

Description

The project introduces routine operation and control procedures for each element of the sewage collection, treatment, re-use and disposal service.

Activities

This project should include the following activities:

- Preparation of operating manuals for the sewage collection, treatment, re-use and disposal facilities to ensure their optimum use.
- Compilation of details of the collection, treatment, re-use and disposal operations from the design files, "as-built" drawings and equipment catalogues.
- Determination of the capacity of each facility in the sewage collection network.
- Establishment of operating procedures under normal, abnormal and emergency conditions.
- Provision, as required, for technical services to support the operation and maintenance of on-site facilities (septic tanks and sub-surface leaching systems).
- Where applicable, monitoring of electricity and fuel consumption and programming of operation with a view to reducing costs.

- Monitoring of any points of connection with the rainwater drainage network when the services are not combined.
- Surveying for possible points of connection with the stormwater drainage system by analysis of maps or site inspection.
- Coding of facilities and equipment.
- Registering of data in the database.
- Regular visual inspection of the system.
- Monitoring of the volume of effluent in each drainage basin and its relationship with the volume of water supplied in the same area. This will involve:
  - —establishment of permanent metering or sampling stations downstream from each drainage basin in the network;
  - —coding of the water connections for each drainage basin and regular reporting on the volume of water supplied to them;
  - —comparative analysis of the volume of water supplied and the total volume of effluent recorded at the metering stations.
- Monitoring of the volume of effluent discharged by users who have their own sources of water in addition to that received from the public network. This will involve:
  - —survey and mapping of private wells and other sources in the area covered by the network;
  - —establishment of permanent metering or sampling stations for private water sources;
  - —analyses to determine the percentage of the volume of water from private sources that is discharged to the sewage collection, treatment, re-use and disposal network;
  - —transmission of information to the commercial system for determining sewage collection, treatment, re-use and disposal tariffs, and for billing and collection of charges for these services.
- Transmission of information to the commercial system on the ratio of water consumption to sewage collected by type of consumer, so that tariffs can be set in accordance with the cost of providing the service.
- Monitoring of the volume of effluent discharged into each receiving body using permanent metering or sampling stations at points of final disposal. (This monitoring can be carried out directly in sewage processing plants, where these exist.)

Quality of effluent and protection of receiving bodies

Objectives

The first objective of this project is to monitor effluent to ensure that at the point of final disposal it conforms with established quality standards. These standards should be set with regard to the characteristics of the receiving body, taking into consideration the need for multiple use of the receiving waters.

The project's second objective is to monitor and control the physicochemical and biological characteristics of sources of pollution to ensure that they remain within established limits. This will help to protect both the sewage network and the receiving bodies.

Description

The project establishes routine procedures for monitoring and control of sewage collection, treatment, re-use and disposal services in terms of pollutant loads in order to ensure that the effluent from these services is compatible with the natural purification capacity of the receiving waters.

Activities

The activities of the project are as follows:

- Determination of the natural purification capacity of the receiving waters and the quality required for the multiple use of the receiving waters.
- Establishment or revision of quality standards for treated sewage effluent at the points of disposal to ensure compatibility with the water quality characteristics of the receiving waters and the need for their multiple use.
- Monitoring of pollutant loads on the sewage network from special users (industry, tanneries, abattoirs, etc.) in order to protect the network. Monitoring of the quantity and quality of effluent from pollutant sources.
- Establishment of quality standards for:
  - — industrial discharges to the sewage collection system;
  - — treatment facility processes;
  - — effluent re-use;
  - — effluent disposal.
- Survey and mapping of pollutant sources.
- Transmission of information to the commercial system for setting special tariffs related to pollutant load (volumes, rates, quality).
- Monitoring of the operation of treatment facilities to obtain maximum removal of pollutants during processing.
- Monitoring of water quality in the receiving bodies to provide guidance for planning and scheduling of additional treatment facilities (additional flows and treatment processes).

- Quality control of chemical inputs and control of procedures to ensure their safe use for their intended purpose.
- Installation of pilot plants to test treatment processes, train personnel and provide design criteria for expansion.

Maintenance and rehabilitation of electromechanical equipment, pipes and fittings

Objective

The objective of this project is to control the operation and maintenance of sewage collection, treatment, re-use and disposal facilities to obtain the maximum useful life with the minimum of failures of service.

Description

This project introduces routine procedures for maintenance and criteria for rehabilitation of facilities in the sewage collection, treatment, re-use and disposal network. This project should be implemented in coordination with the electromechanical maintenance and instrumentation project described on p. 51.

Activities

The activities of this project are as follows:

- Development of a service of preventive and corrective maintenance of electromechanical installations and equipment in the sewage collection, treatment, re-use, and disposal network. This will involve:
  - —inventory of installations and equipment;
  - —establishment of a schedule of regular inspection and cleaning;
  - —establishment of a schedule of preventive maintenance based on cost–benefit analysis;
  - —establishment of procedures for preventive and corrective maintenance.
- Establishment of schedules for the rehabilitation of facilities, based on monitoring of the performance of equipment, the frequency of corrective maintenance and the risk of collapse, in accordance with cost–benefit criteria.
- Analysis and consolidation of information on operation and maintenance. This will require:
  - —supply of information to the accounting service to determine rates of depreciation and for cost control;
  - —drawing up an investment budget for the replacement of equipment and rehabilitation of facilities.

- Establishment of technological development and operational research programmes to reduce the costs of operation and maintenance in the sewage collection, treatment, re-use and disposal network, by:

  — identifying, adapting and introducing suitable tools and equipment for the operation and maintenance of the network;

  — modernizing procedures and methods of work.

- Establishment of occupational safety programmes and ensuring that personnel have all the equipment they need to perform their tasks safely and effectively.

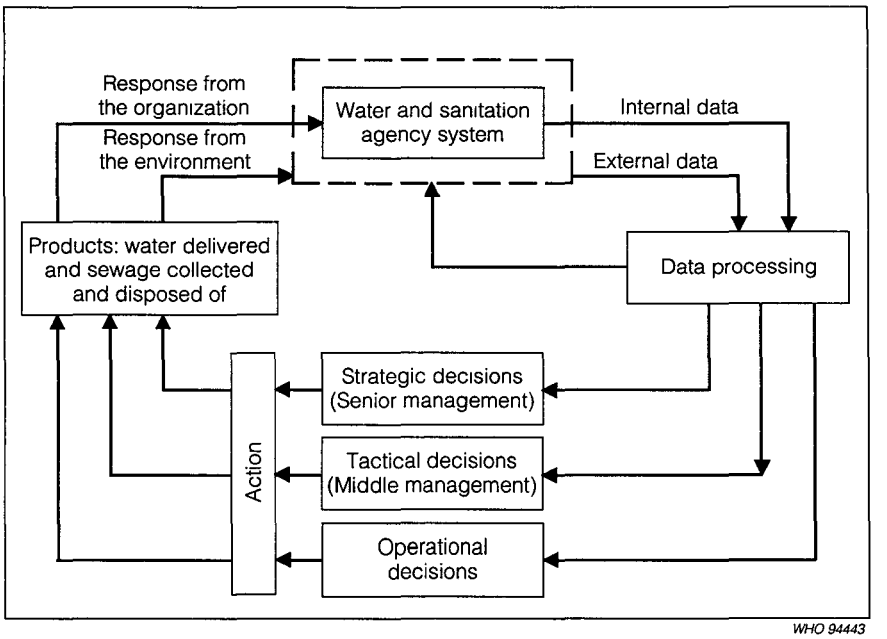
PART 4

Information systems

The efficient and effective performance of an agency depends on a clear relationship between management activities (planning, organization, selection and development of staff, coordination, direction, control) and the functions of the agency (organizational systems). The interaction between individuals at different management levels, together with use of information in the decision-making process, is important to an agency's performance. This interaction should be an integral part of management at senior, middle and operational levels. Each level of management has different centres of decision, and each of these is supported by the information system that is described in this section.

When the information system provides processes and information for management functions to be carried out and decisions to be made, it is known as the

Fig. 10
Information system



management information system. The data fed into the management information system are firstly internal data from within the agency—as a result of measurements, activities and decisions taken—and secondly external data from other institutions and from the community in response to the agency's actions, as shown in Fig. 10.

CHAPTER 10

The basis for management decision-making

Centres of decision

As is shown in Fig. 11, an agency has decision centres at three levels—strategic (senior management), tactical (middle management) and operational. All are supported by different types of information according to the needs of the decision-making process.

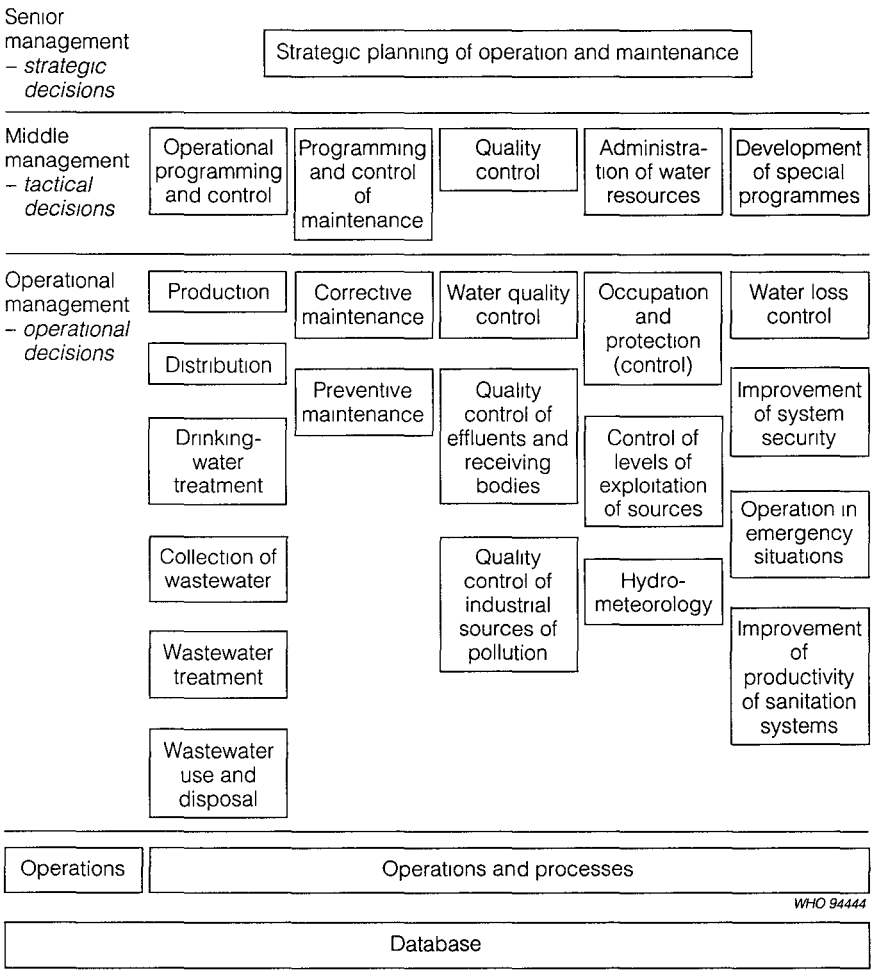
Decisions are characterized, *inter alia*, by their impact on the performance of the agency in the short term, medium term and long term. Strategic decisions are those with long-term influence. Tactical decisions are effective in the medium term and operational decisions apply to the short term.

The different levels of data processing are designed so that the information generated by the different units within the agency can serve as the basis for management decisions. But the management information system does more than just process data. The management information system (Fig. 12) enables management and strategic planning to interact with individuals and their decision-making processes at different levels of the agency. Its configuration as a management information system enables different organizational systems of the agency to fulfil their functions more efficiently. It also gathers information on the environment in which the agency operates and provides information to regulatory agencies in the drinking-water and sanitation sector.

Interactions with individuals take place at different management levels, which means they must take into account the type of information needed at each level and at each decision centre. The structure of the management information system can be characterized as a pyramid (Fig. 13).

The base of the pyramid corresponds to information for transactions and operations in which decisions can be programmed. At the second level, the information is used to support daily, weekly and monthly operational management activities in the various organizational systems of the agency. At the next level, information will tend to combine selected elements of that from the lower levels. Information here will be used in tactical planning, programming (including allocation and organization of resources), and monitoring and evaluation of results as a basis for management control decisions. At this third level, decisions will constantly adjust to changes generated by the environment in which the agency operates and as a result of the agency's own evolution. At the top of the pyramid there must be specialized and selective information to guide long-term planning and policy formulation. Information at this level will also be used for monitoring and evaluation of the effectiveness of the agency, its policies, plans and strategies, so that the necessary adjustments may be made.

Fig. 11
Centres of decision



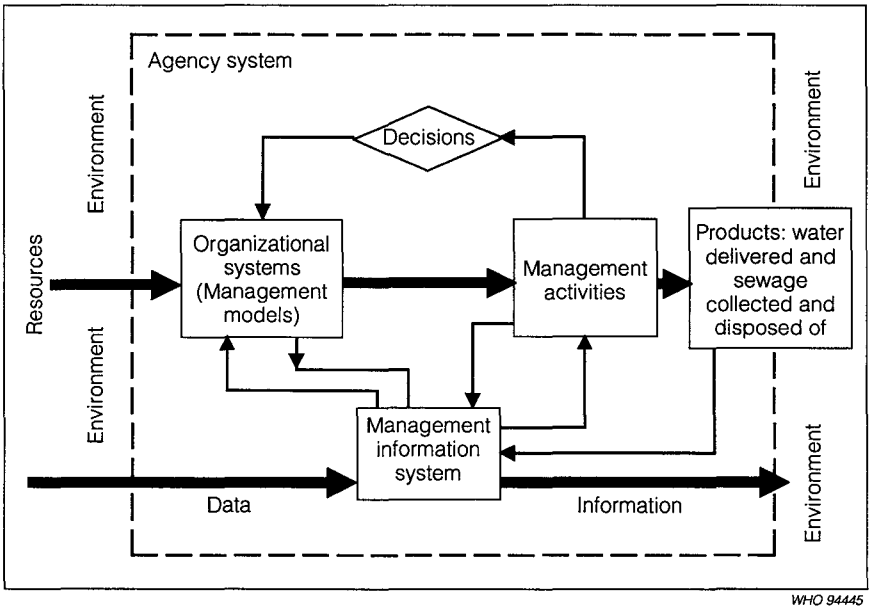
Management indicators

The results of actions at the strategic, tactical or operational planning levels are measured with the help of management indicators. These indicators are based on data from each organizational system or the combination of data from two systems or from the environment in which the agency operates.

A management indicator should represent a situation, an event or a change brought about by action aimed at attaining established targets.

In the planning process, management indicators provide basic figures to support decisions on the allocation of financial resources to long-term, medium-

Fig. 12
Interaction between management and organizational activities through the management information system



term and short-term plans and programmes, resulting in a programme budget with physical and financial targets. In the control process, management indicators provide a measure of what has been accomplished, so that results can be evaluated and disparities corrected. On the basis of results, indicators may need to be changed for others that are closer to reality.

A list of management indicators has been selected from the decision centres and activities identified in Part 2. This list (Table 7) presents indicators that support the strategic planning process for operation and maintenance and provide a basis for the management information system to support decision-making at middle management level. The organizational system and subsystem from which the data originate are identified and the users and frequency of distribution are given. This will in turn serve to determine the best means of communicating the data. Access and recovery of data must be facilitated so that the information allows management to monitor operation and maintenance, evaluate performance of the organizational systems and take the necessary decisions and corrective action.

Fig. 13
The levels of the management information system

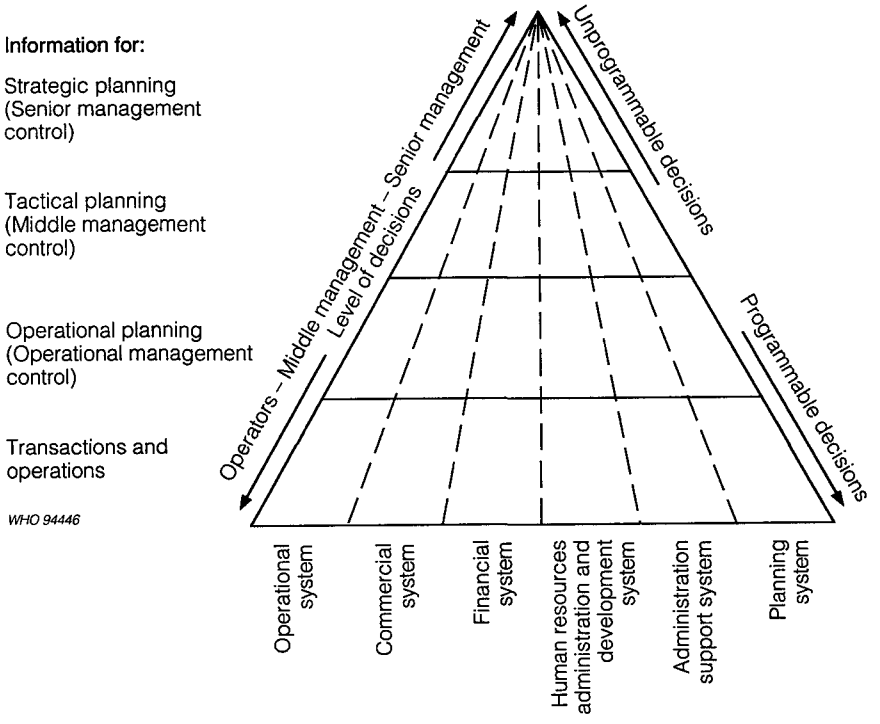


Table 7
Management indicators

Indicator	Calculation (ratio)	Source		Frequency		
		System	Sub-system	Senior management	Middle management	Operational management
Coverage of locality with water systems	Area with water system / Total area	Operational Planning	Operation Physical	Annual	X	X
Coverage of locality with sanitation systems	Area with sanitation system / Total area	Operational Planning	Operation Physical	Annual	X	X
Ratio of water to sanitation services by locality	Area with sanitation service / Area with water service	Operational Operational	Operation Operation	Annual	X	X
Level of water coverage	Population served / Total population	Commercial Planning	Marketing Physical	Annual	Weekly	X
Level of sanitation coverage	Population served / Total population	Commercial Planning	Marketing Physical	Annual	Weekly	X
Per capita water production	Volume of water produced per day / Population served	Operational Commercial	Operation Marketing	Weekly	Quarterly	X
Per capita sewage disposal	Volume of sewage collected per day / Population served	Operational Commericial	Operation Marketing	Weekly	Quarterly	X
Ratio of measured volume to total water distributed	Volume measured per day / Volume produced per day	Commercial Operational	Invoicing Operation	Weekly	Quarterly	Monthly
Water not accounted for	Volume invoiced / Volume produced	Financial Operational	Invoicing Operation	Weekly	Quarterly	Monthly
Staff productivity	Water + sanitation connections / Number of staff	Financial Administration	Survey Human resources	Weekly	Quarterly	X

Table 7 (continued)

Indicator	Calculation (ratio)	Source		Frequency		
		System	Sub-system	Senior management	Middle management	Operational management
Operational costs per staff	Operational costs / Number of staff	Financial Administration	Accounts Human resources	Weekly	Quarterly	X
Operational costs per connection	Operational costs / Water + sanitation connections	Financial	Accounts Survey	Weekly	Quarterly	X
Total operational costs per m^3 of water produced	Operational costs / Volume of water produced	Financial Operational	Accounts Operation	Quarterly	Monthly	X
Operational costs (production) per m^3 of water produced	Production costs / Volume of water produced	Financial Operational	Accounts Operation	Weekly	Quarterly	Monthly
Operational costs (distribution) per m^3 of water produced	Distribution costs / Volume of water produced	Financial Operational	Accounts Operation	Weekly	Quarterly	Monthly
Operational costs (sanitation) per m^3 of sewage collected	Sanitation operating costs / Volume of sewage collected	Financial Operational	Accounts Operation	Quarterly	Monthly	X
Index of use of water system production capacity	Average volume of water produced / Installed capacity	Operational Operational	Operation Operation	Weekly	Quarterly	Monthly
Index of use of catchment capacity	Average catchment volume / Installed capacity	Operational Operational	Operation Operation	X	Monthly	Daily
Index of use of sanitation system	Average volume of sewage collected / Installed capacity	Operational Operational	Operation Operation	Weekly	Quarterly	Monthly

Index of use of capacity of transmission mains	Average volume of transmission / Installed transmission main capacity	Operational / Operational	Operation / Operation	X	Monthly	Daily
Index of use of treatment capacity (water)	Average volume of water treated / Installed treatment capacity	Operational / Operational	Operation / Operation	X	Monthly	Daily
Index of use of pumping stations (water)	Average volume of water pumped / Installed pumping capacity	Operational / Operational	Operation / Operation	X	Monthly	Daily
Reserve supply capacity	Installed reservoir capacity / Average volume distributed	Operational / Operational	Operation / Operation	X	Monthly	Daily
Index of use of disposal capacity	Average volume collected / Installed disposal capacity	Operational	Operation	X	Monthly	Daily
Unit consumption of energy at pumping station	Consumption of energy for pumping water / Volume of water pumped	Operational / Operational	Operation / Operation	X	Monthly	Daily
Unit consumption of energy at wastewater pumping station	Consumption of energy for pumping wastewater / Volume of wastewater pumped	Operational / Operational	Operation / Operation	X	Monthly	Daily
Production water loss ratio	Average volume produced / Mean volume of catchment	Operational / Operational	Operation / Operation	Quarterly	Monthly	Daily
Index of collection of water distributed	Average wastewater collected / Volume of water distributed	Operational / Operational	Operation / Operation	Weekly	Monthly	X
Level of maintenance work	Failures corrected / Total failures	Operational / Operational	Maintenance / Maintenance	X	Monthly	Daily
Level of failure reporting	Service orders prepared / Total failures	Operational / Operational	Maintenance / Maintenance	X	Monthly	Daily
Level of corrective maintenance completed	Service orders executed / Total failures	Operational / Operational	Maintenance / Maintenance	X	Monthly	Daily

Table 7 (continued)

Indicator	Calculation (ratio)	Source		Frequency		
		System	Sub-system	Senior management	Middle management	Operational management
Proportion of pipe failures	Pipe failures / Total failures	Operational / Operational	Maintenance / Maintenance	X	Monthly	Daily
Index of use of wastewater pumping capacity	Average volume of wastewater pumped / Installed pump capacity	Operational / Operational	Operation / Operation	X	Monthly	Daily
Index of use of wastewater treatment capacity	Average volume of wastewater / Installed treatment capacity	Operational / Operational	Operation / Operation	X	Monthly	Daily
Unit consumption of chlorine	Consumption of chlorine / Volume of water treated	Operational / Operational	Operation / Operation	X	Monthly	Daily
Unit consumption of coagulant	Consumption of coagulant / Volume of water treated	Operational / Operational	Operation / Operation	X	Monthly	Daily
Unit consumption of lime	Consumption of lime / Volume of water treated	Operational / Operational	Operation / Operation	X	Monthly	Daily
Unit consumption of energy for catchment	Consumption of energy for catchment / Volume of water catchment	Operational / Operational	Operation / Operation	X	Monthly	Daily
Unit consumption of energy for treatment	Consumption of energy for treatment / Volume of water treated	Operational / Operational	Operation / Operation	X	Monthly	Daily
Proportion of surface catchment systems	Surface catchment systems / Total systems	Operational / Operational	Operation / Operation	Annual	Weekly	Quarterly

Proportion of underground catchment systems	Underground catchment systems / Total systems	Operational / Operational	Operation / Operation	Annual	Weekly	Quarterly
Proportion of mixed catchment systems	Mixed catchment systems / Total systems	Operational / Operational	Operation / Operation	Annual	Weekly	Quarterly
Extent of water treatment	Systems for water treatment / Total systems	Operational / Operational	Operation / Operation	Weekly	Quarterly	Monthly
Extent of wastewater treatment	Systems for wastewater treatment / Total systems	Operational / Operational	Operation / Operation	Weekly	Quarterly	Monthly
Water network coverage	Length of streets with water / Total street length	Operational / Operational	Operation / Operation	Weekly	Quarterly	Monthly
Sewerage network coverage	Length of streets with sewerage / Total street length	Operational / Operational	Operation / Operation	Weekly	Quarterly	Monthly
Ratio of water to sanitation services per network	Length of streets with water / Length of streets with sewerage	Operational	Operation	Annual	Weekly	Monthly
Proportion of well failures	Well failures / Total failures	Operational / Operational	Maintenance / Maintenance	X	Monthly	Daily
Proportion of failures in works	Failures in works / Total failures	Operational / Operational	Maintenance / Maintenance	X	Monthly	Daily
Proportion of failures in dosing equipment	Dosing equipment failures / Total failures	Operational / Operational	Maintenance / Maintenance	X	Monthly	Daily
Proportion of failures in control equipment	Control equipment failures / Total failures	Operational / Operational	Maintenance / Maintenance	X	Monthly	Daily
Proportion of preventive to corrective maintenance	Service orders preventive maintenance / Service orders corrective maintenance	Operational / Operational	Maintenance / Maintenance	X	Monthly	Daily

CHAPTER 11

Decision support systems

The information requirements of an operation and maintenance manager are not confined to the regular information produced by a management information system such as that described above. In complex agencies with trained staff able to operate management information systems through computer networks, managers may wish to use decision support systems that address specific management needs. This means that managers will actively participate in the development and use of their own computerized information system.

This concept of information systems gives users a new role in their design and adaptation. With appropriate data, hardware, software and the necessary training, a user has the opportunity to manage the development of the decision support system. The rapid advance of hardware and software technology, coupled with falling costs, has not only brought these tools within the reach of drinking-water and sanitation agencies but has also made them accessible to the individuals who must take decisions.

The use of decision support systems will contribute to the attainment of the objectives of the operational system and of the agency in the following major respects:

- Decision support systems promote economic efficiency by providing models on which decisions about the design of water supply and sanitation systems can be based. Different possibilities can be analysed to select the best solution at the lowest cost through, for instance, using facilities to maximum capacity and making most effective use of production processes.
- They result in increased productivity of staff at both managerial and operational levels.
- They foster organizational effectiveness by introducing new communication methods that provide top management with key information that can be used for decision-making, influencing policy-makers and enlisting public support for the agency's objectives. This means of communication also facilitates the coordination that is needed to implement decisions and to monitor and evaluate changes in management.

The rationale for introducing decision support systems should be based on an assessment establishing a clear cost–benefit advantage in their development and use. This assessment should consider expected impact (on individuals, on centres of decision and on the entire organizational structure), reduction of uncertainty in decision-making, effect on interpersonal relationships (authority, supervision,

motivation, communication) and the quality of the working environment. The impact of decision support systems in each of these areas is closely bound up with improvements in productivity and the attainment of the strategic objectives of the agency.

Decision support systems differ from the management information systems described in Chapter 10 in the following ways:

- Decision support systems provide management with information to support their decision-making on specific points and do not provide general management back-up.
- The decision support system is rarely a finished product, but rather a variable service which requires regular updating.
- The decision support system should be user-oriented, especially for key decisions.

Since decision support systems apply to the solution of specific non-routine problems, and since their databases relate to the environment in which the agency operates, they become basic information systems for the agency's strategic planning. Decision support systems can be used via an independent microcomputer or microcomputer connected to a network. Direct use of decision support systems by managers and easy access through a computer terminal will change the way management activities at each level are carried out. It will require investment in the training of managers if the systems are to be fully utilized.

Decision support systems can contribute to the operation and maintenance of drinking-water and sanitation facilities in areas such as pre-investment studies, demand projection, selection of alternatives, design, programming and construction, monitoring and evaluation, and effective implementation. Direct applications for operation and maintenance may include computer software for evaluating water-hammer, for simulating the water distribution network and the wastewater collection and rainwater drainage network (quantity, quality, run-off, etc.), for drainage basin management, and for measuring groundwater (capacity, levels, saltwater intrusion, etc.). Some of the software has already been developed for both mainframe computers and microcomputers by engineering and consulting firms which operate and maintain water and sanitation systems, and is available from specialist suppliers.

It will be necessary to train operation and maintenance managers to use the software. It will also be necessary to develop and maintain glossaries, databases, security and quality control routines, and the agency will need to provide leadership in this area.

The success of a decision support system will depend on the collection of accurate data. When a data collection programme is being designed, questions that must be asked include:

— Why are we collecting this information?

— What will the results mean?

— How will we respond to different types of results?

Once information has been collected, it will be compiled and analysed before being presented to the agency's management. This may be done manually or using the computer, depending on the staff and facilities available.

Decision support systems should initially be developed slowly by implementing one function at a time. Development and implementation should be carried out by agency staff and should be aimed at resolving specific problems. This will give staff valuable experience that will enable them to solve problems as and when they develop. The services of a consultant may be valuable during this process as a source of help and guidance. Once a decision support system has been shown to be effective, it can be expanded and additional systems can quickly be developed.

CHAPTER 12

Management decisions

Budget preparation

Every water supply and sanitation agency should have a separate budget for operation and maintenance. The lack of a separate budget often leads to essential maintenance being postponed. The data in the agency's information systems can be vital for the preparation of a budget.

The best justification for the coming year's budget request is an accurate record of the previous year's activities, costs, workload, growth and production. Records of use of materials and equipment, and performance, are very important. In this way, the records can be used to document the importance of the programme and the need for adequate financial support.

Staffing and equipment

Accurate records can provide the justification to budget for necessary additional staff. Analysis of records covering several years will indicate trends in the agency's activities, including the management indicators listed in Table 7. These trends can show where the agency's workload has increased or where performance is deteriorating to the point that more staff are essential.

The need for new equipment must also be justified when a budget is prepared. Age is not the only factor that determines when equipment should be replaced. Records of production and use and costs of maintenance to keep the equipment operational may substantiate the need for replacement.

Additional equipment (including safety equipment) may often be required when additional staff are hired. Frequently the need for newly developed equipment for a specific purpose will become apparent. The best justification for buying new equipment can often be found in the agency's records.

Materials and services

Records of previous requirements and consumption of materials will give the most accurate indication of what materials the agency is likely to need in the future.

The agency should also carefully analyse past expenditures for external services. Agency records can indicate when certain outside services have increased to the point where it would be more efficient and economical to acquire staff and equipment to do the work within the agency itself. Conversely, an agency should

use cost–benefit analysis to identify which jobs should be carried out by specialized contractors.

Evaluation of productivity

The management indicators listed in Table 7 can be used to measure productivity. Total costs can be used as a basis for describing reduction of breakdowns or frequency of breakdowns in terms of operation and maintenance expenditure. A crucial aim of maintenance programmes is to search for a level of maintenance that minimizes overall costs. Each agency should clearly state its objectives and choose appropriate methods of evaluating effectiveness in achieving these objectives.

PART 5

Implementation

CHAPTER 13

Establishing a functional organizational structure

Given the importance of operation and maintenance, it is clear that drinking-water and sanitation agencies must have an organizational structure that allows coordination between the different units responsible for implementing operation and maintenance and related activities.

Human, financial and material resources should be constantly available for carrying out operation and maintenance. Such resources should be allocated to various units according to their responsibilities and objectives. As programmes and projects are implemented, arrangements should be made for training and to ensure the complete involvement of personnel at each stage, from formulation through to operation.

For the agency to function effectively, it must have decision-making processes at different levels. There must be adequate information processing and flow of information to the centres of decision.

Management activities and centres of decision are organized according to lines of authority (hierarchical) and coordination (functional). These elements may be combined in a variety of ways. Success depends not just on the choice of structure but also on the human and material resources available, the quality of the decision-making process and human relations both within the agency and outside it. The effectiveness of the agency will also be restricted by constraints in its working environment.

The agency needs to adapt to the environment in which it operates. For example, in an agency that serves only one local area, all managerial functions can be carried out at the local level. Such an agency will have organizational units to suit its size and complexity. Metropolitan, regional or national agencies, on the other hand, will need to group senior and middle management centrally and delegate operational management and the implementation of operations to local or area levels. Where the number of localities or water supply and sanitation systems so requires, the agency may need to set up intermediate, subregional or regional levels of operational management with a concentration of technical resources (equipment, qualified staff, workshops, transport, etc.) to supervise and support operations at local level.

The organizational structure of a large and complex agency may, for instance, comprise the following three levels:

- A central headquarters would comprise senior and middle management. The latter would be responsible for administration of the agency in terms of organization, planning of activities, management of design and construc-

tion, scheduling and control of the operation of water and sanitation systems, and scheduling and control of the maintenance of equipment and installations. In line with the agency's plans and objectives, middle management would carry out tactical planning, programme development, adaptation of resources to needs, formulation of standard work routines and procedures, coordination and control of the operation of the system, and evaluation of its performance and results.

- At regional or subregional level, management would supervise and support the operation of the water or sanitation system in the area for which it is responsible.
- Operational activities would be carried out at local level. These activities are the operation of the water and sanitation services and the maintenance of equipment and installations. This includes corrective and preventive maintenance in accordance with established schedules as well as any emergency work that may need to be done.

These structural levels can be reduced to two or even one, depending on the degree of decentralization in the agency's organizational structure.

Defining an organizational structure

The organizational structure relating to the agency's operational system (design and construction, operation and maintenance) should be planned in light of the targets and the programmes, projects and functions needed to achieve them. Design and implementation of the organizational structure will require feasibility studies to compare different organizational possibilities, identifying the centres of decision (Chapter 10) at strategic, tactical and operational levels. Possible organizational structures should be evaluated in terms of cost and benefit. Decisions will need to be made about whether functions of the agency's operational system — such as the preparation of investment projects for the upgrading of water or sanitation systems, laboratories for analysis and quality control of water for human consumption and of effluent collection, and mechanical workshops — should be concentrated at central or regional levels. Consideration should also be given to the extent to which the private sector should be involved in project design, supervision, operation and maintenance, and mechanisms for recruitment and performance assessment.

Decisions about the type of organizational structure to be adopted must also take into account the number of water and sanitation systems, their configuration and distribution with respect to physical installations and level of complexity, types of water sources, types of drinking-water and wastewater treatment plants, types of pumps, number of users, service area, geographical situation, means of communication, and inspection and control requirements.

The implementation of a functional organizational structure is described below in terms of a stated objective and appropriate activities.

Implementing a functional organizational structure

Objective

The objective is to implement a functional organizational structure that will enable operation and maintenance to reach objectives and targets, and will ensure proper functioning of the water supply and sanitation system.

Activities

A functional organizational structure can be implemented via a series of activities.

- There must be an assessment of how objectives and targets can be achieved through management activities and organizational functions within the agency's operational system at all levels. This will involve:
  - — determining objectives and targets, as well as criteria for physical and financial measurement;
  - — obtaining information and describing activities carried out by the units responsible for operation and maintenance activities, representing management activities and organizational functions in the form of a matrix (as described in Part 2); identifying existing lines of communication and levels of operation and decision in the different units in relation to management activities (planning and scheduling, organization and co-ordination, direction, selection and development of personnel, evaluation and control) in the long, medium and short term;
  - — determining how many staff (and with what qualifications) are needed to implement activities at the different levels, indicating their employment status (full-time, part-time, etc.);
  - — assessing factors that act as constraints on the implementation of activities and hamper the achievement of objectives and goals (degree of motivation and training of staff, data processing facilities, budget, means of communication, etc.);
  - — assessing effectiveness of the agency's current organizational structure in fulfilling its targets.
- The next step is to formulate or reformulate the agency's organizational structure in terms of the objectives and targets of the operational system. This involves:
  - — classifying zones or localities (size, distance, resources, etc.) and identifying alternative sites for regional or subregional units, where applicable;
  - — defining objectives, physical and financial targets, quantitative indicators, managerial activities and basic organizational functions to be carried out in order to conduct operation and maintenance;
  - — assigning or reformulating the objectives and functions of the various centres of decision, consolidating operational units, setting up lines of

communication between them and establishing decision-making structures for the different spheres of activity at all levels, according to the programmes and projects to be implemented;

— developing the new functional organizational structure, defining the management information system and describing functions;

— determining the human, physical and financial resources required for implementing the project;

— studying the economic and financial viability of programmes and their projects (Part 3); formulating the programme for implementing the organizational structure simultaneously with other programmes and projects (with order of priorities, gradual implementation, etc.), defining objectives at individual and unit levels.

- Finally there is the actual implementation of the functional organizational structure. This stage requires:

  — involving, informing and training staff;

  — implementing, evaluating, adjusting;

  — allocating resources.

CHAPTER 14

Developing human resources

Objective

A water and sanitation agency that wishes to develop programmes to improve its services should give priority to the development of human resources. Human resources administration and staff development — through training programmes, career plans and an adequate salary system — should be given special emphasis if the staff is expected to improve its knowledge and skills to conduct or support the managerial, technical and operational activities required for the operation and maintenance of drinking-water and sanitation systems.

Activities

An agency intending to develop its human resources will need to take action in the following areas.

- Responsibilities for operation and maintenance should be determined by defining the functions to be carried out by the agency, by its consumers and by consultants and contractors supervised by the agency.
- Organizational functions, activities and levels of management should be identified and an occupational matrix should be prepared for the agency (see Part 2).
- Positions concerned with operation and maintenance within the agency should be identified and classified by organizational level, type of activity (management, technical support, operational) and location.
- Job descriptions and performance standards should be prepared in order to provide guidance as to the number of staff required in different categories, and the qualifications and knowledge needed to ensure that the goals and objectives of the agency are achieved.
- Personal profiles of staff currently in important positions should be obtained or updated, a procedure should be established for evaluating personnel, and policies should be prepared for career development and promotion based on performance evaluation.
- The job descriptions should be compared with the personal profiles and performance evaluations of staff to determine where promotion, relocation, horizontal transfer, training or discontinuation of employment are required.

- Training objectives should be defined, in conjunction with programme and project development (Part 3), and staff development and training programmes should be established. These programmes are required not only for staff but also, as necessary, for community workers and for consultants and contractors employed from the private sector.
- A budget should be established for the scheduled training activities.
- There should be cooperative agreements, as necessary, with training institutions.
- Work plans for training should be drawn up annually. These should include on-the-job instruction and practical training of technicians and operators by the agency's senior supervisory staff, appropriate seminars and workshops and, as circumstances require, the training of community workers and private sector personnel who have responsibility for operation and maintenance.
- Simple and easy-to-read instruction manuals, with appropriate illustrations, should be prepared in the local language.
- Human resources development programmes should be implemented on an annual basis (in conjunction with the implementation of programmes and projects, Part 3).
- There should be evaluation of the performance of individual staff members and of the effectiveness of training programmes in order to decide on follow-up (Chapter 13).
- Accident reports should be reviewed and causes of accidents determined in order to develop training programmes to improve safety.
- An operator certification programme should be developed and implemented. If such a programme already exists, operators should be encouraged to participate. Certification is a way of documenting the knowledge and skills of operation and maintenance personnel. Personnel, management and public all benefit from effective certification programmes.
- A programme of employee awards or recognition of outstanding performance should be developed and implemented. Such a programme is another way of enhancing the public image of the agency and its staff, thereby gaining public support.
- A career development plan should be formulated and implemented in order to create a logical system for promotion and professional development within the agency. This plan would increase motivation among the staff and would reduce political influence in the selection of personnel to management or operational posts.

Staff training

A staff training office is essential for the implementation and continuation of a human resources development programme. The office must have a budget and should be staffed with qualified trainers. Their function is to identify training needs at all levels and develop and conduct training programmes. Expertise from outside the agency should be used as needed for programme development, preparation of training materials and presentation of training sessions.

The training office should work in cooperation, with the personnel office to ensure that the activities listed above form part of the agency's human resources development programme. The training office should keep a record of the training received by each employee.

CHAPTER 15

Developing a management information system for operation and maintenance

Objective

A management information system for operation and maintenance aims to provide management at different centres of decision (strategic, tactical and operational) with the information needed to make decisions relating to operation and maintenance (through accurate collection, measurement, recording, storage and retrieval of data), as explained in Chapters 10 and 11.

Activities

In order to achieve the above objective, the agency will need to carry out the range of activities listed below.

- Centres of decision must be determined.
- Information requirements and performance indicators must be identified.
- It should be established how often each decision centre needs to receive information.
- It should be determined which subsystem is responsible for generating and recording data for each performance indicator, and for transmitting that data to the data processing centre or to decentralized processing stations.
- The structure of the management information system needed for the control of operation and maintenance must be formulated, and technical specifications must be developed for the required computer software.
- The feasibility of developing the proposed system should be evaluated and priorities should be determined for its introduction. Elements to bear in mind are:
  - —the extent to which the system contributes to attainment of the objectives of the decision centres;
  - —greatest measurable benefits in relation to production costs;
  - —an assessment of non-measurable benefits that may result from the reduction of uncertainty;
  - —technical relevance to the development of other information systems in terms of priority, precedence and processing capacity.

- Databases must be designed and files set up according to a defined structure, with glossaries, registers, and routines for verification and validation for quality control.
- Information production processes must be set up. These are:
  - —data capture
  - —verification of data
  - —classification of data
  - —ordering of data
  - —processing of data
  - —storage of data
  - —recovery of information
  - —printing and communication.
- It must be decided what computer software is required for data processing and what hardware is needed.
- Staff should be trained in the production and use of information.
- The agency may need to acquire or change computer equipment when setting up the management information and decision support systems.
- There must be scheduling, implementation and testing of the management information and decision support systems.
- Finally there must be analysis, evaluation and adjustment.

CHAPTER 16

Organizing the programmes

The implementation of programmes to make best use of water supply and sanitation facilities involves people with expertise in different areas and from different agencies. Coordination mechanisms are therefore needed to ensure that all parties are motivated and involved in each phase. Implementation of the water loss control programme and other programmes is essential to the efficiency of water supply and sanitation systems. At national level, agencies are encouraged to participate in a national programme for operation and maintenance. Once the programme is functioning and effective within the agency, national support may no longer be needed. The benefit of the programme is obvious and the programme can become self-sustaining at both national and local levels.

When operation and maintenance programmes are to be implemented at national, regional and local levels, a variety of organizational elements should be taken into account. These are dealt with below in terms of structure, tasks, implementation and research.

Functional structure

A unit should be set up for general coordination of operation and maintenance programmes in order to harmonize, standardize and promote appropriate action by staff. The coordinator should be from one of the agencies in the water and sanitation sector and should have easy access to the other agencies. This person should have extensive experience in the operation and maintenance of water systems, and should be familiar with national and international procedures and mechanisms for fund-raising.

Representatives of participating agencies should form a national committee to provide liaison between the general coordination unit and participating agencies. The national committee should take the lead role in operation and maintenance at national level. The experience of the agencies, reported at meetings with the general coordination unit, will be of vital importance for any reformulation of standards, strategies and directives that may be necessary. Similarly, successful implementation of an operation and maintenance programme at national level depends on the motivation and technical skills of members of the national committee and the influence they are able to exercise in their agencies.

Tasks

A national programme for operation and maintenance of water supply and sanitation systems requires activities in the areas of general coordination, the national committee and the agencies themselves.

General coordination

- The activities of all agencies in the national programme should be coordinated with a view to attaining established objectives and targets.
- Standards should be developed, strategies formulated and directives established for the implementation of the national programme.
- Participating agencies should be encouraged to exchange results of any research they may carry out as part of the national programme.
- Funding must be assured for the implementation of the programme.
- Agencies must be able to act jointly to defend their common interests, particularly where these interests require changes in procedures by contractors, suppliers and other external bodies.
- The process of water loss reduction should be supported in all agencies connected with the national loss control programme, by altering priorities, strategies and targets where necessary.
- Criteria should be formulated for the preparation of projects at agency level.

National committee

- The national committee should advise the general coordination unit on the development of standards, directives and strategies for implementing the national programme.
- At the invitation of the general coordination unit, the national committee should attend meetings and other activities related to the national programme.
- The national committee should schedule the exchange of technology acquired by the agencies while implementing the various components of the operation and maintenance programmes.

Water supply agencies

- The water supply agencies should allocate human, financial, technical and logistic resources for implementing programme activities.
- Agencies should adjust their organizational arrangements to incorporate new technical procedures resulting from the programme in the areas of planning, design, construction, operation, maintenance and supply.

- Terms of reference should be prepared, consultants should be recruited and the results of their work should be shared with all the agencies associated with the national programme.
- Human, financial and technical resources should be allocated to research which will generate, adapt and evaluate technology that may be used by other agencies and may serve to support the formulation of projects.
- Agencies should implement the operation and maintenance programmes on the basis of guidelines established by the national committee.
- Information should be disseminated through courses, seminars, conferences, manuals and on-site training promoted by the general coordination unit and the national committee.

Implementation by agencies

A national programme of operation and maintenance aimed at making best use of water supply and sanitation facilities will require each agency to review its current situation and then implement a series of projects. Studies of the situation of each agency should aim to identify major constraints on adequate performance and their probable causes.

The national programme will take the form of a series of projects each addressing one of the factors limiting efficiency (see Part 3). If these projects are formulated and implemented rationally, taking account of the priorities and potential of the programme and the conditions of the water supply systems, they will improve overall performance and reduce water loss.

One of the most important aspects of these projects is that key personnel at different management levels in the water supply agency should be involved in formulating them. This strategy not only ensures that projects match the agency's situation but also develops managerial skills, motivates management and facilitates subsequent implementation of the programme.

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Development of water supplies and sanitation systems has been a priority of many national and local governments and support agencies, as an essential step towards improving the health status of the communities they serve. Unfortunately, in many cases, the available resources have been used largely for design and construction of facilities, and little thought or effort has gone into ensuring efficient operation and maintenance, or into project evaluation. As a result, in many cities in developing countries, more than half the water supply is unaccounted for, wastage is high, tariffs have to be subsidized, and there are no funds to extend the services to fringe areas.

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