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GUIDELINES FOR MAINTENANCE MANAGEMENT IN WATER AND SANITATION UTILITIES IN DEVELOPING COUNTRIES

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Prepared for the Office of Health,
Bureau for Science and Technology,
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by

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RESEARCH TRIANGLE INSTITUTE

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EXECUTIVE SUMMARY

Maintenance is often poorly performed in many water supply and sanitation (WS&S) systems in developing countries. Tasks are not done correctly, at the right time, or completely ignored altogether. Most agencies operate under a crisis management approach, hurrying from one repair to the next, never really getting ahead of the problems. The result is frequent outages, high repair and rehabilitation costs, and a poor level of water service. In the end, intended benefits are diminished and scarce investment resources wasted.

There are many reasons for poor maintenance performance. Common problems include limited financial resources, poor or inappropriate technical designs, lack of key parts, supplies or tools, insufficient and/or undertrained staff, poor institutional organizations, low salaries and incentives for good work, and poor management of the maintenance function. This manual focuses on the last topic, maintenance management, which encompasses most of the above subjects, at least to some extent. In addition, other WASH manuals address some of these topics in more detail.

A maintenance management system (MMS) consists of a series of techniques for planning, organizing, directing, controlling, monitoring, evaluating, and reporting on maintenance activities to ensure maximum program effectiveness at minimum cost. It is not a set of new technical procedures for performing maintenance tasks in a better way. Rather, it is a means of getting organized so that the correct activities are scheduled and performed at the right time and in an efficient and cost effective manner. The manual is not a guide on technical procedures of, for example, pump repair, but on the management tools to ensure that the pump can be and is repaired. It should also be noted that the manual does not cover operations management concerns, such as pump operating procedures, treatment processes, leakage control, water quality monitoring and testing, and the like.

The manual is designed for top management, maintenance managers, and other maintenance workers in medium-sized to large WS&S organizations. It is intended to provide guidelines on an ideal MMS that they can work toward establishing in their own locations and contexts. The discussion does not try to present rigid procedures. It focuses instead on basic principles and practices, sample procedures and forms, and discussion of alternative approaches where appropriate. The manual recognizes that each case is different and tries to help the reader grasp the essential elements and adapt the details to his or her own situation. Examples, forms, and illustrations from a variety of countries are included.

The manual covers the following elements of a complete MMS:

- **Planning and Organizing**
  - Setting goals
  - Task identification and description
  - Resource requirements
  - Annual plan and schedule
  - Staff organization and training
- **Work Order Systems**
- **Equipment Records**
- **Materials Inventory Controls**
- **Monitoring, Evaluating, and Reporting**

A detailed list of references is included, as well as appendices that provide additional examples, blank forms, sample planning, budgeting and recordkeeping techniques, a list of training resources, and brief discussions of computerized maintenance management and contracting of maintenance services.

1

INTRODUCTION TO MAINTENANCE MANAGEMENT SYSTEMS

1.1 Maintenance Management

Maintenance management is a series of techniques for planning, organizing, directing, controlling, monitoring, evaluating, and reporting on maintenance activities to ensure maximum program effectiveness at minimum cost. It is not a set of new technical procedures for performing maintenance tasks in a better way, but a means of getting organized so that the correct activities are scheduled and performed at the right time in an efficient and cost effective manner. It is a way of making maximum use of personnel and materials to provide the best possible level of service at the lowest possible cost.

A key aspect of good maintenance management is preventive maintenance (PM). It is worthwhile at this point to define this term and contrast it with corrective maintenance (CM). A recent World Health Organization report gives a concise definition:

> *Preventive maintenance is considered to be systematized and periodic maintenance procedure applied to the components of a system in order to minimize breakdowns, ensure their efficient working, and prolong their respective lives. Such maintenance is not to be confused with corrective action taken to repair or replace system components after a breakdown has occurred, as the latter is not the subject of a planned procedure but rather a response to an operational requirement.*[1]

Good maintenance management is not limited to preventive maintenance--it also can greatly help improve performance on corrective maintenance. Work orders, equipment records, materials inventories, and other techniques (which will all be described in detail below) can greatly improve the repair effort.

1.2 Benefits of Maintenance Management Systems

It has been shown conclusively that it is far less expensive, and far more effective, in the long run to spend time and money on a regular basis for maintenance activities upfront, rather than to wait until equipment deteriorates and breaks down, causing service outages and large repair costs. In other words,

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[1] *Preventive Maintenance of Rural Water Supplies*, WHO/CWS/ETS/84.11 (Geneva: World Health Organization, 1984).

Unfortunately, this idealized statement is often heard but frequently ignored. There can be many reasons for poor preventive maintenance, such as the lack of financial resources (tariff revenues are low either because the tariffs themselves are low or because the billing and collection functions are weak), lack of qualified staff (utilities often have many workers but few who are well trained), and lack of good management. Staff tend to perform crisis management, running from one repair to the next, with improvised solutions. One breakdown follows another, and the situation gets worse and worse. The level of service declines until ratepayers refuse to pay and revenues fall even further.

Improved maintenance management cannot be seen as a complete solution to the above problems, but it is a necessary component of any service improvement program. To reach full impact, the application of a maintenance management system (MMS) will have to be accompanied by program efforts in strategic planning, financial planning, technical training, and commercial activities.

The benefits of MMS can be summarized as follows:

- increased reliability of equipment
- minimized service interruptions and downtime
- increased plant performance through better overall equipment condition and reliability
- minimized large repairs
- better utilization of staff through planning and scheduling
- increased productivity of staff
- improved worker safety
- reduced maintenance costs
- controlled maintenance costs
- accurate records on work performed and costs incurred
- accurate records on equipment performance
- data for more effective financial and capital improvement planning
- more reliable supply of parts, supplies, equipment, and tools.

Introducing preventive maintenance is often not an easy process. Where budgets and staff levels are fixed, the staff may be too overloaded to take on these additional tasks. The introduction of PM leads to a reduction in repair work, but only after a period of time. Agencies may find it hard to "get over the hump." Yet in the long term, the injection of more personnel and material resources so that PM can be started and continued is the only way to achieve improved water supply service.

1.3 Key Elements of Maintenance Management Systems

MMS includes a number of interconnected components. The key elements of an idealized MMS, illustrated in Figure 1, are summarized below. Chapters in this manual cover each of these topics in greater detail.

Planning and Organizing. During the initial startup, and annually thereafter, the maintenance staff will have to spend time and effort to plan their activities and organize themselves for maximum effectiveness. This process involves setting goals, identifying and describing tasks, outlining resource requirements (staff, materials, equipment, and other inputs), preparing annual plans and budgets, defining schedules, and organizing and training staff. From this base, the work can proceed logically and directly. The year's activities can be monitored in this context, and plans for the future can be made based on the progress achieved.

Preventive maintenance planning is crucial to the overall planning process. Based on an inventory of all equipment to be maintained, a clear definition must be made of all tasks to be performed. Task specifications must then be developed that detail the procedures to be performed, their frequency, and all required inputs (labor, materials, equipment). Then, the total resource requirements can be estimated, and a schedule of all tasks at all sites can be compiled. These results form the core of an annual plan and budget on the basis of which the work can proceed in an organized, planned fashion.

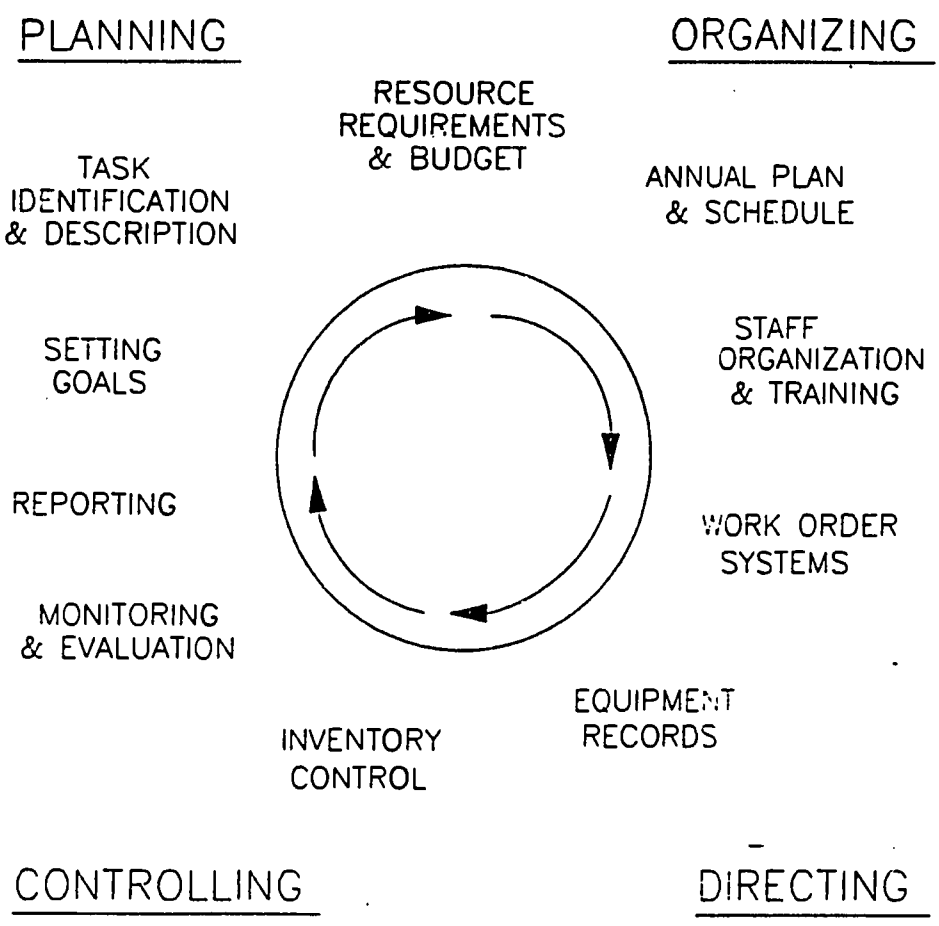
Work Order Systems. A key component of a MMS is the ability to direct maintenance personnel to do planned work at the right times. Using a system of written work orders allows a water system operator or maintenance manager to direct the staff according to plan. The work orders direct the staff, but they are not detailed technical instructions. The PM task descriptions and repair manuals provide the instructions. Once issued, work orders must be tracked to ensure that work is completed in a timely fashion. Work orders also serve as a place to record data on time spent, materials used, and costs incurred. Many organizations contract out repairs or other maintenance work to private firms. This option should be examined carefully. All such contract work should be linked to the work order system.

Equipment Records. Detailed information on the equipment being maintained and the work performed on it must be stored in detailed equipment records. Equipment must be inventoried and assigned identification numbers. Equipment history files should be developed for the storage of equipment specifications, manuals, a log of the work performed, and the actual completed work orders. The exact form of these files will depend on the type of equipment being maintained and its geographic distribution.

Materials Inventory Controls. Maintenance personnel must have easy and rapid access to the required spare parts, supplies, tools, equipment, and other inputs necessary to perform their work. Preventive or corrective maintenance work should not have to wait for some part to come in. While it would be easy to purchase and store every conceivable part and supply, that would be prohibitively

Figure 1

An Ideal Maintenance Management System



expensive. The staff must decide on the most important issues, such as how to balance the cost of delays and how to deal with the cost of supplies. Good inventory control is necessary and is based on using paper forms for tracking the receipt and issuing of materials, using ledgers for monitoring stock, and using a streamlined ordering process.

Monitoring, Evaluating, and Reporting. As work progresses, results and costs must be monitored, evaluated, and reported. The monitoring enables managers to gauge progress, identify weak spots, and plan corrective action. Reporting enables the managers to convey these findings to other maintenance personnel, engineering staff, top management, and outside interested parties. This process feeds directly into the planning and organizing process described above.

1.4 Successful Maintenance Management

The attributes and requirements of a successful MMS can be defined as follows.

Simplicity. The system must be easy to understand by those who use it. The purpose of all forms and procedures must be understood by all, otherwise they will not be used. Lengthy paperwork should be minimized.

Completeness. The system must provide periodic, reliable information concerning the status of all maintenance work that is under way or pending, including both PM and CM. All maintenance work must be planned, directed, controlled, and reported on by the same system.

Flexibility. Although paperwork should be uniform and carefully followed, the managers must be open to changes that will improve the system. Opportunities for improvements are almost always available. Improvements should be adopted incrementally, however. In the beginning, a very basic system should be put in place, and the system expanded or improved as time goes on and the staff develops.

Clear Responsibilities. All staff must know what their responsibilities are, and each job must be allocated to a specific person. When a task arises, it should be clear to all which staff member has responsibility for the job.

Compliance. All staff must comply with forms and procedures and perform the tasks demanded of them within the MMS. People tend to ignore paperwork and often forget to write things down. Paperwork may seem less important than "getting the job done," but detailed records enable the whole system to work well.

Decentralization. The responsibility for day-to-day running of the system should be decentralized. Some operations and maintenance (O&M) functions, such as accounting or procurement, may best be centralized, but the actual control and monitoring of the work should be decentralized as much as possible.

Full Support of Top Management. Upper management and external oversight agencies must give full support to the allocation of human and financial resources to the

maintenance management system. Top management must give the maintenance manager the authority and control over the resources required to implement the system. This is particularly true in the early stages of implementation; otherwise, the system will not be able to achieve its goals.

Strong Leadership. It is essential that the maintenance manager, who will have responsibility to start up and run the MMS, be a strong leader. He or she must ensure that all clerks, craftspersons, and others involved fulfill their responsibilities under the system. The manager must motivate staff to do good work. He or she must strive to keep work on schedule and ensure that necessary follow-up work is done.

Sufficient Transport. Whether in a rural or urban context, the maintenance staff requires sufficient and reliable transport for people, materials, parts, and tools. If transport is often unavailable or unreliable, work will be greatly hampered and delayed. Activities will take longer than expected, and staff will not be able to keep up with schedules. Vehicles often break down, causing transport problems. This manual does not focus on vehicle maintenance or management, but vehicles should be treated like other equipment to be maintained--a schedule of tasks should be developed, maintenance work ordered, parts and supplies stocked, records kept, and performance monitored and evaluated.

Rapid Information Flow. Communications regarding problem notification, work orders, difficulties in completing work, and maintenance reports must be rapid so that personnel have the latest information and can respond rapidly.

Link to Operations. Operations personnel and maintenance personnel must work together in a mutually supportive way. Operators can assist in PM and CM activities, inform maintenance personnel of problems, and advise on parts stocking, PM schedules, and other aspects. Maintenance, of course, keeps things running so that operators can do their work.

1.5 Layout of This Manual

This manual is organized into chapters, which correspond to elements in the ideal MMS shown in Figure 1. Several chapters cover a number of elements in that circular diagram, and several focus in detail on just one. To help the reader keep the whole picture in mind, Figure 1 is repeated at the start of each chapter, in reduced size, with the topic of the chapter highlighted. The reader can immediately see which topic is to be discussed and how it fits into the entire maintenance system.

In each chapter, the basic elements are introduced and explained, sample forms are given, and a discussion follows on how to develop and utilize the forms and procedures. Readers may adapt the sample forms to their own situation. For convenience, the forms also appear in Appendix A.

1.6 Intent of This Manual

This manual is primarily written for government agencies that have the lead responsibility for maintaining water and sanitation systems. It is generally intended for medium-sized to large organizations, to help them manage a staff to ensure better maintenance.

This manual can be useful to agencies of various organizational structures--simple or complex, centralized or decentralized, single autonomous entity or large, national agency with offices at many levels. Perhaps the simplest water utility structure would be a municipal water authority with its own intake, treatment plant, distribution system, and maintenance office and staff. Such an organization could apply these MMS components directly and easily. At the other end of the spectrum of applicable agency structures would be a national water supply agency that runs many small town or village water systems through a series of local, regional, and national offices. Multilevel agencies are more complex, but the procedures and forms presented here should apply, with some adaptations.

This is not a guide for villagers on how to maintain their own handpump, a guide on training village caretakers, or a guide for agency managers on how to elicit community participation in O&M. Those must be the subjects of other manuals.

The manual is written for new or existing water and sanitation agencies. In most cases an improved MMS will be worked into an existing organization. Rarely is a new agency begun "from scratch." Sometimes two agencies are merged, or a large one divided. This restructuring may provide a good time to incorporate improved maintenance management.

These guidelines should be useful for top management, maintenance managers, and other maintenance personnel in water and sanitation utilities. Top management can learn about the basic components and benefits of good maintenance management, which should convince them of the need to support it. Maintenance managers can learn the techniques they will have to adapt and apply. The manual may also be useful in training lower level maintenance personnel in these methods. Specific chapters can be useful for specific personnel, such as the chapter on inventory controls for the storekeeper and the section on work orders for crew foremen.

This manual explains all aspects of a maintenance management system. Yet the information cannot be taken directly and implemented. Managers will have to study these guidelines and adapt the procedures and forms to their own situations. It is intended to be a useful guide, not a packaged system to adopt blindly.

It is also important to note that these procedures are somewhat complex and cannot be implemented overnight. At the start, it will make sense to adopt a simplified version of each MMS component. Applying the techniques to a single pilot plant or system is a sensible approach. Over time, each MMS component can be refined and improved. As experience is gained and procedures refined or adapted, a more widespread implementation can be made. It will take a large

agency serving many small water systems or an entire region several years to develop a full-scale system with all the features described in this manual.

1.7 Limitations of This Manual

This manual (and the system it describes) makes some assumptions about the organizations that will use the information. The manual assumes that the agencies have reasonably efficient purchasing and accounting, personnel, and commercial offices. It also assumes that channels of communication and means of transportation are relatively open and free. Without good performance in these areas, the MMS will be hampered, and poor maintenance will result. In order to correct such problems, agencies will have to focus on making improvements in the functions mentioned above. This manual is designed to cover just the MMS; the other topics are covered elsewhere.

This manual does not consider such everyday management concerns as personnel relations, time reporting, payroll, accounting, purchasing, wage scales, and the like. Although many of these management functions affect maintenance, they are generic to a variety of utility operations. Also they can be better covered in other texts.

The forms and examples in this manual are oriented toward plant equipment and distribution systems in water utilities. However, the same principles or approach can be applied to other system components and to the wastewater field. Some changes in the tools provided here will be needed, however. The manual, as noted above, does not cover vehicle maintenance and other aspects of transportation, which can be a major problem in many countries. Vehicle maintenance can be incorporated into a plant/distribution MMS or be managed under a separate MMS. The principles of maintenance management presented here can be directly applied to vehicles.

This manual is not a technical reference on O&M tasks, such as what maintenance tasks should be performed, how, or when, for any particular type of hardware. These guidelines will not tell you which oil to put in a Lister diesel engine in the Sahara Desert, or how often to change it, or whether a water distribution network should be flushed every six months or every six years. It assumes the reader can collect the necessary information on the maintenance requirements of the systems, components, and equipment involved. Manufacturers' manuals, water system O&M manuals (if any were prepared), engineering handbooks, and manuals on engineering practice can help provide such technical information. The records developed by following these guidelines will, however, help in defining technical aspects of discrete O&M tasks.

These guidelines do not consider operations management. Such aspects as water quality maintenance, chemical dosing, routine operating procedures, pump operating rules, leak detection, distribution pressure regulation, and drought management are outside the scope of these guidelines.

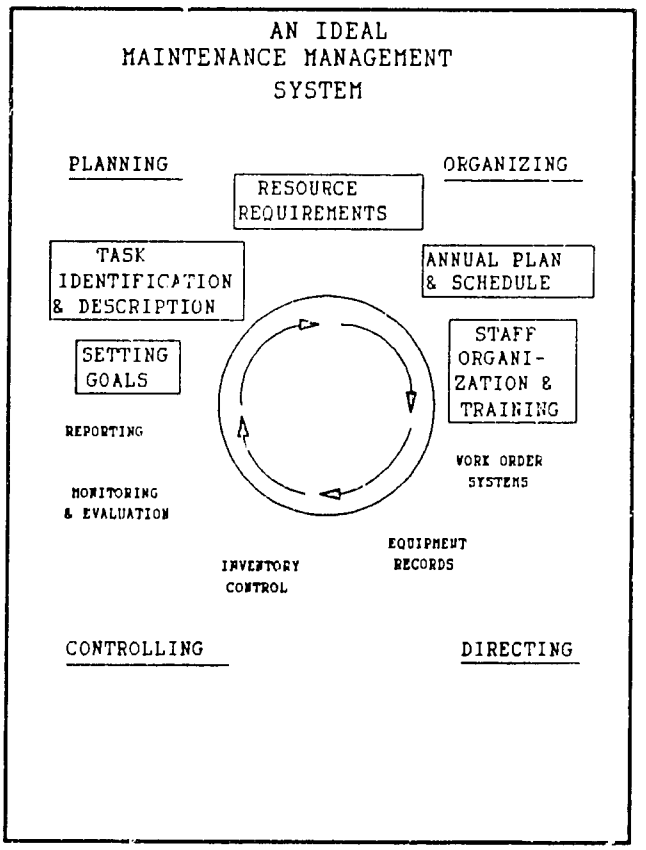
This manual is designed to illustrate a paper-based maintenance management system, not a computerized one. The principles and practices in this paper

system are the same as in many computer systems. Computers do offer many advantages, such as the capability to handle large volumes of work rapidly and accurately. But they can also pose problems. They are expensive, require special skills, tools, and parts beyond the capability of many organizations, especially those in rural areas. For large water systems and agencies, the extra power will be worth the cost, but not so for small ones. For interested readers, notes on computerization are provided in Appendix B, along with a list of some MMS software packages.

2

PLANNING AND ORGANIZING MAINTENANCE MANAGEMENT SYSTEMS

2.1 Purpose/Overview



To achieve maximum effectiveness, maintenance staff must plan all maintenance work. The main elements of planning and organizing include

- Setting goals
- Identifying and describing tasks
- Estimating resource requirements
- Developing an annual plan and schedule
- Defining organizational responsibilities
- Training and developing staff

These steps must be carried out in the development phase of a maintenance management system and annually thereafter. This exercise is hard work initially, but future annual cycles will be simplified by the existence of previous plans and records on previous work pertaining to equipment and cost performance. This chapter will first review these basic elements and then describe the actual process of starting up such an MMS.

2.2 Setting Goals

Establishing goals for the maintenance program is an essential first step in the planning process. The purpose of setting goals is to know beforehand what you are setting out to do, so that afterwards you can see how well you did. Thus, setting goals is closely linked to evaluating performance (see Chapter 6 and Appendix C). Without goals the manager and staff will have no sense of direction and no idea of what they have accomplished or where they are going. Work will proceed in a haphazard fashion. Goals also serve an important function in

motivating staff and showing top management that improvements can be targeted and achieved.

The long-term goals of a maintenance department were described in Chapter 1. Those goals will provide the best possible level of maintenance service at the lowest possible cost. While those goals will be the driving force behind all work performed, short-term annual goals are needed as performance targets. Such goals can be oriented toward staff performance, equipment performance, or cost (see evaluation approaches in Chapter 6). For example, an annual goal might be to reduce unplanned water system outages to one per year per water system, or completing 90 percent of the work orders on schedule, or reducing material costs per kilometer of distribution to a certain level. Once one goal is achieved, a new one can be set and efforts continued. Key areas should be identified, such as timeliness of completion or ratio of PM to CM tasks, and goals should be established for each area.

Another type of goal would be the achievement of certain features of the maintenance management system itself. For example a first-year goal in establishing a new large-scale MMS might be the completion of an MMS plan, designation of a leader, and completion of an equipment inventory.

Goals must be realistic so that they are not too hard or too easy to reach. They must give managers a target to strive for and staff a sense of accomplishment when reached. Different water systems or regional offices may have similar or perhaps quite different goals. For example, they both might be trying to reduce overtime pay, but one regional system may seek to reduce overtime pay to 10 percent of the total and the other to 30 percent. Every organization and every region will be different. The only rule is to set realistic goals, try to achieve them, measure progress toward them, and set new goals.

2.3 Maintenance Task Identification and Description

2.3.1 System/Equipment Inventory

The very first step in planning what work is to be done is to decide which water systems are to be maintained and to compile an inventory of all equipment contained in those systems. The purpose of such an inventory is to learn which equipment is where. Conducting a detailed inventory can be a very lengthy exercise if no records are available, but it is a fundamental part of good maintenance management.

Some decisions may have to be made about locations or areas of responsibility before a maintenance manager can begin this inventory process. That is, the basic decision as to which office or department is to maintain which water system or water plant must have been made before the inventory can begin.

Procedures for carrying out equipment inventories are described in Chapter 4. Suffice it to say here that an inventory must be conducted, and it must yield a full list (with specifications) of all equipment at all systems or plants.

2.3.2 Task Identification

Once a detailed list of equipment is developed, the maintenance tasks that must be performed on each one must be identified. This identification process is necessary to estimate resource requirements and develop a schedule. To define each maintenance task properly, the following information must be specified:

- Task name
- Brief task description
- Frequency (daily, weekly, monthly, annually, etc.)
- Responsible party (operator, regional crew, outside shop, etc.).

The identification of tasks will be based on data from a number of different sources. Ideally, there would be an O&M manual for each water scheme outlining all tasks on all pieces of equipment, but such guides are often not prepared. So the task identification must be done "from scratch." The best place to start is the manufacturer's recommendations. A supplier or manufacturer of an engine, pump, motor, or other such piece of equipment should be able to specify the above data (and more) on each task to be done. Past experience with a particular model will also be useful. However, such experience should not be the sole basis for task identification, as old procedures may, in fact, be inadequate. Discussions with operators and users of the equipment may also be useful, but the same cautions should apply. Engineering handbooks and manuals will also be useful references. A final source of information would be outside consultants with maintenance planning experience with the relevant equipment. A sample task identification list for small diesel engines is shown in Figure 2.

In identifying tasks, it will be important to decide who, or what type of person, will do them. This will depend on the type of task, skills required, and the frequency. A task that must be done every day and requires no special skills or tools should be done by the system operator or caretaker. A more major task, such as a pump leather change or a motor bearing repacking that is conducted only annually, should be the job of the maintenance staff and included in the MMS planning. This allocation of responsibility is necessary to ensure that all tasks are done by someone. This assignment process will be the first step in defining staffing requirements.

The use of outside contractors is always an important option in allocating tasks. Contractors can be used to do specific PM tasks or repairs, such as engine overhauls, which are sufficiently complex and may be too expensive and demanding to develop the in-house capability to do the work. Contractors can also be used when there is a seasonal peak in workload or when unexpected repairs arise. However, in many areas skilled contractors are not available. In addition, the use of contractors requires good oversight skills on the part of the utility. A more detailed discussion of the use of private contractors is given in Appendix D.

Figure 2

Task Identification Sheet for Diesel Engines

The following summarizes the recommended service intervals for Lister engines. The engine model is given in parentheses (e.g., ST, LT, 8/1). Where no model is specified, the procedure applies to all.

Daily	Check supply of diesel fuel and oil level Check air filter (in dusty conditions)
125 hrs	Check air filter (in moderately dusty conditions, renew if necessary) Check for oil and fuel leaks Check and tighten nuts and bolts as necessary Clean engine and mounting
250 hrs	Change engine oil Clean the restrictor banjo union in the lubricating oil feed line Renew oil filter if fitted (ST) Clean injector nozzle if exhaust is dirty Renew fuel filter if necessary Check belt tension
500 hrs	Decarbonize if necessary (LT) Renew fuel filter element (ST) Adjust valve clearances (LT) Change oil in oil bath air filters (8/1 so equipped)
1000 hrs	Decarbonize (8/1) and if necessary (ST) Change filter elements (8/1) Adjust valve clearances (LT)
500 hrs	Decarbonize (LT) Examine and clean fan blades (LT) Check governor linkage and adjustment (LT) Drain and clean fuel tank (LT) Renew fuel filter (LT) Clean and test the injector nozzle (LT) Check fuel pump timing (LT) Check oil pump and its valves (LT) Renew the air filter element (LT)
2000 hrs	Decarbonize (ST) Clean inlet and exhaust system (ST) Examine and clean fan blades (ST) Check governor linkage and adjustment (ST) Drain and clean fuel tank (ST) Renew fuel filter (ST) Clean and test the injector nozzle (ST) Check fuel pump and its valves (ST) Renew the air filter element (ST)

2.3.3 Task Description Sheets

Once a major task has been identified, a task description sheet should be developed. These sheets, also called maintenance procedure sheets, will serve as guidelines in planning and executing work. They will help ensure uniform work performance and will be useful in training new staff.

Task description sheets should be written for major PM tasks for each type of equipment. Simple routine tasks that are performed every day probably will not need a task description sheet. No doubt there will be systems with multiple units of the same model pump or motor, in which case the same task description will be used for each unit. A typical description sheet includes the following information:

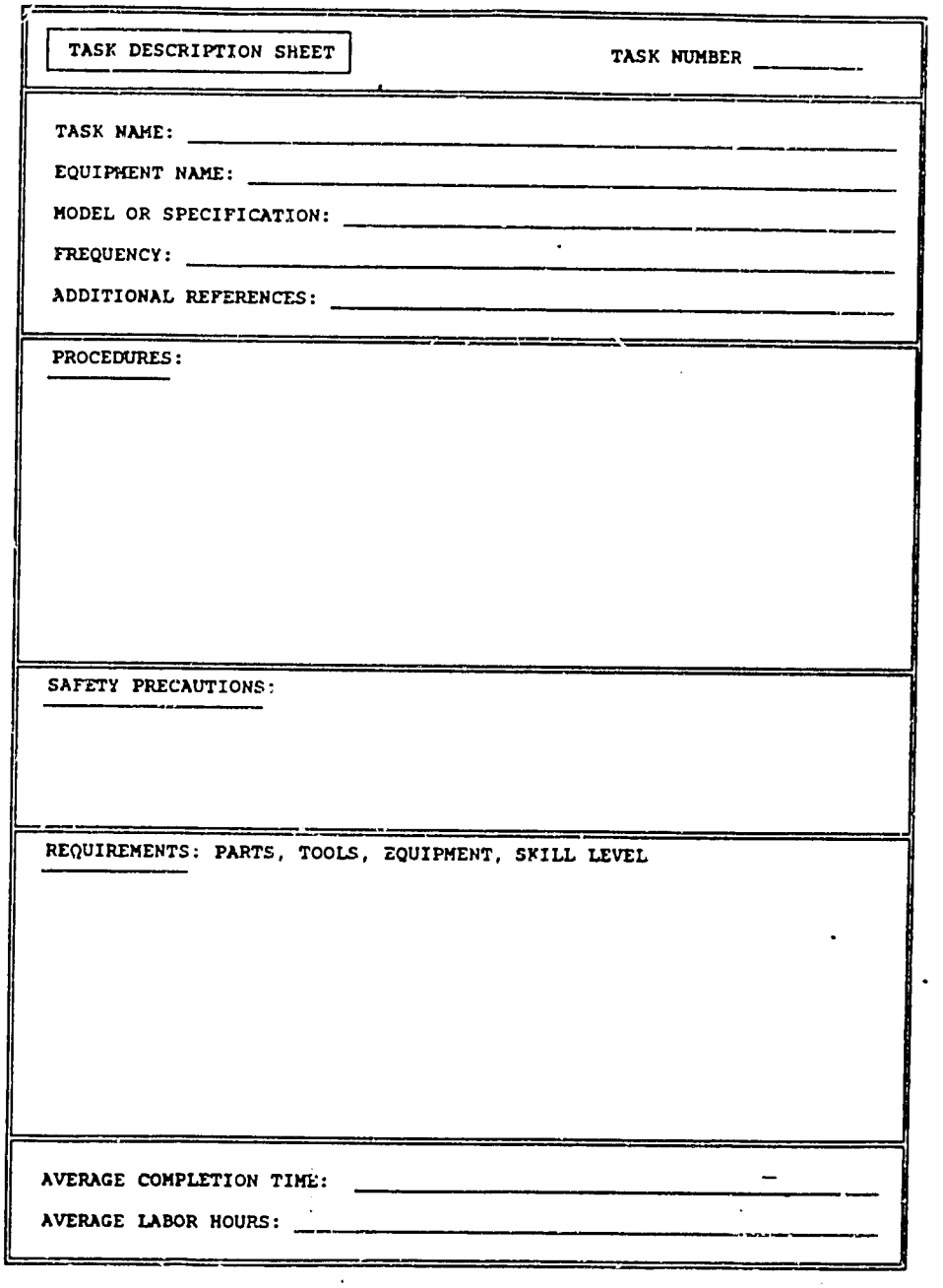
- Task name
- Task number or code (optional)
- Equipment
- Frequency of performance
- Step-by-step procedures
- Safety precautions
- Materials required (parts, supplies, other)
- Tools or special equipment required
- Skill level required or type of personnel required
- Additional references (manuals or other useful documents)
- Average or estimated time to complete task
- Average or estimated labor hours to complete task.

A blank task description sheet is shown in Figure 3. Appendix E provides sample sheets for chlorinators, motors, and other water supply equipment.

Copies of these sheets should be stored in the equipment history file for each piece of equipment. (See Chapter 4.) Also, a master file of task description sheets should be stored in the office, and the sheets should be accessible to a manager completing a work order and craftsmen planning and performing work. When a work order is issued, the sheets can be attached to the work order for quick reference by the craftsman. If work is done by a contractor, the sheets can also be a useful guide.

Figure 3

Task Description Sheet


TASK DESCRIPTION SHEET

TASK NUMBER _____

TASK NAME: _____

EQUIPMENT NAME: _____

MODEL OR SPECIFICATION: _____

FREQUENCY: _____

ADDITIONAL REFERENCES: _____

PROCEDURES:

SAFETY PRECAUTIONS:

REQUIREMENTS: PARTS, TOOLS, EQUIPMENT, SKILL LEVEL

AVERAGE COMPLETION TIME: _____

AVERAGE LABOR HOURS: _____

Development of task description sheets for each major task, for each piece of equipment, and for each water system in a region will be a major undertaking. Without these guidelines, however, the quality of work will be poorer, and labor hours and time spent on the job will be higher. A practical plan for future water systems would be to require construction contractors to include task description sheets in O&M manuals developed for the system.

Ideally, these sheets should include estimated completion times and labor hours, thereby creating a target performance standard. The work order system, equipment records, and the monitoring process can also use these standards to track work performance.

Staff should strive to complete work rapidly and correctly. Completion times and costs should be compared with the current standard, and the standard revised as necessary. In any given year, if experience shows that a particular task can be completed in less time or requires more time, new standards and task descriptions can be developed.

For situations in which there are a large number of tasks, it will be worth developing a numbering system. A simple sequential number system would be adequate. A more elaborate two-part code could also be developed with the first part denoting the equipment and the second the specific task. For example for diesel engines, the tasks could be designated DIES-1, DIES-2, and so on, and assigned to each task in order of frequency. Such identification codes (ID) will be useful in various parts of the planning process, as described below.

2.4 Estimating Resource Requirements

Once tasks have been identified and described, estimates can be prepared for all resources required to carry out these activities. This estimation process will help ensure that these resources are made available. Such an estimate will include the following:

- Number and types of staff
- Materials, including parts and supplies
- Tools and equipment
- Transport
- Contract services
- Other inputs.

When a full tabulation of these needs has been made, the costs of each can be added up to form a direct cost budget.

Such an estimate can be prepared from the equipment inventory and the task descriptions discussed above. There is no trick to this process; it is simply a matter of painstakingly adding up all the requirements from each task

description for all equipment in the inventory. Consultations with operators, mechanics, electricians, and other craftsmen will help in preparing an accurate estimate. It will make sense to do this with one water system or plant area at a time.

As an example, in order to estimate labor requirements and costs, it will be necessary to estimate total man-days required to execute a particular task at a number of different water systems (under a regional maintenance office) with the following formula:

Task man-days per year	=	Number of systems	x	Task frequency	x	Estimated man-days for that task

Such calculations should be made for each of the PM tasks and then added to get total man-days per year. Separate computations of man-days in different skill areas, such as mechanic, electrician, etc. can be made. A preliminary estimate of the staffing requirements can be found by dividing the total man-days in each skill area by the workdays per year (typically 260). A detailed example of this type of procedure is given in Appendix F. A series of worksheets from a maintenance planning handbook from Sri Lanka are shown in the appendix, including forms on task identification, labor requirements, material requirements, and maintenance budget.

While such calculations are quite straightforward for preventive maintenance activities, the resources required for repairs will be a little harder to estimate. The planner will have to make some estimates of repairs to be made at each system. These CM tasks can then be treated like PM tasks, with labor, materials, and other costs estimated for each.

The results of the material requirements estimations will be useful for planning the materials to be stocked. The number of different parts needed will be useful in planning which parts to stock, the minimum quantities, and reorder quantities (see Chapter 5).

This type of computation will give an estimate of direct maintenance costs but not a full operating budget. It will not include, for instance, the costs of chemicals and electric power necessary to run the system. This process won't include the operator salaries, and unless it is expressly added in, the salary of the maintenance manager (and clerks). The reader is referred to another WASH publication, *Estimating Operations and Maintenance Costs for Water Supply Systems in Developing Countries*, for more guidance on preparing a full O&M budget.[2]

[2] WASH Technical Report 48, January 1989.

2.5 Annual Plan and Schedule

Once a budget has been developed, it must be approved by top management. Revisions may have to be made, which may affect the tasks to be undertaken. Once approval is obtained, a finalized annual plan and schedule are made.

The annual plan should mostly summarize the information listed below:

- Goals for the year
- Staffing requirements
- Training requirements
- Material requirements
- Equipment/tools requirements
- Contracting requirements
- Transport requirements
- Other requirements
- Direct maintenance cost budget
- A precise PM schedule.

The precise PM schedule should detail which work should happen where and when, such as a checklist of daily, monthly, semiannual, and annual tasks. From this list, work orders will be written to direct staff.

Scheduling can be a complex task. It is a matter of ensuring that all the work is done with the correct frequency and with as smooth a workload as possible. One way to start is to define an annual schedule for one water scheme or plant area at a time. Using a calendar, all tasks on all pieces of equipment should be written down for each month. Then the same should be done for other systems, filling in the same monthly sheets. Tasks that are somewhat irregular (such as every two months or six months) should be staggered so as to make the workload as smooth as possible. Adjustments will have to be made as the schedule gets filled up, but eventually a balanced schedule can be made. As mentioned above, contractors will be a useful safety valve to meet varying workloads.

An example of a PM schedule for a group of rural water supply schemes is given in Appendix G. A series of pages from a WHO document show the development of the schedule, including

- An equipment inventory at each site
- An equipment ID numbering system, for each site
- A series of task description sheets for different types of equipment

- A calendar or schedule of events for a full year.

An excerpt from the final result of all this work and the precise maintenance schedule are shown in Figure 4.

Appendix G also contains some scheduling worksheets from Sri Lanka that take a step-by-step approach. First, a rough annual plan is defined that outlines what is to happen each quarter. Then, a quarterly work schedule outlines task assignments for six half-month periods, and finally, a semimonthly schedule defines a precise schedule.

2.6 Staff Organization and Development

As the personnel requirements are defined, and as the annual maintenance plan is being made, the human resources to implement these tasks must be planned. Staff organization and development will involve good institutional organization, the correct number and type of staff, and ongoing training programs for all.

2.6.1 Organization

As a MMS system is being developed, the organizational structure of the agency will have to be examined. A new structure may have to be developed to promote clear lines of responsibility, authority, and communication and efficient work performance. The type of organizational structure will depend on the nature and service territory of the agency; the size, number, and technical sophistication of the water systems involved; and other factors.

There are many of types of organizational frameworks, with wide differences, but a few general guidelines will be useful:

- There should be a close link between operations and maintenance. In smaller agencies they may be merged, in larger ones separate functions.
- Maintenance (or O&M) should have a direct link to top management.
- Maintenance (or O&M) must have its own manager and its own authority, budget, and resources. Maintenance (or O&M) should not be a minor adjunct under construction or engineering divisions.

The MMS planning effort should involve the development or refinement of an organizational model, expressed graphically in the form of an organizational chart and written job descriptions for each slot. The chart should show clearly the lines of supervisory

Figure 4

Sample Maintenance Schedule

Month: January			Month: February			Month: March			Month: April		
Working* Day No.	Location Village	Task to be performed	Working* Day No.	Location Village	Task to be performed	Working* Day No.	Location Village	Task to be performed	Working* Day No.	Location Village	Task to be performed
1,2	A	C1-1y H1-1y P1-15-1y Q1-1y	1	A	H1-1m	1	A	H1-1m	1	A	H1-1m
			2,3	F	B1-3m H5-3m J9-3m J10-3m L7-1m H5-1m	2	F	J9-1m J10-1m L7-1m H5-1m	2	F	J9-1m J10-1m L7-1m H5-1m
3	F	J9-1m J10-1m L7-1m H5-1m				3	B	J1-1m J2-1m L1-1m H2-1m	3,4,5	B	C1-1y H1-1y I1-1y I3-1y J1-1y J7-1y L1-1y L2-1y P16-24-1y Q2-1y
4,5	B	C1-3m H1-3m H1-3m J2-3m L1-1m H2-1m	4	B	J1-1m J2-1m L1-1m H2-1m	4	C	J11-1m J12-1m L8-1m H6-1m			
6	C	J11-1m J12-1m L8-1m H6-1m	5,6	C	A7-3m H6-3m I11-6m I12-6m J11-3m J12-3m L8-1m H6-1m	5	L	B4-3m L13-1m H10-1m	6	C	J11-1m J12-1m L8-1m H6-1m
7	L	L13-1m H10-1m	7	L	L13-1m H10-1m	6,7,8	H	E1-1y L14-1y H11-1y O4-1y P152-172-1y Q13-1y	7	L	L13-1m H10-1m
8	H	L14-1m H11-1m O4-1m	8	H	L14-1m H11-1m O4-1m	9	H	J13-1m J14-1m L9-1m	8	H	L14-1m H11-1m O4-1m
9	H	J13-1m J14-1m L9-1m	9,10	H	A8-3m H1-3m J13-3m J14-3m L9-1m	10	C	J3-1m J4-1m L3-1m H3-1m	9	H	J13-1m I14-1m L9-1m
10,11	C	A1-3m A2-3m H2-3m I3-6m I4-6m J3-3m J4-3m L3-1m H3-1m	11	C	J3-1m J4-1m L3-1m H3-1m	11	I	L10-1m H7-1m O1-1m	10,11	C	A1-3m A2-3m H2-3m I3-3m J4-3m L3-1m H3-1m
12	I	L10-1m H7-1m O1-1m	12,13,14	I	B1-1y L10-1y H7-1y O1-1y P81-96-1y Q9-1y	12,13	H	F1-3m L15-1m H17-1m	12	I	L10-1m H7-1m O1-1m
13	H	L15-1m H12-1m	15	H	L15-1m H12-1m	14	D	J5-1m J6-1m L3-1m L4-1m L5-1m	13	H	L15-1m H12-1m
14,15	D	A3-3m A4-3m A5-3m H3-3m J5-3m J6-3m L3-1m L4-1m L5-1m	16	D	J5-1m J6-1m L3-1m L4-1m L5-1m	15,16	O	B2-3m H8-3m I15-6m I16-6m E1-6m E2-6m L16-1m H13-1m	14,15	D	A3-3m A4-3m A5-3m H3-3m I5-6m I6-6m J5-3m J6-3m L3-1m L4-1m L5-1m
16	O	L16-1m H13-1m	17	O	L16-1m H13-1m	17	E	J7-1m J8-1m L6-1m H4-1m	16	O	L16-1m H13-1m
17,18,19	E	A6-1y H4-1y I7-1y I8-1y J7-1y J8-1 L6-1y H4-1y P46-56-1y Q5-1y	18	E	J7-1m J8-1m L6-1m H4-1m	18	J	L11-1m H8-1m	17,18	E	A4-3m H4-3m J7-3m J8-3m L6-1m H4-1m
			19	J	B2-3m L11-1m H8-1m	19	K	L12-1m H9-1m O2-1m O3-1m	19	J	L11-1m H8-1m
20	J	L11-1m H8-1m	20	K	B3-3m L12-1m H9-1m O2-1m O3-1m				20	K	L12-1m H9-1m O2-1m O3-1m
21	K	L12-1m H9-1m O2-1m O3-1m									

*It is assumed that there are 20 working days per month. Actual dates should be used when known.

responsibility. Sample organizational charts for two types of agencies, a large autonomous municipal water authority and a local/regional/national water supply agency, are shown in Figures 5 and 6.

Job descriptions are an important complement to the organizational chart. With job descriptions, staff and management are completely clear about what is expected of each staff member (see sample in Figure 7). Job descriptions usually include the following information:

- Title
- Grade
- Supervisor and subordinates
- Duties and responsibilities
- Qualifications and training required
- Salary range.

2.6.2 Training

Training is an essential part of maintenance management, both during the establishment of an MMS and regularly thereafter. Efforts will be needed to train staff at all levels, from the maintenance manager to the crew foremen to craftsmen. Training on both technical and managerial matters will be important.

An initial assessment of the need for training will have to be made and followed up in future years. Establishing job descriptions with training requirements will help identify the training needs. However, additional training needs can be identified in the performance evaluation process, For example, if a particular task consistently takes longer than expected, that is a sign that craftsmen or others may need more training. If a particular type of machine frequently breaks down, that could be addressed with additional training for operators or maintenance personnel.

Although many utilities do not have their own training office, such a unit will help promote effective training. Staff who specialize in training and who conduct regular programs tailored to agency needs will provide the most effective approach. This may appear costly, but a well-trained staff of efficient workers reduces O&M costs.

A variety of training mechanisms can be used, depending on the content. For the technical aspects of maintenance procedures, both classroom and hands-on sessions will be the most effective approach. The courses will, of course, have to be customized to the particular equipment being used. Specialists associated with the specific manufacturers of equipment may provide needed technical expertise for training programs. Such technical orientations can be used for existing and new staff. Periodic refresher courses to polish craftsmen's technique may also be warranted.

Figure 5

Municipal Water Supply Agency Organizational Chart

O&M DEPARTMENT – MUNICIPAL WATER AUTHORITY

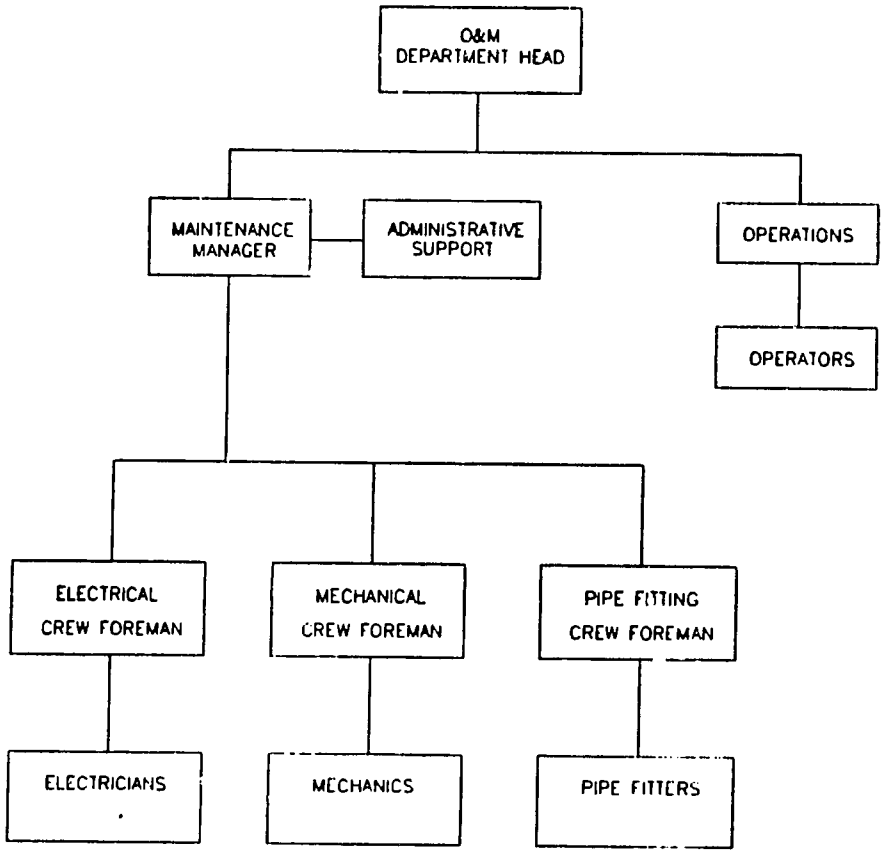


Figure 6

Multi-Level Water Supply Agency Organizational Chart

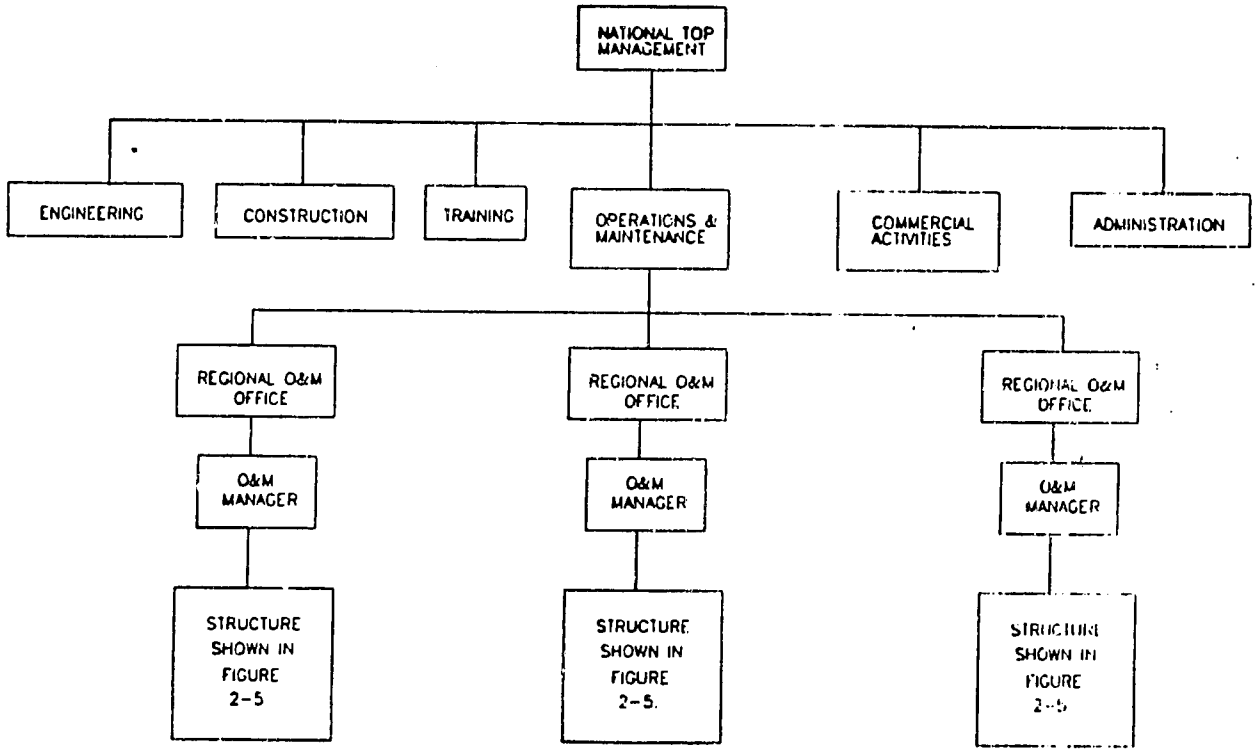


Figure 7

Maintenance Manager Job Description

TITLE: MAINTENANCE ENGINEER

GRADE:

REPORTS TO: Regional Manager

IMMEDIATE SUBORDINATES: Electrical Mechanical Foremen

DUTIES AND RESPONSIBILITIES:

1. Provides general supervision of the foremen and technicians in his section with respect to scheduling of PM and CM and deployment of personnel and transport.

2. Ensures that the work order system for PM and CM is operating correctly.

3. Advises electricians and mechanics on proper equipment repair procedures.

4. Coordinates electrical mechanical work with appropriate district engineers.

5. Ensures that significant delays in completion of PM tasks are not permitted due to lack of materials, manpower or transport.

6. Evaluates the performance of employees working in his section.

7. Works with construction managers to ensure that his section is prepared to adequately provide maintenance for equipment in new and rehabilitated schemes.

8. Advises the regional manager of any major equipment problems in his region.

9. Coordinates equipment repairs done by shops outside the regional workshop, e.g., private workshops or the Central Workshop.

10. Prepares the annual budget for E/M maintenance for submittal to the regional manager (RM).

11. Submits a monthly report for the RM detailing significant equipment problems and PM and CM tasks completed.

QUALIFICATIONS AND TRAINING:

Experience

1. Three or more years as a practicing mechanical or electrical engineer with one year in a supervisory role, preferably at a water utility.

2. Graduation from a recognized university with a B.S. in electrical or mechanical engineering.

3. Preferably training in the development of management skills.

Abilities

1. Possession of good written and verbal skills.

2. Supervise effectively the work of others.

Management training can be conducted at specialized local institutes, if they exist. This manual can serve as a reference for such courses. If local management training capability is lacking or weak, local instruction can be based on courses developed elsewhere. Appendix H lists training resources on maintenance management, including self-study courses on maintenance management and sources of books and training materials on the subject. Another approach that is gaining some acceptance is "twinning" or "sister utility" programs with agencies in other countries. Under these programs, personnel from one agency or region can spend time (perhaps two to three months) at another agency that has already implemented a MMS and can learn by working with an operating management system. If MMS is implemented in one part of the country, as a pilot effort, it can be the local site for this "twinning" approach as MMS is brought to other regions.

2.7 Developing a Maintenance Management System

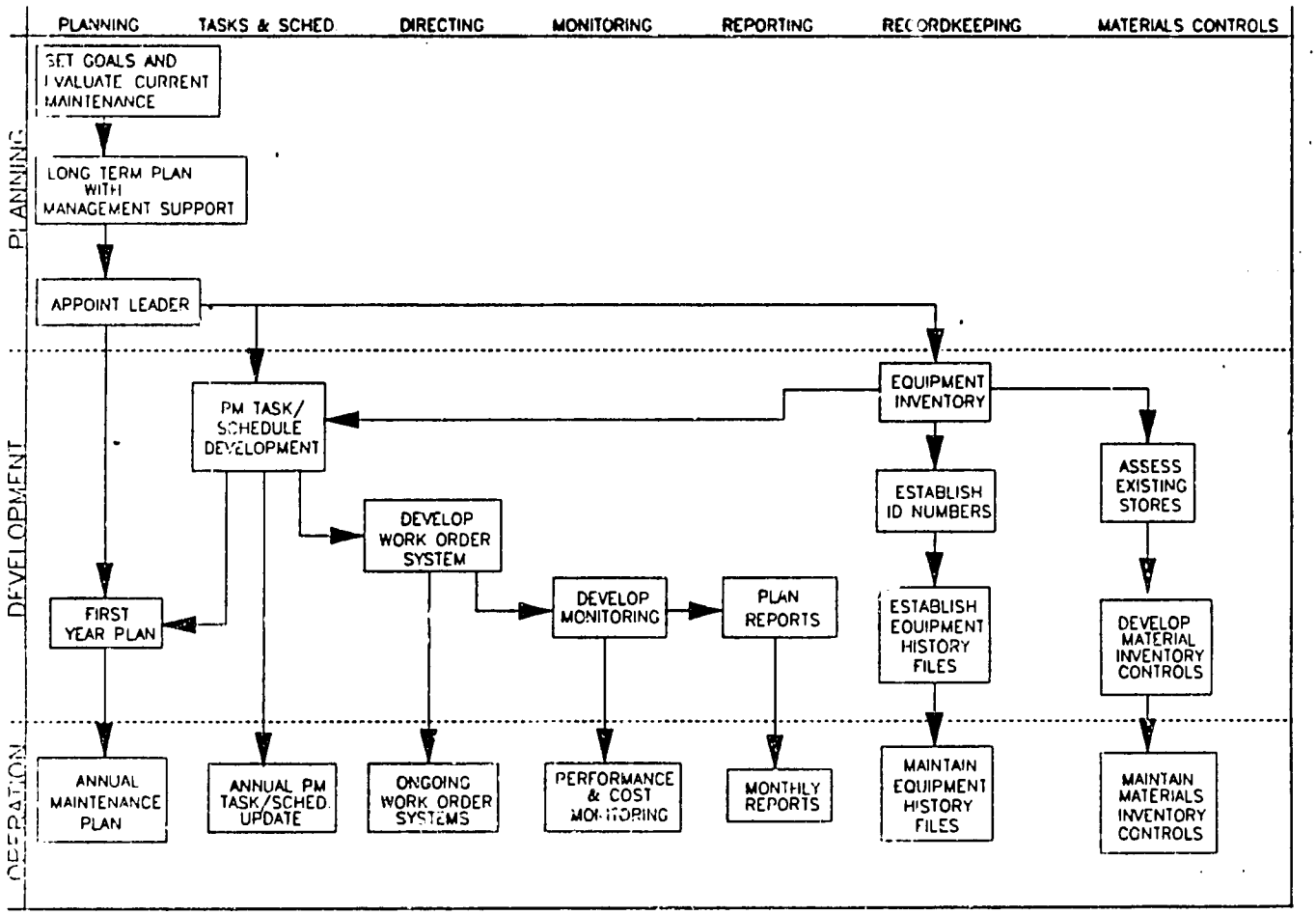
The steps involved in developing an improved MMS are shown in Figure 8. These activities are no different from the steps in the planning and organizing process described above. However, in developing a new system, they will be implemented in a particular order and will be much more demanding. In an annual planning process, it will be a matter of updating and refining the existing techniques, schedules, and procedures. A new water system or two may be added into the workplan. However, when a complete MMS is being developed for the first time, current practices must be reviewed, and all steps carried out in depth.

Implementing an improved MMS in an agency with a weak maintenance system will be a time-consuming, laborious effort. There will be a lot of up-front work to conduct inventories, identify and describe tasks, and develop budgets and schedules for the first time. It will take a dedicated leader, a good plan, and the support of management. It will be important to ensure that management understands the lengthy lead times required before the benefits of MMS make themselves apparent.

The very first step will be for managers to learn about improved maintenance management. This manual will be a useful guide, in that it covers the full scope of an improved MMS. The training resources in Appendix H will also be useful. Next, as described in Section 2.2, goals should be established. Then, the current procedures must be reviewed and evaluated. Existing approaches should be compared with the ideal presented here. Strengths and weaknesses of the existing system must be pinpointed, and efforts must be focused on selected key areas. There are a variety of ways that an evaluation of an existing system can be performed. Some will be more useful in the annual evaluation/planning cycle (see Chapter 6), others more useful in a first-time evaluation. First of all, the evaluator can read through this manual and examine the techniques described and the principles behind them. As the reader goes through the text, he or she can mentally compare current practice with that described here. A running self-evaluation can be performed in this way and the desired improvements noted and then acted upon.

Figure 8

Development of a Maintenance Management System



Another approach that will be especially useful in developing a new or improved MMS system will be to use one of several maintenance management evaluation checklists that have been developed. Such a list is given in Appendix C. For each of the key components of maintenance, the checklist asks a number of "yes/no" questions, with the phrasing such that a "yes" answer is desirable in each case. Whenever there is a "no" response, an area needing attention has been identified.

There is a third approach, which may be difficult to use in the development phase of a MMS, but which should be commonly used in the annual planning cycle. That approach is the use of performance measures, which is described in detail in Chapter 6. In many cases, the baseline data from which to calculate performance measures will not be available in the development phase.

The result of the review of current practice will be the identification of key areas where efforts should focus. If materials inventory procedures appear to be reasonable, or shortages of parts and materials are rare (or not of great consequence), then other MMS features should be focused on first. If records are completely lacking, that area should receive the most emphasis. However, it would be a mistake to think that some parts of the MMS can be completely skipped over. All are required parts of a whole system. Efforts should emphasize those aspects that need the most help.

The next step is to designate a leader to manage a staff to carry out the time-consuming chores of inventories, maintenance task identification and description, etc. Over time, the work order systems, equipment records, monitoring and reporting procedures (that will be used every day thereafter) can be set up. Throughout the later stages of the development process, training efforts will be a major part of the activities. New staff, including the leader, may have to be hired so that ongoing O&M does not suffer.

It is important that an agency, and the particular staff involved, not get overwhelmed by this development process. There are several ways this can be avoided. First, a new MMS should be implemented on a pilot scale and then expanded later. For example, in Sri Lanka, where a number of rural schemes are supported by a regional maintenance office, a new MMS was implemented in just one of a dozen regions in the country. In this way, a basic system, such as described in this manual, can be tested, adapted, and refined to suit local conditions. Later, once the system is working well in one place, it can be expanded to include other areas. Staff working in the pilot region can become leaders or advisors in other areas, and the operating pilot system can be a training ground for other staff.

In Ivory Coast, the national water utility (SODECI) took an interesting approach. There, the town water systems are administratively organized into regions. Each town scheme carries out most O&M functions autonomously, but regional centers provide maintenance support, stores, vehicle garages, engineering support, and commercial activities. Operators at different town schemes regularly meet at the regional headquarters to discuss their work. When SODECI planned to implement an improved preventive maintenance system, it hired a local engineering firm with PM planning experience in industry to develop a

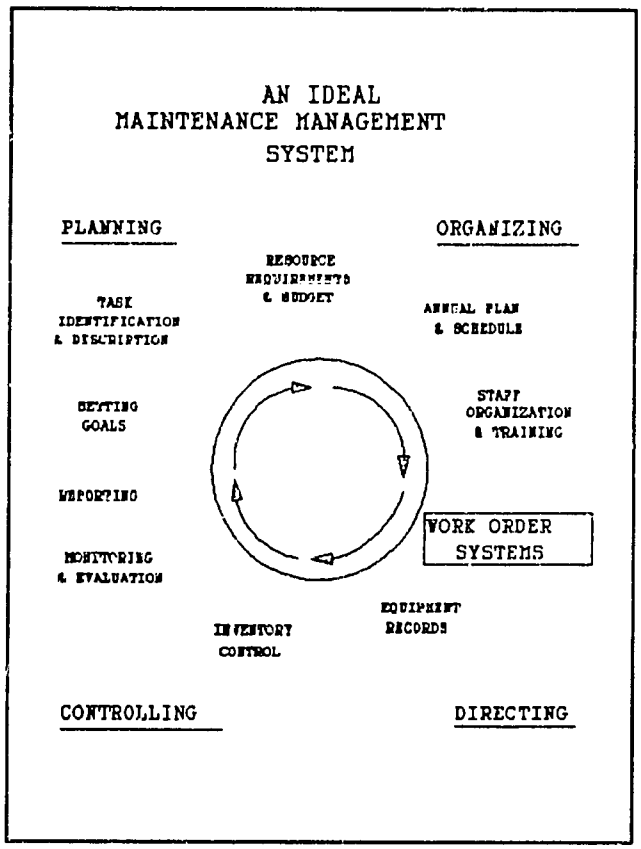
full MMS plan and provide training at one system in each region. After a break-in period, other systems were brought in under the same approach by SODECI staff, and training was given to the additional system operators. This limited use of outside contractors allowed SODECI to implement the plan with the benefit of experience and without the burden of adding extra staff.

Another way of keeping this development process manageable is to develop simple procedures first and sophisticated ones later. A scheme, plant, or region might start off with simplified, very basic systems for work orders, records, materials inventory, and monitoring and reporting. In the second or third year, more sophisticated tools, such as performance standards, budget tracking, and historical analyses could be programmed in, as staff experience permits. This approach must be contrasted with trying to develop a single, highly sophisticated MMS component at the expense of others, such as developing a fancy work order system without keeping equipment records. A balanced approach, with some competence in all aspects of MMS, is far superior to an imbalanced one.

3

WORK ORDER SYSTEMS

3.1 Purpose/Overview



The main purpose for work order systems is to direct maintenance craftsmen to conduct a particular set of tasks at a particular time. In other words, the work order tells people what to do and when. In general, a work order will be written by the maintenance manager, sent to the craftsman, completed, and then returned to the maintenance manager. In the case of repairs, the operator will often notice the problem first. He or she can submit a work request to the maintenance manager, who can then prepare a work order. This same type of work order system can be used to direct workers at each water scheme or plant and to direct work by regional personnel.

The work order should not give full details of all the subtasks associated with a given activity or state exactly how to carry out a job. Prepared task descriptions, equipment maintenance manuals, or experience should tell workers how to perform a task. For example, a work order might direct a mechanic to do an oil change on a particular engine on a particular date, but it need not explain all the technical steps to complete the job.

Work orders also serve other important functions related to monitoring, scheduling, recordkeeping, accounting, and reporting. If a crew is experiencing delays in completing a job, the outstanding work order will be the signal to the manager to investigate. Completed work orders, as they are returned to the office, let the maintenance manager know that a given task is complete and whether any follow-on work is needed. A copy of the completed work order is sent to accounting for allocation of expenses to the correct cost code. Completed work orders, as they accumulate, form a useful body of data for analyzing equipment performance and cost history. A record of data on a particular maintenance task can allow new time and cost standards to be developed. Keeping a log of the work orders is useful in reporting.

For work order systems to be a helpful tool, all involved must do their part--the maintenance manager must ensure that a work order is prepared for all work, the clerks must follow the paperwork carefully and promptly, and the craftsmen must complete the work order, describing the work accomplished. People have a tendency to skip the paperwork for small jobs or for emergencies. Craftsmen may not see the value in recording work performed, may complain about the paperwork, or may not fill out work orders completely. Without such adherence, however, the work order system will be of much less value.

This chapter presents the basic work order cycle and then gives details on the content of the forms. The list below identifies the main work order elements:

Forms

- Work request form
- Work order form

Logs

- Work order log
- Work request log

Files

- Pending work order file
- Equipment history file (described in Chapter 4)

This work order system is designed for a large water utility or a regional office maintaining many systems or pieces of equipment over a wide area. It allows delegation of many tasks to a rather large staff. Simpler types of work order systems are possible, especially for smaller, less complex water systems or different institutional structures. Variations on the work order system described below are discussed in Section 3.3.

3.2 Work Order Cycle

The work order cycle consists of a number of steps, from the identification of the need for work to the filing of a completed work order. These steps are outlined below and described graphically in Figure 9 (corrective maintenance) and Figure 10 (preventive maintenance).

Origin. The origin of a work order will depend on the type of work. In the case of corrective maintenance, the process will actually start with a work request, written by someone observing a problem (such as an operator or other maintenance staff member). The work request should be sent or delivered to the responsible maintenance manager as soon as possible. Telephones, if they are available, can help speed problem notification, but if a call is made a written work request form should follow. The work request form is designed to provide all the necessary information for a work order to be written.

Figure 9

Corrective Maintenance Work Order Cycle

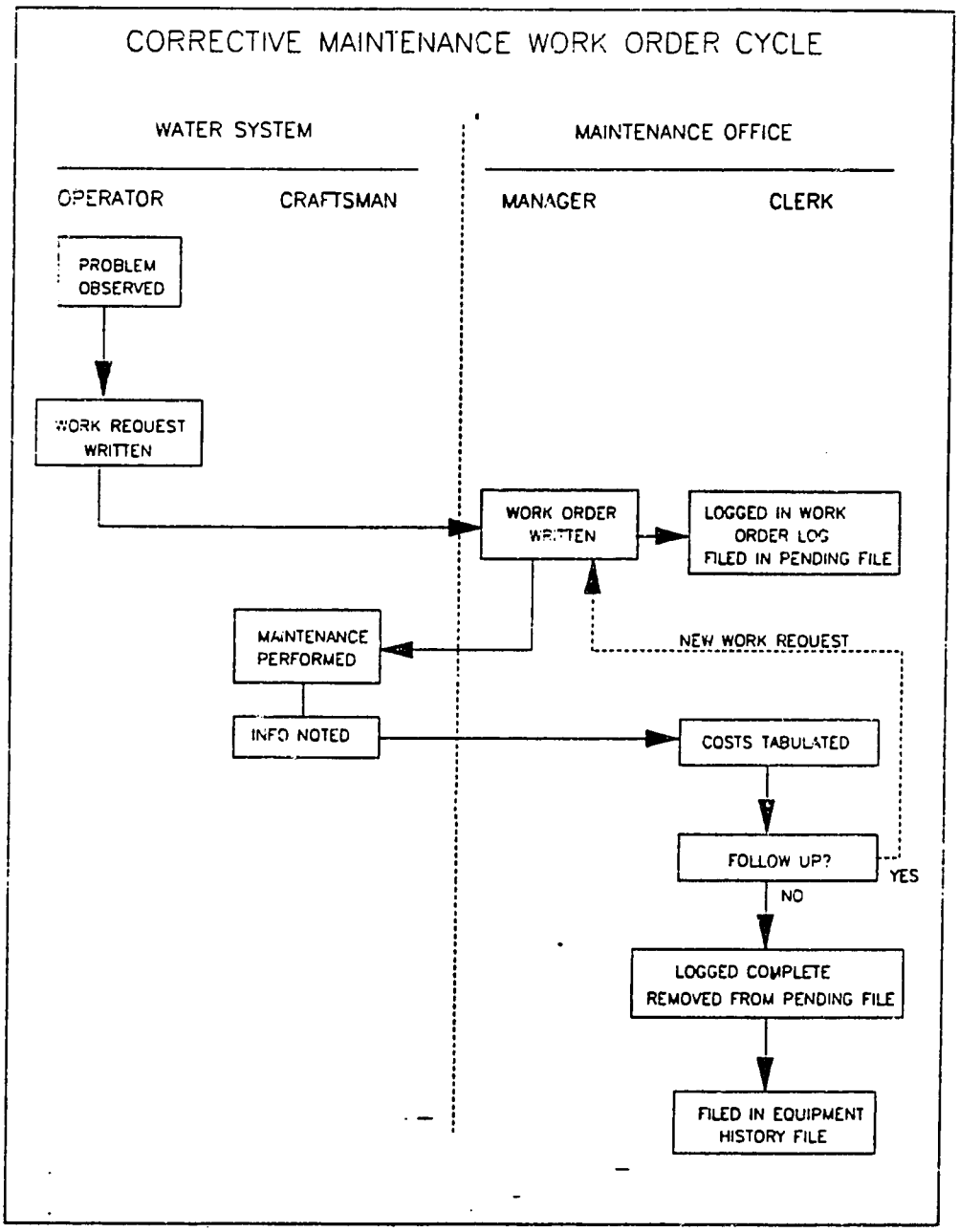
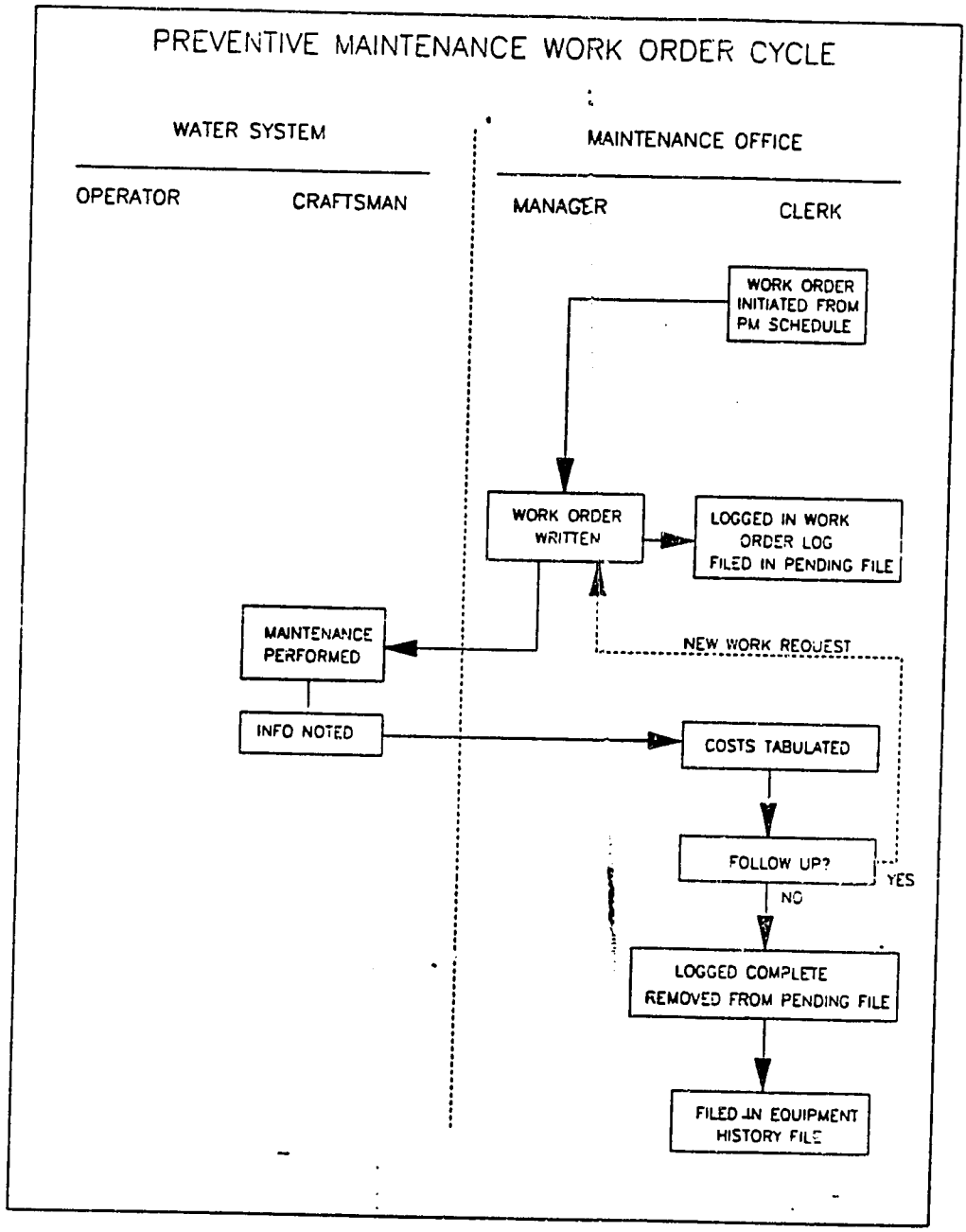


Figure 10

Preventive Maintenance Work Order Cycle



For preventive maintenance, the origin of the work order will be an annual plan, as discussed in Chapter 2. A given water system or piece of equipment should have a PM plan, including a schedule outlining what work is to be performed and when and a set of task descriptions outlining the steps, tools, equipment, and supplies required to complete each task.

In a water treatment plant or scheme that has its own PM plan and its own MMS, near the end of the month, the clerk could consult the schedule for the coming month and start preparing work orders. He or she could partially fill them out, attach PM task descriptions, and send them to the maintenance manager to complete and issue to craftsmen.

Work Order Writing. Once the need for maintenance work has been established the clerk/manager will write the work order. The work order should be prepared in duplicate using carbon paper or a copy machine. Once written, the manager or clerk must enter it into the formal work order log, file one copy in the pending work order file, and send the other copy to the craftsman.

The manager must decide the priority of the work. This can be done by assigning a number from a system such as the following:

1	Emergency--Immediate	(full overtime authorized)
2	Important	(partial overtime authorized)
3	Routine	(no overtime authorized)
4	During slack periods only	(no overtime authorized)

The priority assigned will depend on the nature of the work and its urgency relative to the other ongoing tasks. The manager will also have to determine who will do the work. This assignment will depend on the nature of the work, skills required, and the assignment of other duties. The work order log, which indicates previous and current activity, will be useful in this assignment procedure. Once the work order is written, the office should deliver, post, or otherwise send the work order, along with task descriptions, to the craftsman.

Work Performance. Once the work order is issued, the craftsman should first consult the equipment history file, distribution maps, or other records on the hardware to be maintained. Next, he or she will have to collect the necessary tools, equipment, parts, materials, and supplies from stores or other sources. The craftsman will also have to complete a requisition form to obtain items from stores, as described in Chapter 5. A copy of the requisition form should be attached to the work order, outlining the items and associated costs.

Once the work is finished, the crew foreman or craftsman should complete the remaining parts of the work order by describing work done, labor and materials used, the need for any follow-up work, and other items (see details in Section

3.4). Any unused supplies or parts should be returned to the stores and a materials credit form attached (see Chapter 5).

Processing. Once all work and data recording are done, the craftsman should return the work order to the maintenance manager's office. A clerk should immediately review the form and total up all costs. The clerk should then update the work order log. The completion date, cost, and filing location (file number) should be noted in the work order log. Next, the clerk should remove the work order copy from the pending work order file. One copy of the form, along with all requisitions, credits, etc., should be filed in an equipment history file for that water scheme or piece of equipment. One copy of the work order with costs noted should be sent to accounting.

3.3 Institutional Application of Work Order Systems

Work order systems can be applied at a variety of levels, within a local, municipal, regional, or national organization. The simplest example would be the municipal water department that has its own employees, maintenance office, stores, workshop, and water treatment plant and distribution system. A work order system just like the one described above would be ideal.

For rural water systems, multilevel institutional frameworks are often used. One common scenario involves using a number of handpumps in small rural communities, each with a caretaker, and a regional office for support and major maintenance. Under this structure, a work order system for each site, as described above, would be unnecessary. The "work order system" might just be a schedule of PM activities to be completed by a caretaker. As each task is done, it could be checked off. At the end of every quarter, the sheet could be sent into a regional office for monitoring. The regional office would then verify receipt of these forms and check their completeness. One could also imagine a book of prepared "task orders," which when completed, could be sent into the office, allowing for more careful tracking. The caretaker could also maintain a very simple log of repairs. A duplicate log could be kept at regional headquarters. The regional office would definitely use a work order system to control work done by regional personnel. Work request forms, sent in by the caretaker for problems that he cannot handle, will be a very important part of the maintenance system.

Another common scenario involves a number of larger water schemes in larger towns in a region, each with its own staff, and a regional office with its staff. The staff at each town scheme would do some maintenance, and the regional support office would do major maintenance. The same type of work order cycle can be used at each level. A work order system would be set up for all work ordered and conducted by scheme personnel, perhaps run by an operator. Another work order system would be run by the regional maintenance manager to direct regional personnel. If a problem arose that required regional intervention, a work request would be written, and the resulting CM work would be performed and controlled by regional personnel using their work order system. PM work done by local or regional personnel would be controlled by the respective work order

system. For good recordkeeping, scheme and regional maintenance personnel must communicate about work performed. Monthly reports from the scheme operator to the regional office should detail work performed and outstanding work requests. Although it is burdensome for the town scheme to send copies of all work orders to the regional office, it is done in some countries. It is imperative that the regional office send a copy of completed work orders for work on a given scheme for inclusion in the local records.

There will often be cases in which a motor, pump, engine, or other component will have to be sent away for repair, either to a central workshop or a private repair facility. Some type of "work order" should accompany the device to instruct personnel receiving it as to what is needed. It is not uncommon for a device to come back with incorrect actions having been taken; precise definition of the desired work is needed. Such a form is sometimes called a repair requisition, sometimes a "trip ticket." This type of form could be developed from the standard in-house work order form (presented in Figure 11). When the work is done, the device should be returned, along with information outlining the work done and costs incurred. It is essential that all such exterior work be tracked by the same tracking system used for regular work orders. The use of contractors has been mentioned in Chapter 2 and is discussed in some detail in Appendix D. If equipment is being sent to a private shop, the contractual relationship will have to be consistent with paper delegation of work. Utilities may require that contractors provide estimates before starting work.

3.4 Work Order Forms

3.4.1 Work Request Form

A work request form is a notification form for staff observing a problem to communicate the need for work to the responsible maintenance office. The form could be used by a plant worker to inform plant maintenance of a problem within that plant. Or it could be used by a rural water scheme caretaker to inform regional maintenance personnel of a problem requiring their attention. The form, shown in Figure 11, should have spaces for the following information:

- Date, time
- Requestor
- Priority
- Water scheme name and location
- Equipment needing attention, including name, ID number, and exact location
- Malfunction observed
- Date, time, and person observing
- Action already taken

Figure 11

Work Request Form

WORK REQUEST FORM (FRONT SIDE) PRIORITY _____

REQUESTOR _____ DATE AND TIME _____

WATER SCHEME NAME AND LOCATION _____

SPECIFIC EQUIPMENT NEEDING ATTENTION - NAME: _____

EXACT LOCATION _____ ID# _____

MALFUNCTION OBSERVED _____

DATE, TIME, PERSON OBSERVING _____

EXPECTED CAUSE OF PROBLEM _____

_____

ACTION ALREADY TAKEN _____

ANTICIPATED WORK TO BE DONE _____

SPECIAL INSTRUCTIONS _____

WORK REQUEST FORM (BACK SIDE) PRIORITY _____

- Expected cause of problem
- Anticipated nature of work to be done
- Special instructions.

3.4.2 Work Order Forms

The work order is the actual instrument on which a manager directs craftsmen to do work. A sample work order form is shown in Figure 12. The form should include spaces for the following information:

For the clerk/manager to complete when writing the order

- Type of work order: PM or CM
- Priority
- Date
- Work order number
- Person writing work order
- Person(s) or crew to conduct work
- Account number or charge code
- Water system name and location
- Equipment needing attention, including name, ID number, and location
- Nature of work to be done, with any special instructions
- Date and time to be completed

When writing a CM work order

- Attach work request
- Additional comments by maintenance manager

When writing a PM work order

- Attach PM task description sheet

For the craftsperson(s) to complete when the work is finished

- Summary of work performed
- Problems encountered, means of resolution
- Parts and materials used: number of requisition (attach)
- Labor use: hours (or days) per employee

Figure 12

Maintenance Work Order Form

MAINTENANCE WORK ORDER | TYPE: PM CM | WORK ORDER NO. _____

DATE _____ ORIGINATOR _____ PRIORITY _____

PERSON TO CONDUCT WORK _____ ACCOUNT # _____

WATER SCHEME NAME AND LOCATION _____

EQUIPMENT NEEDING ATTENTION - NAME _____

EXACT LOCATION _____ ID# _____

NATURE OF WORK TO BE DONE: _____

TARGET COMPLETION DATE AND TIME _____

WORK PERFORMED: _____

PROBLEMS / RESOLUTION _____

COMPLETION: DATE AND TIME _____ PERSON _____

FOLLOW-UP NEEDED _____

OTHER OBSERVATIONS _____

LABOR USE				MATERIALS USE		VEHICLE/ EQUIP. USE			OTHER COSTS
PERSON	HRS	RATE	COST	REQUIS. #	COST	ITEM	MILES	COST	
									TOTAL COST
TOTAL				TOTAL		TOTAL			

- Vehicle/equipment use: vehicle type and mileage
- Work completion: date, time, signature of craftsman or foreman
- Follow up needed, if any
- Other observations

When completing a CM work order

- Cause of malfunction
- New PM requirements, if any
- Additional instructions given to operator, if any

When completing a PM work order

- Any observations on equipment condition
- Anticipated upcoming CM, if any.

For the maintenance management clerk to complete:

- Subtotal costs for labor, materials, vehicles/equipment
- Total cost.

Work order forms should be written in duplicate and numbered sequentially. Various numbering approaches are possible. The simplest would be to have pre-printed numbers in sequence, with the same number on each duplicate copy. Another approach would be to have the maintenance manager enter the number when the form is written. The first two numbers could correspond to the issuing office, the next two numbers to the year, the next two numbers to the month, and the last four would be sequential numbers.

There are many possible variations to the work order form presented here. In some utilities, different work order forms are used for preventive and corrective maintenance tasks. In others, identical forms are used, as in Figure 12. One interesting approach would be to have different color forms for PM and CM. Alternatively, different colors could be used could be used for distribution system components and plant equipment, or different colors for electricians, plumbers, or masons.

In cases in which a regional office is performing maintenance on a number of different systems, the forms could be coded or colored to distinguish the work location. The exact style of the forms is not that important, but it is essential that the same system of issuing and tracking work orders be used for all maintenance work.

In general, work orders are written by a manager for people under him or her. One would not want a system in which an operator in a rural scheme writes work orders for regional mechanics--chaos would result. If a rural scheme needs help, it should write a work request to the regional maintenance office. The manager

should then write the work order for one of the staff to travel to the scheme to do the work and report back. Under such a system, the scheme will monitor the response to work requests, and the maintenance manager will control the work he has ordered.

Some maintenance management manuals suggest that the work request and corrective maintenance work order be combined into a single form. This simplification might seem desirable, and within a self-contained, single plant operation, it might work. But if a number of facilities and maintenance offices are operating at different levels, the process of tracking work will be difficult. In general, the use of separate work requests and work orders, with separate monitoring, will be best.

3.4.3 Work Order Files and Logs

Pending work order file. The clerk in the maintenance office should maintain a pending work order file and store the forms in sequential order. Dividers or markers corresponding to the beginning of each week or month are useful. When a work order is completed, it should be lifted from the pending file. The work order, with all supporting documentation (requisitions, credits, etc.), should then be filed in an equipment history file or distribution record for that water scheme or that piece of equipment. The manager or clerk can scan through the file to see what jobs are under way.

Work Order Log. A formal work order log should also be maintained by the clerk in the maintenance manager's office. The log should retain data from each work order, including the following:

- Work order number
- Date written
- Person or crew responsible
- Brief work description (a few words)
- Location (scheme or plant location)
- Priority
- Completion date
- Total cost
- Location of completed work order (file name or number).

This log could be a simple notebook for keeping data on all work orders for future reference. A sample work order log is shown in Figure 13.

Maintenance managers may want to develop additional tools to help track work orders. For instance, the manager or clerk could note down each week on a chalk board a few key facts on each outstanding job for quick reference. Thus, the manager or clerk could check current activities at a glance. If more information is desired, he or she could consult the work order log or pending work order

file. Another approach would be to use index cards on a bulletin board. The bulletin board could be divided into different parts for different locations, schemes, or functions. Color-coded cards for different skill areas would also be useful.

Work Request Log. The caretaker or operator at each scheme or plant should also maintain a log of work request forms he or she has submitted to a regional or district maintenance office. A simple notebook, with column entries as in Figure 13, would work well.

3.5 Development of Work Order Systems

Many water utilities have some form of work order system already in place, but the systems are often deficient. Managers, craftsmen, and clerks often do not run the systems as they were designed to be run. Craftsmen who are trained in physical skills may have poor literacy. Many will not see the value in spending time noting down technical details or consulting manufacturers' manuals. Thus, many work orders are filled out incompletely or inaccurately or equipment records are incomplete. Also, in many instances, work orders are not logged correctly or are filed in the wrong place. Some managers bypass the work order system, giving verbal orders, to avoid paperwork when their jobs get busy. Managers are often overloaded with work and may be tempted to cut corners in this way.

The development of an improved work order system will involve an evaluation of the current system and adaptation of a work order system like the one described above. This must be an evolutionary process, starting with the basics, and being refined as time goes on. However, there are three essential, minimum components of a system:

- A work order must be written and completed accurately for each job.
- All work orders must be logged and filed correctly.
- Good communication among all staff is essential to success.

As a work order system is used and staff become more experienced at scheduling and performing work, additional enhancements can be added. One recommended enhancement to the system described above would be to add a place in the work order form for standard or estimated values for labor hours, material costs, and other costs. As work is completed, the standard and actual values can be compared. This would allow for careful monitoring of work performance and costs. An investigation as to why a particular job took longer or cost more than expected can identify weaknesses and improve efficiency.

A study of records on the manhours, materials used, and costs could allow a set of targets or performance standards to be developed for most common tasks. A table of such standards could be developed and kept handy for writing work orders (and for budgeting). Development of these standards will not be a trivial

Figure 13

Work Order Log

WORK ORDER LOG

MAINTENANCE OFFICE _____

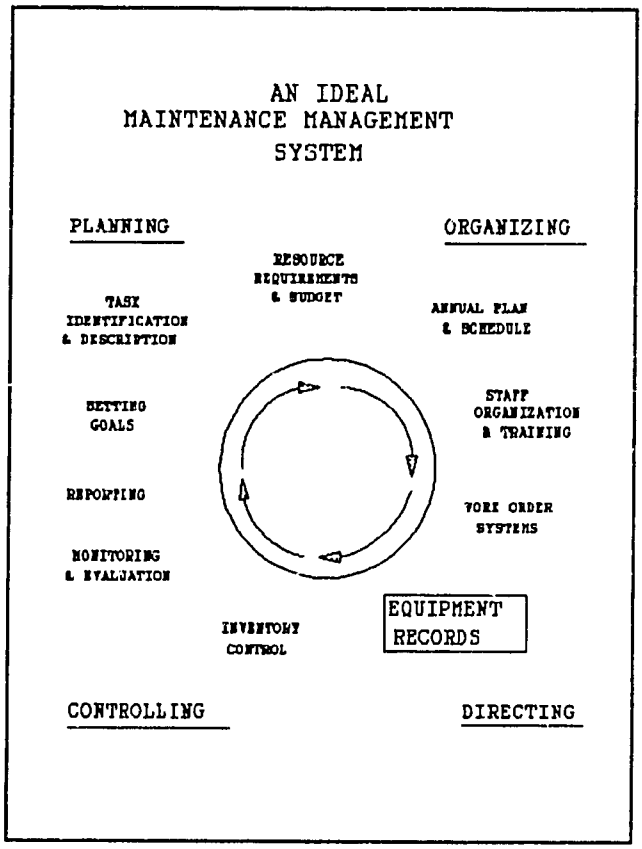
WORK ORDER #	DATE WRITTEN	PERSON RESPONS.	WORK LOCATION	WORK DESCRIPTION	PRIORITY	COMPLETION DATE	TOTAL COST	FILE LOCATION

task, however. It would be worthwhile to investigate records for the plant, scheme, or region in question, but also at other plants, schemes, or regions. Performance in other places may be better, which would point to a more ambitious target. In addition, careful studies of the actual steps involved in a given maintenance task may be needed to pinpoint the amount of time the job should take, as opposed to the amount of time it has been taking. Such study efforts may only be worthwhile on major tasks that require a lot of labor and expense.

4

EQUIPMENT RECORDS

4.1 Purpose/Overview



The purpose of equipment records is to store specification data and historical maintenance information on all equipment. Such records will be extremely useful in performing maintenance work, planning future work, planning an inventory of spare parts and materials, and designing new water systems.

Each piece of equipment, such as pumps, and motors, should be assigned an ID number, and a nameplate should be attached to the equipment itself. Equipment descriptive data and maintenance records should be stored in file folders, generally sorted by location. Some equipment is moved from one location to another over the course of the years, so separate files for such pieces of equipment will make sense. For distribution network equipment, such as mains, service lines, and valves, specification data should be stored in the form of maps and revisions noted when changes are made. Files should be kept on all sections of the system, including maps and records on all maintenance work performed. These "tools" are summarized below:

Equipment ID systems	Based on equipment function, technical characteristics, location
Equipment history files	Detailed data files for specific pieces of electromechanical equipment
Distribution Records	Maps, files, and other records for piping, valves, meters, and other items in water distribution networks

4.2 Equipment ID Numbers

Equipment ID numbers are a concise method of referring to or identifying hardware. The ID numbers should be established during an inventory of existing equipment or during commissioning of a new system. They should be noted on the equipment data sheet for that piece of hardware and used on work orders or other references to that item.

There are different type of numbering schemes for different types of equipment and situations. The simplest approach would be a simple number assigned sequentially during the inventory process, but this would not be very useful. Almost all numbering (or lettering) schemes denote information about the function or purpose of the equipment. Some systems add a part for technical data such as the horsepower of a motor or pump capacity. Many ID schemes also denote the location of the equipment. Some equipment, such as small diesel engines for well pumping, are moved around from site to site, so a location reference in the ID scheme would not be used. No one system is best, and a custom-designed approach can be developed in each situation, as shown in the examples below.

Figure 14 shows a simple scheme used in Sri Lanka that combines notations on location and function (see also Appendix I). A three-letter code is used for each rural water scheme, and a two- or three-part function code follows.

Example of Equipment ID System

Suppose an agency has been buying a series of diesel engines for use at a number of village water schemes. It has attempted to standardize a line of engines using Lister (0-25 HP) for the smaller sizes and Fiat for the larger sizes (>25 HP). Agency staff have devised an ID scheme illustrated by this example:

ENG-L-ST1-4.5-1500-87

where:

ENG - Engine (as opposed to pump or other device)
L - Lister
ST1 - Lister Model Name
4.5 - Nameplate horsepower
1500 - RPM setting used
87 - Year of purchase (1987)

Appendix J shows a more elaborate ID scheme used at a wastewater treatment plant in the United States. The first three digits of the five-number code correspond to the function performed, and the second two digits sequentially list equipment in that function category. A full equipment configuration list, sorted by the three-digit function code, lists ID number, equipment name, equipment type, and location. The equipment type is based on a list of equipment type codes, also shown in Appendix J.

Figure 14

Sri Lanka Equipment Codes

EQUIPMENT CODES AND IDENTIFICATION NUMBERS - EXTRACT

	Item	Code	Example
1.	Low Lift Pump	P-LL	Low lift pump No.1 at Galle - GAL-P-LL
2.	Motor Driving above pump	M-LL	GAL-M-LL-1
3.	High Lift Pump	P-HL	High lift pump No.1 at Anuradhapura ANR-P-HL-1
4.	Motor Driving above pump	M-HL	ANR-M-HL-1
5.	Filter Backwash Pump	P-BW	Backwash Pump No.1 at Matara MAT-P-BW-1
6.	Motor Driving above pump	M-BW	MAT-M-BW-1
7.	Motor Starter	M(ST)	Motor Starter for Backwash Pump No.2 at Galle - GAL-M(ST)-BW-2
8.	Alum Dosing Pump	P-AL	Alum Dosing pump No.1 at Matara MAT-P-AL-1
9.	Motor for Alum Dosing Pump	M-AL	Motor for the above pump - MAT-M-AL-1
10.	Alum Mix Tank Stirrer Motor	M-AL-(STR)	Alum tank stirrer motor for tank connected to alum pump No.2 at Matara. MAT-M-AL(STR)-2
11.	Ferric Chloride Dosing Pump.	P-FC	Ferric Chloride dosing pump No.2 at Galle - GAL-P-FC-2.
12.	Motor for Ferric Chloride Dosing Pump	M-FC	Motor for above pump - GAL-M-FC-2
13.	Ferric Chloride Mix Tank Stirrer Motor	M-FC(STR)	Ferric Chloride stirrer motor for tank connected to Ferric Chloride Pump No.1 GAL-M-FC(STR)-1
14.	Lime Dosing Pump	P-L	Lime Dosing Pump No.1 at Matara MAT-P-L-1
15.	Motor for Lime Dosing Pump	M-L	Motor for the above pump - MAT-M-L-1
16.	Lime Mix Tank Stirrer Motor	M-L(STR)	Lime tank stirrer motor for tank connected to Lime Pump No.1 at Matara MAT-M-L(STR)-1
17.	Filter Air Scour Blowers	BL	Blower No.1 at Galle - GAL-BL-1
18.	Blower Motors	M-BL	Motor for above Blower - GAL-M-BL-1
19.	Air Compressors	C	Air Compressor No.1 for Surge Tank at Galle Plant - GAL-C-1

Such ID numbers are less important on distribution hardware. There would be little point in numbering pipes in the ground. However, sections or branches of distribution networks could be assigned ID numbers. Also, large valves and certainly water meters should be part of an ID number scheme, as covered later. See Appendix K for examples of distribution system maps.

4.3 Equipment History Files

Equipment history files are intended to store information on the electro-mechanical hardware itself, on the maintenance requirements and procedures, and on the actual maintenance performed. These files become an important resource in planning, scheduling, and performing both preventive and corrective maintenance work. Such files should be developed as a water system is being commissioned or at the end of an inventory of existing equipment.

The discussion below is mostly concerned with to plant equipment, such as motors, water pumps, dosing pumps, and other electromechanical equipment. For water distribution equipment, another type of record will be needed, including system maps, which is discussed in Section 4.4.

4.3.1 File Contents

The basic contents of equipment history files are listed below:

- Equipment data sheet (see figures 15 and 16 and text below)
- Manuals: assembly, operation, parts list (or location of manuals)
- Operational procedures
- Copies of operator's log sheets, if any
- List of spare parts stocked, and location
- PM tasks and schedule
- PM task instructions
- CM task instructions, if any
- Log of PM and CM work done (see maintenance log below)
- Completed PM work orders
- Completed CM work orders.

Detailed descriptions on some of these records items are given below.

Some sample equipment data sheets, operators logs, and other record sheets from rural water project maintenance organizations in Botswana are shown in Appendix L.

Figure 15

Sample Equipment Data Sheet - Pumps

EQUIPMENT DATA SHEET — PUMPS — DATE COMPLETED _____

IDENTITY

NAME: _____

ID #: _____

MODEL NAME _____

MODEL NO. _____

SERIAL NO. _____

LOCATION

REGION _____

SYSTEM _____

PLANT _____

INSTALLATION DATE _____

PREVIOUS LOCATION _____

SPECIFICATIONS

PUMP TYPE _____

STAGES _____

IMPELLER DIAMETER _____

RATED RPM _____

RATED CAPACITY _____

STATIC HEAD _____

EST. TOTAL HEAD _____

INLET DIAMETER _____

OUTLET DIAMETER _____

DRIVER:

NAME _____

ID NO. _____

AQUISITION

DATE PURCHASED _____

P.O. NUMBER _____

FOB COST _____

MANUFACTURER _____

_____

LOCAL SUPPLIER _____

_____

LOCAL SERVICE _____

_____

PARTS STOCKED LOCATION _____

NAME	PART NO.

PM REQUIREMENTS:

TASK	FREQ

Figure 16

Sample Equipment Data Sheet - Motors

EQUIPMENT DATA SHEET — ELECTRIC MOTORS — DATE COMPLETED _____

IDENTITY

NAME: _____

ID #: _____

MODEL NAME _____

MODEL NO. _____

SERIAL NO. _____

LOCATION

REGION _____

SYSTEM _____

PLANT _____

INSTALLATION DATE _____

PREVIOUS LOCATION _____

SPECIFICATIONS

MOTOR TYPE _____

HORSEPOWER _____

PHASES _____

VOLTS _____

AMPS _____

HZ _____

RPM _____

POWER SOURCE _____

DRIVEN UNIT:
NAME _____
ID NO. _____

AQUISITION

DATE PURCHASED _____

P.O. NUMBER _____

FOB COST _____

MANUFACTURER _____

LOCAL SUPPLIER _____

LOCAL SERVICE _____

PARTS STOCKED LOCATION _____

NAME	PART NO.

PM REQUIREMENTS:

TASK	FREQ

4.3.2 Equipment Data Sheets

At the front of the file there should be a summary equipment data sheet listing key information. Different types of data sheets will be useful for different types of equipment, as shown in Figures 15 and 16. Generally, an equipment data sheet for plant equipment such as pumps, motors, and agitators, should include the following items:

- Location: region, system, plant, date of installation at current location, previous locations
- Equipment identity: name, ID number, manufacturer, model name, model number, serial number
- Technical specifications: varies depending on type of equipment
- Acquisition data: date purchased, purchase order number, FOB cost, freight, installation
- Manufacturer name and address
- Local supplier name and address
- Local service agent, if any, with name and address
- Associated equipment ID numbers: for example, ID number of motor associated with a given pump
- Other information as space allows: maintenance tasks and timing, spare parts stocked.

4.3.3 Maintenance Log

A simple log should be kept of all maintenance performed. It should consist of a simple sheet with seven columns for entering information, including:

- Work order number
- Date issued
- Brief summary of work performed (PM and CM)
- Person or crew performing work
- Manhours
- Date completed
- Cost.

4.4 Records for Distribution Network Hardware

The above discussion is oriented toward plant equipment, such as motors and pumps. Instead of equipment history files, a similar set of distribution records should be developed for storing configuration data and records on work

performed. These files should contain maps of distribution hardware, a simple log of maintenance work performed, and completed work orders.

Distribution system configuration data should be stored in the form of maps. Detailed maps will be extremely useful in executing line repairs, fixing or detecting leaks, and in doing other distribution system maintenance. Large distribution networks can be broken down into sections, to make the files a manageable size and the maps legible. A detailed discussion of map requirements and configuration is beyond the scope of this manual, but generally, area maps using a scale of 5000:1 and more detailed maps using a scale of 1000:1 will be useful. Such maps should note location and size of mains, service lines, valves, and meters. As changes are made, clear notations should be added to the file. Periodically, as changes accumulate, new drawings should be made. Appendix J shows sample maps for distribution systems for urban water systems in the United States and a sample map for small rural systems in Botswana.

The distribution records, like equipment history files, should contain a log of preventive and corrective maintenance work done, drawings of changes made, and the actual completed work orders for that area or section.

It is also worth keeping careful records on water meters. Meters will occasionally have to be repaired and checked for accuracy. A simple meter log can be maintained on every meter, as shown in Figure 17. All meters can be issued a simple numerical ID number or a code including size and a sequential number. When installed, the address and account number should be noted. If a repair is needed the meter will be removed, repaired, and retested. If operating within desired limits it can be reinstalled elsewhere. In addition, meters should be rotated out and retested every 5 to 10 years. The logs will help track these operations. The cards should be kept in their own file, ranked by ID number.

4.5 Filing Systems

Equipment history files or distribution records can be organized several different ways. In the case of a regional office maintaining many small handpumps, organizing records into "site files" with a separate folder or file box for each location makes obvious sense.

For slightly more complex rural water systems, such as systems with wells, diesel engine/pumps and several kilometers of distribution, site files will also make sense. But these files may have to be subdivided to keep file size practical. Such division would probably be on the basis of function. For a simple water system with a well, submersible pump, an elevated storage tank, a distribution network with 5 km of piping, 100 house connections and 5 standposts, the records could be set up with one file for the well, pump, and tank, and another for the entire distribution network.

Figure 17

Meter Installation Repair and Testing Forms

METER CARD

MFG. _____ SIZE _____ ID NO. _____

MAKE _____ COST _____ MATERIAL _____

INSTALLATION RECORD

INSTALLED		ADDRESS	ACCOUNT NO.	REMOVED		REASONS FOR REMOVAL
DATE	READING			DATE	READING	

METER CARD (BACK SIDE)

MFG. _____ SIZE _____ ID NO. _____

TEST AND REPAIR RECORD

DATE	AMT. WATER PASSED BEFORE TEST	TEST AMOUNT	TEST READING	% ERROR	REPAIRS MADE	REMARKS

If site files are developed, equipment data sheets can be developed to summarize information on equipment at each site. Appendix L shows several system equipment data sheets from Botswana that were developed for small rural water systems. These sheets store basic information on all equipment at each site, in a standardized format.

On the other hand, if the organization is just maintaining equipment in one location (a single municipal water treatment plant, for example), then filing by equipment type (motor, pump, valve, etc.) or process function will make sense. Filing by ID number is also a possibility, but this may make records harder to find as people usually do not think in terms of ID numbers, but they do think in terms of locations, equipment types, or functions.

Equipment files are closely linked to the work order process because all completed work orders will be stored in these folders. Thus these records should be housed with the responsible maintenance manager or clerk. As maintenance work orders are completed, they should be filed in the equipment history file for that piece of equipment, distribution section, or water scheme, and the completion of the work should be noted in the file log.

If maintenance at a moderate-sized rural water scheme is performed primarily by local personnel and occasionally by regional personnel, equipment recordkeeping should be well coordinated. In general, it will be best to house the physical files at the local level. This is especially true if local staff are doing most of the work on the system. Local storage will allow easiest access to reference data needed during maintenance work. Regional personnel would probably like to make use of the data stored in these files, as well, to conduct studies of breakdown frequency and other analyses described below.

4.6 Establishing Equipment Records

The basic steps in establishing records will be to develop a list of all equipment to be maintained, note down all specification data, assign ID numbers, and then develop the equipment history files.

The very first step is to develop a complete list of all hardware, with relevant technical details. Obviously this could be a very burdensome task. However, as a new water system is being designed and constructed, engineering drawings of pumping stations, pipelines, and distribution networks should be available. The final as-built drawings will help immensely in establishing this inventory. However, there will be many cases in which no up-to-date, reliable drawings exist, so a lengthy inventory process must be undertaken. Simple inventory forms will have to be developed and completed, site by site, location by location.

As each piece of equipment is inventoried, the equipment data sheet can be completed and equipment ID numbers can be assigned. It would be impractical to try to do a detailed codification on existing distribution equipment that is inaccessible, but a listing of the lengths and diameters of the main piping would be useful. An exemplary set of inventory sheets from Sri Lanka is shown in Appendix I.

Once the raw data have been collected, useful equipment lists can be prepared. For example, a list of all equipment at a given rural scheme can be prepared and filed. Similarly, a list of all submersible pumps, or all alum dosing pumps, at a number of water schemes in a given region can be complied. These lists will be quite useful in planning work and also in analyzing equipment performance. Appendix I also shows a set of inventory summary sheets that outline equipment in three sections of a single water scheme--head works and storage, gravity/pumping main, and distribution system.

If no distribution network drawings exist, they should probably be developed. This process can be done in stages. A preliminary schematic can be drawn by the technicians conducting the distribution inventory. Additional configuration details can be collected as maintenance work is conducted and piping replacements are made. Later, once the burden of work lightens a bit, new drawings can be prepared and filed for future use.

During the equipment inventory process, notes can also be made as to the operational status of the various system components. That is, if a particular pump is badly in need of service or a water line obviously is leaking, these problems can be noted and corrective action requested using a work request, as outlined in Chapter 3.

4.7 Using Equipment Records

The equipment history files and distribution records will be an important archive of reference material for all aspects of maintenance. Some examples follow.

Planning Repair Work. When a clerk or manager is preparing work orders, details on the equipment involved will be very useful. A crew foreman, beginning a repair he has never executed, will find data on the equipment, manuals, and a record of recent work on the machinery to be highly instructive. A quick check of specification data will help ensure that the right spare parts are brought to the job site. Of course, information on distribution network details will be indispensable in water line repairs.

Developing Job Standards. Records on maintenance performed will be very useful for establishing job standards for particular tasks. Historical records on the time, labor, and materials for common preventive and corrective maintenance tasks can be used to create these performance standards. Historical information should not be the only guide, however, as past performance may be consistently poor. Still, the records will be useful in developing these measures.

Planning Staffing. The incidence of particular tasks and the volume of different types of work can be useful in determining the number and type of staff needed. For instance an examination of rural water system repairs would be helpful in deciding how many mechanics and how many electricians should be retained.

Planning Materials Inventory. Equipment history files and distribution records will be very useful in planning what parts and supplies should be stocked in a storeroom. These records can indicate which parts are used frequently and which are not and allow calculation of monthly usage of commonly used supplies (see Chapter 5).

Analyzing Equipment Maintenance Costs. Work orders will show total values for labor, material, and other costs for a job. These data can be assembled into historical cost summaries, which will be useful for budgeting and planning future equipment selection. Annual cost totals for each individual equipment item or group of equipment could be prepared. Trends can be plotted graphically. A particular piece of equipment that is getting more and more expensive to maintain can also be considered for replacement. The evolution of costs with equipment age can be examined. A particular line of pumps or motors can be evaluated against others.

Analyzing Equipment Performance. The use of work orders and the storage of data in equipment history files allows useful analyses to be made of the performance of a particular piece of equipment or a group or type of equipment. These analyses can pinpoint equipment that is operating poorly and allow corrective action to be taken before major problems develop. Also, these data can be used in future water system designs and in considering equipment replacement.

Usually such analyses would be conducted by national- or regional-level personnel, based on data stored at the regional or local level and on reports from those administrative levels.

These analyses can be conducted in two basic ways:

- Performance of a particular piece of equipment as compared with the "norm" for that particular type of equipment; for example, the performance of a submersible Grundfos SP 4-42 motor/pump set at Rural Water Scheme #123 compared with other SP 4 pumps in other schemes.

- Performance of a single type of equipment compared with other types; for example, the performance of Grundfos pumps as contrasted with other brands, or the performance of submersible pumps compared with vertical axis turbine pumps.

The "breakdown rate" is a common type of analysis that can be made. The breakdown rate is simply the annual incidence of a service outage of a particular piece of equipment. Such an event will usually result in a work request and a corrective maintenance work order. It will be important to look at the frequency of breakdowns by type of problem or by cause. For example it would be useful to know the percentage of breakdowns on submersible pumps that are due to motor problems, controller problems, low water level, well contamination, or other causes. Also, interesting trends can be revealed, such as the breakdown rate as a function of equipment age, utilization rate, region, number of PM work activities conducted, distance from a regional maintenance

center, etc. Breakdown studies on distribution equipment will also be useful. Analysis of the breaks per kilometer of line for each size and type if pipe material will provide useful statistics.

Another commonly used statistic is the "mean time between failure (MTBF)," which is simply the inverse of the breakdown rate. That is, it is the average period of time between failures. It is usually computed for a model or group of equipment rather than on a single piece of hardware.

"Availability" is another useful measure for plant equipment or even entire systems. The availability of a piece of equipment is the percentage of the time the unit is available for operation. It can be calculated as:

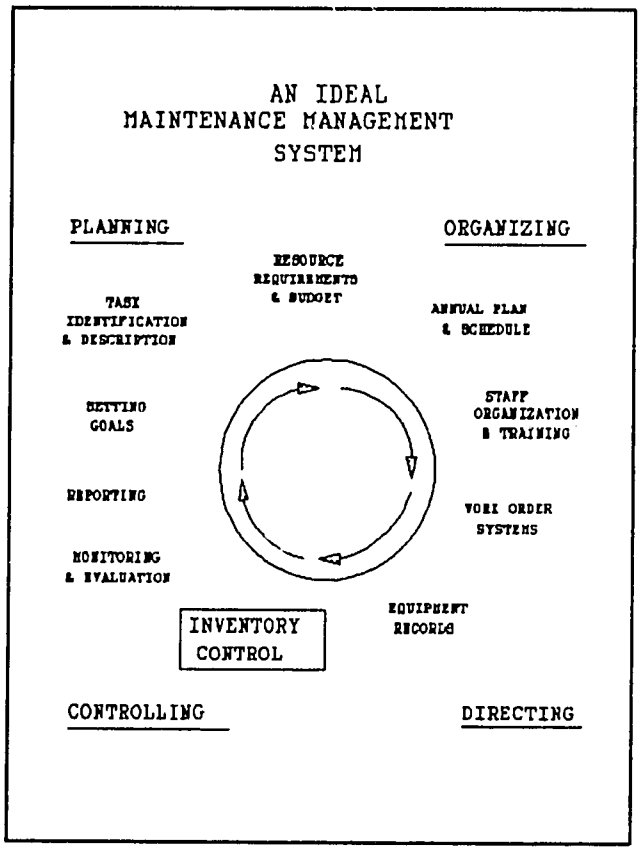
$$\text{Availability} = \frac{\text{(total time) - (equipment downtime due to PM or CM)}}{\text{(Total time)}}$$

Note that this figure does not indicate how frequently the equipment was actually used, but what time period it could have been used. Availability is linked to the breakdown rate, but it is not the same. That is, a high breakdown rate will lead to low availability because considerable time will be spent with the equipment down for maintenance. However, even with a high breakdown rate, the availability can be relatively high if the duration of the breakdown is low.

5

MATERIALS INVENTORY CONTROL

5.1 Purpose/Overview



The purpose of materials inventory control is to ensure that necessary items are readily available when needed. Without good controls, the storekeeper will not know how many of a given item are in stock or when or what to order, and items will be out of stock when they are needed. Lack of controls makes a storeroom more vulnerable to loss or theft. A maintenance department cannot allow lengthy downtimes on equipment due to out-of-stock parts. Important maintenance should not wait on certain supplies to arrive. It would be easy to stock a big quantity of every conceivably useful part or supply, but this would be very expensive. A stock of commonly used and critical materials, with controls, is the best approach.

This chapter reviews control procedures and associated forms, including requisition and credit forms, ledger cards, travel order cards, and inventory reports. Guidelines on establishing and using these procedures are also given.

5.2 Inventory Control Procedures and Forms

5.2.1 Materials Ledger

The materials ledger is the heart of the materials inventory control system. There is usually a two-part form for each material item, with spaces for the following information:

Basic information on the particular item:

- Folio number
- Name of the part or supply
- Part number and manufacturer, if the item is a spare part
- Specification and size, if the item is a general supply
- Specific equipment or system using this part, if relevant
- Bin number or storage location
- Reorder point
- Reorder quantity.

Ledger: A line for each transaction with columns for the following:

- Date
- Material requisition or material credit number
- Quantity
- Unit cost
- Quantity on hand (balance).

The following forms, log, and files are also part of the inventory control system:

Forms

For each transaction

- Materials requisition
- Materials credit

For each material item

- Ledger card
- Traveling order card

Logs

- Order log

Files

Historical

- Materials requisition file
- Materials credit file

Permanent

- Ledger card/traveling order card

A sample ledger form for parts is shown in Figure 18. Appendix A includes this form and a similar one for supplies.

The physical form of the ledger cards and their storage will vary with the size of the stores. Paper cards can be stored in a box, file drawer or vertical file cabinet. Ledgers can also be written in a notebook with different pages for different parts. The type of physical arrangement will depend on the number of different parts stocked and the volume of parts used. A small store with relatively few parts could get by with a simple notebook or card box, but a large store will need a more sophisticated system. Very large stores will need a computer-based system.

In some organizations, storekeepers prefer to keep the ledger cards on the shelf or in the bin with the particular item. This has the advantage of quick and easy ledger entry when the part is taken out of stock. Also, the storekeeper can quickly check the ledger quantity-on-hand against the actual number in stock. However, this approach has the disadvantage that ledger cards are dispersed around the stores. Overall, a central location for all the ledger cards makes the most sense.

There are occasions when a ledger system can be burdensome. Small, inexpensive components that are used very frequently may not be worth tracking in such detail. The cost of these parts can be seen as a general expense and spread over all maintenance work.

The ledger should be maintained by the storekeeper only, to ensure accuracy. The storekeeper will make ledger entries when materials are issued, based on requisitions submitted. When materials are received, similar data entries must be made. Note that the form allows for continual updating of the unit cost to ensure accounting accuracy. When a quarterly or annual stock verification is made, corrections can be noted on the ledger. When a ledger card is full, the descriptive information at the top of the form and the quantity-on-hand are transferred to a new card.

5.2.2 Materials Requisitions/Credits

Materials requisitions and credits are used to control the movement of materials in and out of stores. Requisitions are used when materials are issued, and credits when materials arrive. Forms used for the two purposes are quite similar. Information to be completed on these forms include:

- Requisition/credit number (sequentially numbered)
- Date
- Name of part or supply, or brief description

Figure 18

Parts Ledger

INVENTORY LEDGER - PARTS

STORE NAME _____

PART NAME _____ FOLIO # _____

PART NUMBER _____ REORDER POINT _____

HOST MACHINE _____ REORDER QUANTITY _____

BIN NUMBER _____ CARRYOVER STOCK

DATE	RECEIVED			ISSUED			BALANCE
	CREDIT NO.	QTY	UNIT COST	REQUIS. NO.	QTY	UNIT COST	

- Part number or specification
- Quantity received or to be issued
- Issuing individual
- Receiving individual
- Approval, for the case of requisitions
- Work order number, for the case of requisitions
- Purchase order number, for the case of credits
- Account number or charge code
- Unit cost
- Total cost.

A sample requisition form is shown in Figure 19, and a sample credit form in Figure 20. Generally, these forms should be completed in duplicate, one for the person receiving or depositing materials, and one for a historical stores file.

These forms can also be used for other occasions when materials go in or out of stores. For example, the materials credit form can be used to control items going into stores, such as the arrival of parts from suppliers or other stores and unused materials being returned at the completion of the job. The requisitions can also be used to control the transfer of materials from one store to another, for example, from a central warehouse to a regional or satellite stores. Such special issues should be noted on the form.

Generally, a requisition is completed by a craftsman collecting material to complete a maintenance work order. He or she completes all the necessary information, except the unit and total cost, which are completed by the storekeeper, as the material is issued. The craftsman receiving the items should also note the materials received and cost on the work order. A credit is normally filled out by the storekeeper when materials arrive. Once a material requisition or credit is written, the storekeeper must immediately enter the information in the ledger for that material and update the quantity-on-hand. If the reorder point (the quantity at which more supplies are to be ordered, as described in Section 5.3.1) is reached, the storekeeper must order more material.

5.2.3 Traveling Order Cards/Order Log

The storekeeper must reorder materials at the correct times when the quantity-on-hand reaches the reorder point and keep a log of all order. This process can

Figure 19

Material Requisition Form

MATERIAL REQUISITION

No. _____

Date _____ Work Order No. _____

Location _____ Account No. _____

PART NO.	QTY	DESCRIPTION	UNIT COST	TOTAL

Issued by _____ Received by _____ Approved _____

Figure 20

Material Credit Form

MATERIAL CREDIT

No. _____

Date _____ Purchase Order _____

Location _____ Account No. _____

PART NO.	QTY	DESCRIPTION	UNIT COST	TOTAL

Issued by _____ Received by _____ Approved _____

be streamlined and simplified with the use of traveling order cards. These cards are simple forms, filed with the ledger card for the particular item, which contain the following items:

Basic Information (permanently written on card)

- Name or location of the stores
- Name of the part or supply
- Part number and manufacturer if the item is a spare part
- Specification and size if the item is a general supply
- Reorder point
- Reorder quantity
- Suppliers--a list of several local suppliers.

Order history ledger

- Date of Purchase Order (Completed by purchasing)
- Selected Supplier name (Completed by purchasing)
- Unit cost (Completed by purchasing)
- Quantity ordered (Completed by purchasing)
- Expected Date of delivery (Completed by purchasing)
- Quantity Received (Completed by storekeeper)
- Date delivered. (Completed by storekeeper)

A sample traveling order card is shown in Figure 21.

When it is time to reorder, the storekeeper pulls the card and sends it to the purchasing office, which contacts suppliers and orders the material. The date of the purchase order, supplier, quantity, unit cost and expected date of delivery are filled in by the purchasing office, and the form is sent back to the storekeeper. The storekeeper refiles the traveling order card, checking the unit cost, supplier, and delivery date. When the material actually arrives, a material credit form is completed, the ledger is updated, and the date and quantity received are entered on the traveling order card.

Once the reorder point is reached, use of that part or supply will have to be restricted. One approach would be to limit use of the part or supply to only those work orders with a high or critical priority. Thus if other crucial needs for the part arise, there will at least be some in stock. Obviously, the delay in actually receiving the ordered items will be important in managing the use of parts in short supply. Parts that take a long time to restock will have to be subject to more careful control. With experience and consistent demand and ordering times, the reorder point and reorder quantity can be fine tuned to the point that the stock is drawn down to almost zero as the next shipment arrives. Unfortunately, consistency of demand and supply are not always common, so the restrictions will have to be enforced.

The storekeeper must also maintain a simple Order Log of which traveling order cards have been sent to purchasing. The log would list the material name, date sent for ordering, and expected delivery date. Thus, the storekeeper can remind purchasing or suppliers if ordering or delivery is delayed.

Figure 21

Traveling Order Card Form

TRAVELING ORDER CARD

STORE NAME _____

Name _____ Folio # _____

Part No. or Spec _____ Reorder Point _____

Size _____ Reorder Qty _____

SUPPLIERS

1 _____ 4 _____

2 _____ 5 _____

3 _____ 6 _____

ORDER LEDGER

P.O. Date	Supplier	Unit Cost	Qty Ordered	Expect. Date of Delivery	Qty Recd	Date Delivered

The traveling order card system may have to be modified if the stores and purchasing office are located geographically far apart. For example, if a district maintenance store orders all supplies from a purchasing office in the national headquarters of a water authority, problems can result if order cards are lost or take a long time in transit. In such a case, a simple supply ordering form should be used with duplicate copies--one copy for the stores to retain and one copy to send in when placing the order.

5.2.4 Inventory Verification

On a regular basis, the materials inventory will have to be verified. The storekeeper will have to close the stores to all nonessential activity and check the ledger versus actual stock for each item. An entry into each ledger should be made, noting the actual stock. Ledger/stock discrepancies should be investigated and corrected. A team of supplemental labor can be assigned to complete the job in large stores. The frequency of inventory reports will be determined by the size of the stores, but the inventories should be made at least once a year.

As staff experience grows and store operations become streamlined, additional activities can take place at the time of the annual inventory check. Inventory reports can be prepared, including a list of quantity consumed and the quantity on hand for each material item. The reports should be kept on file, but a copy should also be submitted to the maintenance manager for review. The maintenance manager and the storekeeper can then review the activity for each item stocked. Items that are being used very infrequently can be reassessed for stocking. Also reorder points and quantities can be reassessed.

5.3 Establishing Inventory Controls

The procedures and forms described above should be rather straightforward to develop and implement. The forms can be modified to add extra features or eliminate some aspects to suit local conditions. The hard part with establishing and controlling a stock of materials will be deciding what parts to stock, the reorder points, and the reorder quantities. There are no simple rules for deciding these issues, and the best solution will probably be different in each case. Some basic guiding principles on these issues are reviewed below.

During the initial planning of a MMS, the existing stores must be assessed in relation to the equipment to be maintained. Once the equipment inventory is completed, and the preventive maintenance plan under way, parts and supply requirements will become known. The existing stock must be reviewed in light of this information. Some items probably will no longer be stocked and new ones will be added to the inventory. A team involving the maintenance manager, operators, maintenance crew leaders, and the storekeeper should examine the different types of equipment in use, make some estimates on the materials to stock, quantities, etc. This process should be performed regularly to fine tune it with experience.

5.3.1 Materials to Stock

The decision on what to stock is a balance between the cost of purchasing and storing the parts versus the cost of the downtime. Any parts whose absence will lead to long or otherwise significant downtimes will be worth stocking. Engines, motors, pumps or other equipment that perform critical functions or have no back-up system, will need a complement of parts. Manufacturers' guidelines will help in determining the parts to stock, but local experience will be an even better guide. Local availability of the part is another important factor. Imported equipment with no local representative will require special consideration. Frequency of use is important, too. Stocking commonly used parts will speed work and reduce costs. Also, if a local supplier stocks parts, the water utility should only stock parts it uses often.

Reorder Point

The reorder point can be found from the usage rate, the time from the start of the order process to actual delivery, and the desired minimum stock:

Reorder point = (usage rate x order period) + desired minimum stock

Example of Reorder Point

Suppose 4 oil filters for a particular type of engine are used in an average month, the average lead time for delivery is 2 months, and a minimum stock of 1 month's supply is desired. Then:

Reorder point = (4 x 2) + 4 = 12.

5.3.2 Reorder Quantity

The best reorder quantity will be influenced by the usage rate, quantity required for discounted prices, the cost of making orders, the cost of storing parts and supplies, and other factors. The team can calculate the "economic order quantity" (EOQ) for key parts, as described below. Economic order quantities are a theoretically optimal order quantity (in units or dollars) that correctly

balances the cost of carrying inventory against the cost of placing orders. The EOQ for a particular part or supply can be found as follows:

$$EOQ = \sqrt{(2 \times Q \times P) / (C \times I)}$$

where:

EOQ = economic order quantity, in units
Q = quantity of units consumed annually
P = administrative cost of issuing a purchase order
C = unit cost of the item
I = cost of carrying inventory in %, as a decimal (includes cost of capital, space, labor)

Example of Economic Order Quantities

Suppose 50 fuel filters are used in a year, costing $10 each. If the cost of preparing a purchase order is $30 and the inventory cost rate is 25%, the EOQ will be:

$$EOQ = \sqrt{(2 \times 50 \times 30) / (10 \times 0.25)}$$

= 35 units, or an order every 8 months or so.

Note that if the inventory cost rate falls to 10%, the EOQ is 55.

5.4 Using Inventory Controls

Once the inventory control system is established, it should flow quite smoothly, if several key practices are followed:

- Everyone must adhere to the system.

  Craftsmen, storekeepers, clerks, maintenance managers, and purchasing agents must all believe in the system and follow it. Otherwise it will break down rapidly and be of little use. A key management principle is to make it clear to the storekeeper that it is his or her responsibility to encourage others to abide by the system.

- Honesty is essential.

  The storekeeper plays a critical role; a reliable and trustworthy individual must be placed in this position. The potential for materials to "disappear" can be very high if an irresponsible individual is placed in this position. His or her accountability is important. The maintenance manager will have to decide what type of oversight is required.

- Keep the system up to date.

  The storekeeper and maintenance manager should conduct regular reviews of the inventory. At the occasion of the annual inventory report, the two individuals, perhaps in consultation with operators and maintenance crew foremen, should review which parts are stocked and quantities consumed for the most important parts and supplies. A graph of actual use and restocking can be made to illustrate the ebb and flow of the stock level of the part. The reorder points and reorder quantities can be adjusted if necessary.

- Diagnose problems to find improvements.

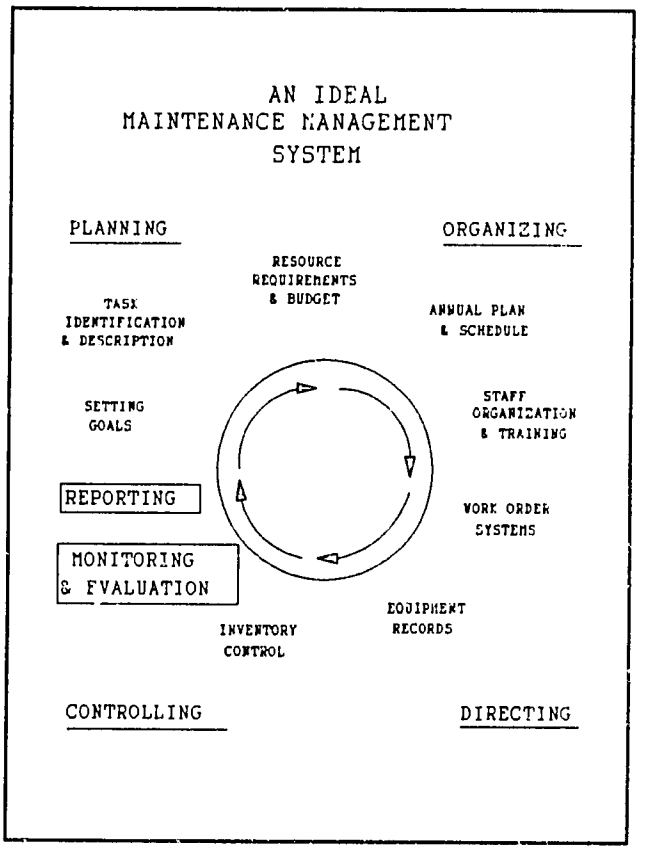
  Specific inventory control problems should be discussed and changes considered and implemented. Specific shortfall events, while troublesome, should be used as an occasion to reexamine the inventory controls on a given part or supply.

6

MONITORING, EVALUATING, AND REPORTING

6.1 Purpose/Overview

The purpose of monitoring and evaluating is to compare what has been done to what was planned, determine if there are deficiencies, and take corrective action if needed. The purpose of reporting is to inform management, engineering, government oversight agencies, funding agencies, and other interested parties as to the progress of maintenance activities and any needed changes in operating procedures or resource requirements. Forms and procedures used for monitoring and evaluating make up the core material for reports.



6.2 Monitoring and Evaluation

6.2.1 Monitoring Work Progress and Costs

A simple monthly work order summary sheet will be useful for monitoring and reporting. This form, shown in Figure 22, includes the following items:

- Maintenance office
- Month
- Number of work orders outstanding from previous month
- Number of work orders originated this month
- Number of work orders originated this month, but still outstanding
- Reason for incomplete work for each outstanding work order.

Figure 22

Sample Monthly Work Order Summary

MONTHLY WORK ORDER SUMMARY

MAINTENANCE OFFICE _____ MONTH _____

	PM	CM	TOTAL
No. of Work Orders outstanding from last month			
No. of Work Orders originating this month			
No. of Work Orders originating this month but not completed			

INCOMPLETE WORK ORDERS:

WORK ORDER NUMBER	DATE	REASON FOR DELAY	EXPECTED COMPLETION

The form should present the above data for both preventive and corrective maintenance. The form can be completed by a clerk from the work order log and given to the manager for review. This form will remind the manager of progress made and can be used to transfer this same information to other personnel in other offices. Depending on the volume of work and the organizational structure, reports may be made for each portion of a water system, each system, or an entire region.

A simple monthly cost summary sheet will be useful for monitoring and reporting on costs incurred in a given month, based on work orders completed in that month. A sample is shown in Figure 23.

The sum of the work order costs will not be the total accounting cost of the maintenance function, in that the salaries of the manager, clerk, and other administrative personnel will not be included, nor will the cost of idle labor hours be included. A cost center type of accounting procedure, based in the accounting department not the maintenance department, will be needed to arrive at such a cost. Still, the sum of work order costs (labor, parts and supplies, and other direct costs) will provide to a worthwhile indication of direct maintenance costs.

Both of these summary formats can also be used on quarterly and annual bases. In addition, as capabilities and experience increase, more parameters can be monitored and evaluated. Additional data can also be developed and presented in a work summary to provide more in-depth details. For example, tracking manhours spent executing work orders and manhours idle will give an indication of staff utilization. The following data can be tabulated from work orders and presented:

- Total labor manhours
- Total manhours on work orders/total labor manhours
- Total overtime manhours/total manhours on work orders
- Manhours on PM and CM work orders and resulting percentage
- Manhours or work orders devoted to work on pumping plant, treatment plant, or distribution system
- Percentage of work orders completed on time
- Number of system breakdowns per month
- Average response time on repairs.

These and other performance measures are discussed in detail in Section 6.3.

Figure 23

Sample Monthly Cost Summary

MONTHLY COST SUMMARY

MAINTENANCE OFFICE _____ MONTH _____

	PM	CM	TOTAL
Number of Work Orders Completed:			
Total Labor Cost: Total Material Cost: Total Other Cost:			
TOTAL COST:			
Average Cost Per Work Order:			

OTHER COMMENTS:

6.2.2 Graphic Techniques for Monitoring and Evaluation

Graphic techniques can be used to examine trends in these indicators and evaluate results. For instance, a line graph showing work orders executed and work orders outstanding in each month over a year will give a good picture of the volume of work and whether the management system and labor force are able to keep up with this volume of work. See two contrasting exemplary cases as shown in Figure 24. Such a graph could be made for both preventive and corrective maintenance.

Another useful graphic would be a plot of Preventive and corrective maintenance work orders, manhours, or costs over time, for a given region or a water system, as shown in Figure 25. It is not uncommon that before a full-scale preventive program is implemented, corrective maintenance will take up about three times the labor input as preventive. It is expected that the adoption of preventive will, after some delay, lead to a decline in corrective maintenance activity. Hopefully breakdowns will become less frequent as preventive efforts begin to bear fruit. The long- term goal will be to reverse the above trend, so that labor is spending 3 times as much effort on PM as CM.

6.3 Performance Measures

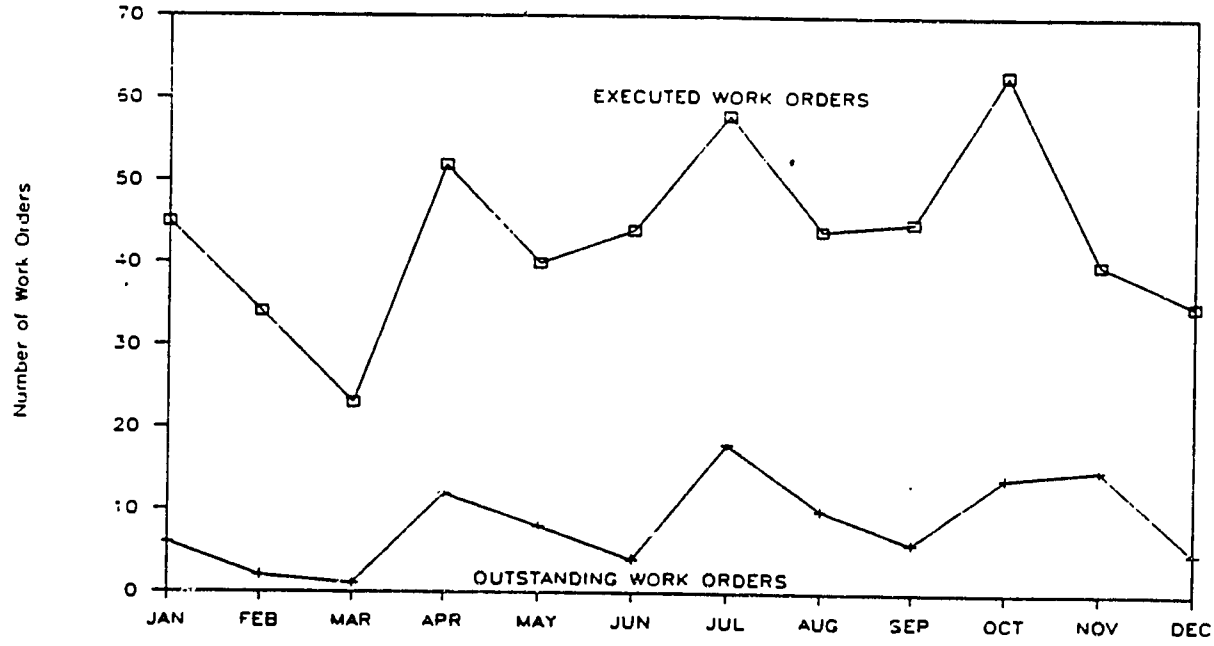
A powerful approach to performance evaluation is the use of performance measures. These ratios are simple, "easy to grasp" indicators that allow current performance to be compared with a target or goal. A good example is the ratio of labor hours on corrective work to labor hours on preventive work. The value of this ratio, before a good MMS is implemented, might show about three times as much effort on corrective work as contrasted with preventive work. However, the target under good management should be the reverse--for more preventive than corrective work.

If the planning and scheduling capabilities and work order system are developed to the point that figures for planned (or standard) and actual manhours and costs are recorded, then detailed monitoring and reporting on work performance can be made. Tabulations of planned and actual values for work quantity, manhours and costs can be determined and variances shown. Also, labor or cash expenditure against budget can be determined. Figure 26 shows such a detailed report from Sri Lanka.

The type of monitoring discussed above can be applied to analyzing performance on a particular task, that is regularly performed, such as many PM functions. Also, analyses on individual systems or types of equipment can also be conducted. Analyses of technical performance (such as the breakdown rate) and development of cost histories can be performed. Both of these are discussed in Chapter 4.

Figure 24

Work Order Monitoring



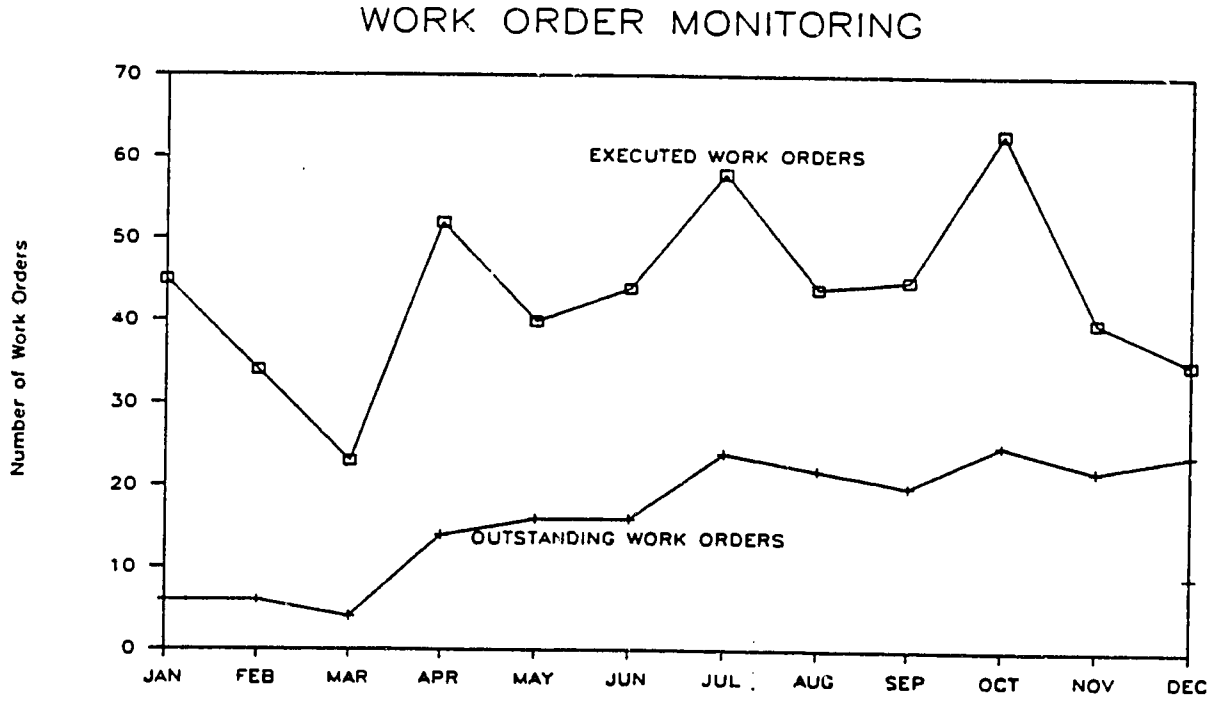
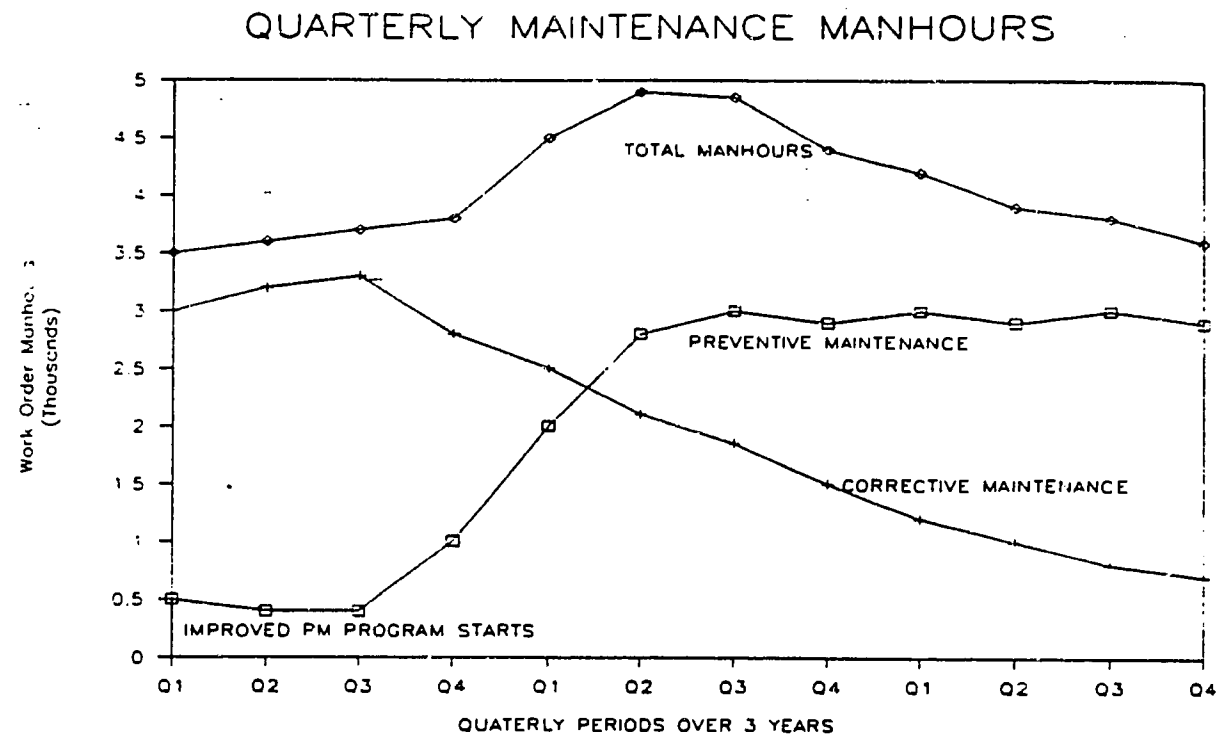


Figure 25

Quarterly Manhours Maintenance/Costs



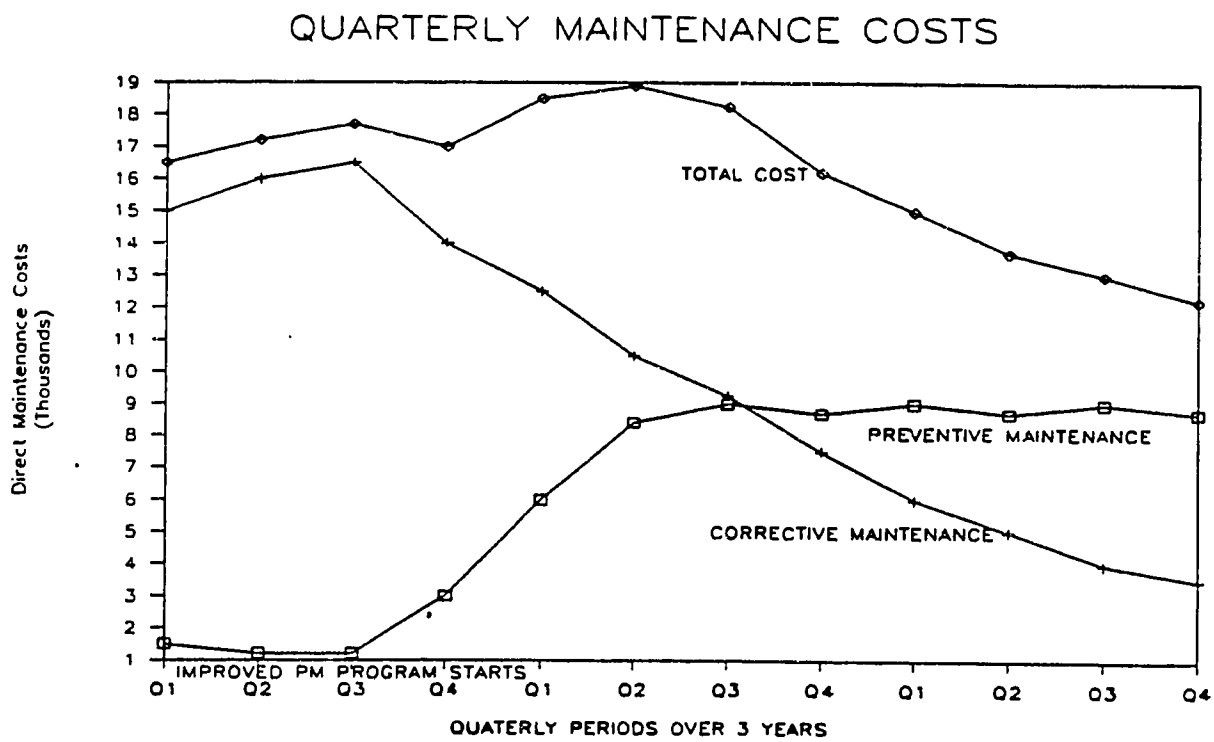


Figure 26

Monthly Performance Summary

AUTHORITY

MONTHLY PERFORMANCE SUMMARY

Form No 18/W

PERIOD FROM JAN: 1 TO JU

CODE	WORK ACTIVITY DESCRIPTION	WORK UNIT	WORK QUANTITY (Q) Annual program	To Date	% Program Comp. (Q÷Q)	% Program Pl'd	MAN DAYS Annual Program	To Date	% Program Comp. ($÷$)	% Program Pl'd	COST RS This Month	COST RS To Date	UNIT COST TO DATE (11÷5)	PRODUCTIVITY Q÷ Man days Std	PRODUCTIVITY Q÷ Man days Actual
22/W	Clean intake externally	No. of intake	720	355	49	50	720	355	49	50	3000.00	17750.00	50.00	1	1
23/W	Clean intake adjacent area	no. of intake	24	12	50	50	192	96	50	50	800.00	4800.00	400.00	0.13	0.13
21/W	Check and tighten gland pack	No.ofpumps	1440	720	50	50	192	96	50	50	800.00	4800.00	6.67	7.5	7.5
22/W	Grease pump bearings	No.of pumps	16	8	50	50	8	4	50	50	-	200.00	25.00	2	2
23/W	Clean pump suction strainer	No.of pumps	720				120								
24/W	Clean pump suction and gland feeder lines	No.of pumps	16				6				AND	CONTINUE	COMPLETIN	G	
25/W	Record pressure gauge readings	No.of pumps	1440				72				THIS	FOR	TO FILL	EVERY	
29/W	Grease motor bearings	No.of meters	16				8				ACTIVITY				
31/W	Exercise valves	No.of valves	48				4								
41/W	Service air valves of pumping main	No.of valves	22	10	45	47	15	6	40	47					
42/W	Open washout of pumping main	No.of valves	24				16								
43/W	Check leaks of p. main	km	852.8				171								
62/W	Open manholes of distribution	No.of valves	15				10				THIS	FORM	TO BE	COMPLETED	
63/W	Check leaks of distribution	km	871.2				174				MONTHLY	AND	AT THE	END OF	
64/W	Check and test water meters	No.of meters	2				1				EACH	QUATER	YEAR.		
71/W	Other maintenance										A COPY	SHOULD	BE SENT	TO	
											UPU	FOR	THE ATTENTION	OF	
											THE	ENGINEERING	(O&M)		
											SECTION.				

The extent to which these different monitoring and evaluation options are used will depend on the local conditions. A given agency should start out with a simple monitoring program, perhaps just monitoring basic work order progress and basic costs, as shown in the monthly work order summary and the monthly cost summary. As staff skills improve and data accumulate, more elaborate monitoring can be phased in. The essential point is not to get overburdened with paperwork, so as to sacrifice work efficiency.

A number of ratios and other calculated parameters to indicate work and cost performance were described above. A full list of these and additional performance measures are summarized in Figure 27, for easy reference. These measures can be useful in monitoring and evaluating performance and in reporting. They can be used by local, regional or central personnel to perform quick evaluations and easy comparisons between different water systems, different regions, etc. Maintenance managers can use them to grade performance, identify weak spots, and focus improvement efforts. These results can be communicated to top management and form the basis for maintenance planning efforts.

The use of performance measures is an evolutionary process. Candidate measures must be proposed, such as those summarized in Figure 27. In a pilot effort, raw input data should be collected and values calculated for these preliminary measures. Then, the usefulness of the proposed measures should be evaluated and any new measures identified. Finally a wider, more formalized data collection and performance measurement program should be adopted.

6.4 Reporting

The purpose of reporting on maintenance is twofold:

- To inform management, engineering, oversight agencies, funding agencies, and other interested parties on the progress of maintenance
- To explain needed changes in goals, procedures, lines of authority, responsibility and control, and available material and human resources.

More specifically, reports should include information on activities conducted, results obtained, performance attained, costs incurred, problems encountered, solutions found, assistance needed. Progress toward overall maintenance program goals should also be briefly reviewed.

Figure 27

PERFORMANCE MEASURES FOR WATER SYSTEM MAINTENANCE MANAGEMENT

LABOR FORCE

Population served/Maintenance employee
Water connections/Maintenance employee
Cubic meters per day delivered/Maintenance employee
Kilometers of distribution piping/Maintenance employee
Maintenance workers/Supervisor

WORK LOAD

Total number of work orders per month per water system
Number of work orders/Water connection (or per capita)
Number of work orders/Cubic meters per day
Number of work orders/Kilometers of distribution piping
Number of days without water service/Total days (for different systems)
Work requests by operations/Total work requests
Work requests by maintenance/Total work requests

TYPE OF WORK

CM work orders/Total work orders
PM work orders/Total work orders
Emergency work orders/Total work orders
CM manhours/Total manhours
PM manhours/Total manhours
Emergency manhours/Total manhours
Intake and pumping plant maintenance work orders/Total work orders
Treatment plant maintenance work orders/Total work orders
Distribution Maintenance work orders/Total work orders

WORK PERFORMANCE

Uncompleted work orders/total work orders (at end of month)
Work orders completed on schedule/Total work orders
Number of work orders delayed by out-of-stock parts/Total work orders
Number of work orders delayed by transport problems/Total work orders
Number of work orders delayed by work backlog/Total work orders
Number of work orders delayed by other problems/Total work orders
Work orders completed +/- 15% of estimated cost/Total work orders
Total manhours on work orders/Total manhours
Overtime manhours/Total manhours
Standard manhours/Total manhours
Actual labor hours/Planned hours (for different people/crews)
Actual labor hours/Planned hours (for typical tasks)
Average CM response time (work request receipt to CM work start-up)

COST DISTRIBUTION

PM cost/Total maintenance costs
CM cost/Total maintenance costs
Material costs/Total
Labor costs/Total
Other costs/Total

COST LEVEL

Average work order cost
Direct maintenance cost/Water connection
Direct maintenance cost/Cubic meter of water
Material costs/Kilometers of distribution piping
Labor cost/Manhour

The results of monitoring and evaluation efforts should be conveyed in the form of brief reports. One should avoid a lot of burdensome paperwork, but it is important to inform others so they can render assistance, and remain involved and supportive of resources expended on maintenance. In addition such reports will be quite useful to those doing engineering design and financial planning of new water systems.

A variety of different reports should be issued by different levels of the maintenance system at different times of the year. Generally, the lower the administrative level, the more frequent and less elaborate the reports. It is difficult, and probably unwise, in a general set of guidelines like this, to give any precise prescription. Reporting formats must be tailored to local conditions. Nonetheless, some exemplary guidelines are given below. Let us take the example of a number of fairly autonomous, moderate-sized town water schemes, each with its own small maintenance office. Let us assume that above this level, regional and national water authority offices exist. It would be common for the operators of the town water schemes to submit monthly work order summaries and monthly cost reports to the regional oversight/support office. Simple summaries, such as those in Figures 23 and 24, would do. The regional office, in turn, would submit quarterly (or annual) reports to the central maintenance office. These less frequent reports would summarize the monthly reports from all systems under it, but also provide some performance and cost analysis, using performance measures mentioned above. Special problems, trends, needs or requirements would also be conveyed. The central maintenance office would probably also provide a quarterly (or annual) report to upper management, engineering, and outside parties.

It will be highly useful for the reporting format to be uniform, and flexible. That is all town schemes should report in the same way, and all regional reports should provide the same data. Such uniformity allows cross comparisons, which will be useful to regional and central office, but also will allow town schemes to "grade" themselves against their peers. While uniformity is good, rigidity is not. It should be stressed that the reporting process should by no means be static. New performance measures should be added as the maintenance system grows in strength and sophistication.

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APPENDIX A

Sample Forms

TASK DESCRIPTION SHEET

TASK NUMBER _____

TASK NAME: _____

EQUIPMENT NAME: _____

MODEL OR SPECIFICATION: _____

FREQUENCY: _____

ADDITIONAL REFERENCES: _____

PROCEDURES:

SAFETY PRECAUTIONS:

REQUIREMENTS: PARTS, TOOLS, EQUIPMENT, SKILL LEVEL

AVERAGE COMPLETION TIME: _____

AVERAGE LABOR HOURS: _____

WORK REQUEST FORM (FRONT SIDE) PRIORITY _____

REQUESTOR _____ DATE AND TIME _____

WATER SCHEME NAME AND LOCATION _____ _____

SPECIFIC EQUIPMENT NEEDING ATTENTION - NAME: _____

EXACT LOCATION _____ ID# _____

MALFUNCTION OBSERVED _____

DATE, TIME, PERSON OBSERVING _____

EXPECTED CAUSE OF PROBLEM _____

_____

ACTION ALREADY TAKEN _____

ANTICIPATED WORK TO BE DONE _____

SPECIAL INSTRUCTIONS _____

WORK REQUEST FORM (BACK SIDE) PRIORITY _____

ADDITIONAL INSTRUCTIONS, COMMENTS, AND SKETCHES

MAINTENANCE WORK ORDER | TYPE: PM CM | WORK ORDER NO. _____

DATE _____ ORIGINATOR _____ PRIORITY _____

PERSON TO CONDUCT WORK _____ ACCOUNT # _____

WATER SCHEME NAME AND LOCATION _____

EQUIPMENT NEEDING ATTENTION - NAME _____

EXACT LOCATION _____ ID# _____

NATURE OF WORK TO BE DONE: _____

TARGET COMPLETION DATE AND TIME _____

WORK PERFORMED: _____

PROBLEMS / RESOLUTION _____

COMPLETION: DATE AND TIME _____ PERSON _____

FOLLOW-UP NEEDED _____

OTHER OBSERVATIONS _____

LABOR USE				MATERIALS USE		VEHICLE/ EQUIP. USE			OTHER COSTS
PERSON	HRS	RATE	COST	REQUIS. #	COST	ITEM	MILES	COST	
									TOTAL COST
TOTAL				TOTAL		TOTAL			

WORK ORDER LOG

MAINTENANCE OFFICE ______________________

WORK ORDER #	DATE WRITTEN	PERSON RESPONS.	WORK LOCATION	WORK DESCRIPTION	PRIORITY	COMPLETION DATE	TOTAL COST	FILE LOCATION

EQUIPMENT DATA SHEET

PUMPS

DATE COMPLETED _____

IDENTITY

NAME: _____

ID £: _____

MODEL NAME _____

MODEL NO. _____

SERIAL NO. _____

LOCATION

REGION _____

SYSTEM _____

PLANT _____

INSTALLATION DATE _____

PREVIOUS LOCATION _____

SPECIFICATIONS

PUMP TYPE _____

STAGES _____

IMPELLER DIAMETER _____

RATED RPM _____

RATED CAPACITY _____

STATIC HEAD _____

EST. TOTAL HEAD _____

INLET DIAMETER _____

OUTLET DIAMETER _____

DRIVER:

NAME _____

ID NO. _____

AQUISITION

DATE PURCHASED _____

P.O. NUMBER _____

FOB COST _____

MANUFACTURER _____

LOCAL SUPPLIER _____

LOCAL SERVICE _____

PARTS STOCKED LOCATION _____

NAME	PART NO.

PM REQUIREMENTS:

TASK	FREQ

EQUIPMENT DATA SHEET ELECTRIC MOTORS DATE COMPLETED _____

IDENTITY

NAME: _____

ID #: _____

MODEL NAME _____

MODEL NO. _____

SERIAL NO. _____

LOCATION

REGION _____

SYSTEM _____

PLANT _____

INSTALLATION DATE _____

PREVIOUS LOCATION _____

SPECIFICATIONS

MOTOR TYPE _____

HORSEPOWER _____

PHASES _____

VOLTS _____

AMPS _____

HZ _____

RPM _____

POWER SOURCE _____

DRIVEN UNIT:
NAME _____
ID NO. _____

AQUISITION

DATE PURCHASED _____

P.O. NUMBER _____

FOB COST _____

MANUFACTURER _____

_____

LOCAL SUPPLIER _____

_____

LOCAL SERVICE _____

_____

PARTS STOCKED LOCATION _____

NAME	PART NO.

PM REQUIREMENTS:

TASK	FREQ

METER INSTALLATION REPAIR AND TESTING FORMS

METER CARD

MFG. _____ SIZE _____ ID NO. _____

MAKE _____ COST _____ MATERIAL _____

INSTALLATION RECORD

INSTALLED		ADDRESS	ACCOUNT NO.	REMOVED		REASONS FOR REMOVAL
DATE	READING			DATE	READING	

METER CARD (BACK SIDE)

MFG. _____ SIZE _____ ID NO. _____

TEST AND REPAIR RECORD

DATE	AMT. WATER PASSED BEFORE TEST	TEST AMOUNT	TEST READING	% ERROR	REPAIRS MADE	REMARKS

INVENTORY LEDGER - PARTS

STORE NAME _____

PART NAME _____ FOLIO # _____

PART NUMBER _____ REORDER POINT _____

HOST MACHINE _____ REORDER QUANTITY _____

BIN NUMBER _____

CARRYOVER STOCK

DATE	RECEIVED			ISSUED			BALANCE
	CREDIT NO.	QTY	UNIT COST	REQUIS. NO.	QTY	UNIT COST	

INVENTORY LEDGER - SUPPLIES

STORE NAME _____

NAME _____ FOLIO # _____

SIZE _____ REORDER POINT _____

SPECIFICATION _____ REORDER QUANTITY _____

STORAGE LOCATION _____

CARRYOVER STOCK

DATE	RECEIVED			ISSUED			BALANCE
	CREDIT NO.	QTY	UNIT COST	REQUIS. NO.	QTY	UNIT COST	

MATERIAL REQUISITION No. _____

Date _____ Work Order No. _____

Location _____ Account No. _____

PART NO.	QTY	DESCRIPTION	UNIT COST	TOTAL

Issued by _____ Received by _____ Approved _____

MATERIAL CREDIT No. _____

Date _____ Purchase Order _____

Location _____ Account No. _____

PART NO.	QTY	DESCRIPTION	UNIT COST	TOTAL

Issued by _____ Received by _____ Approved _____

TRAVELING ORDER CARD

STORE NAME _____

Name _____ Folio # _____

Part No. or Spec _____ Reorder Point _____

Size _____ Reorder Qty _____

SUPPLIERS

1 _____ 4 _____

2 _____ 5 _____

3 _____ 6 _____

ORDER LEDGER

P.O. Date	Supplier	Unit Cost	Qty Ordered	Expect. Date of Delivery	Qty Recd	Date Delivered

MONTHLY WORK ORDER SUMMARY

MAINTENANCE OFFICE _____ MONTH _____

	PM	CM	TOTAL
No. of Work Orders outstanding from last month			
No. of Work Orders originating this month			
No. of Work Orders originating this month but not completed			

INCOMPLETE WORK ORDERS:

WORK ORDER NUMBER	DATE	REASON FOR DELAY	EXPECTED COMPLETION

APPENDIX B

Computerized Maintenance Management Systems

APPENDIX B

Computerized Maintenance Management Systems

GENERAL CONSIDERATIONS

In the United States and other countries, both paper and computerized MMS systems are in use. The maintenance management system described in this manual is a simple, paper-based system designed for use in developing countries. Typically, small independent water or wastewater utilities find paper systems to be the best, but larger institutions use computerized ones. The programs given in the list below range in price from U.S.$2000-U.S.$5000. For smaller organizations, the extra power and extra expense of a computer and software are simply not needed.

In general, the computerized MMS systems offer the same features that the paper systems have. Mainly, they can handle a larger volume of activity faster and easier. The computerized systems are based on the same fundamental principles that underlie the paper system explained in this manual. In fact, a computer-based system could be developed from the content shown here. Also, if an organization cannot keep a paper maintenance system working, just having a computer based system may not help. If the fundamental principles of maintenance management are not followed, they will not be followed any better with a computer.

The dependence on computer systems in developing countries can be problematic. Computers are expensive, they require specialized skills, and are often hard to keep running in many developing country contexts. Computers could be appropriate to large complex water/wastewater systems and organizations in cities where computer sales and service are available. If computers are used for other parts of utility operations, such as accounting, payroll, billing, or engineering, then chances are good that a computerized maintenance management system could be successful.

COMPUTERIZED MAINTENANCE MANAGEMENT PROGRAMS

A variety of computerized maintenance management software packages are available from commercial suppliers. A partial list of packages for the IBM-PC family of microcomputers is given below:

1. **Micro Maint**

   Package features include:

   - work order entry, scheduling, and printing
   - materials inventory
   - equipment history
   - reports
   - cost history

   Available from:

   Diagonal Data Corporation
   2000 E. Edgewood Drive
   Lakeland, FL 33803
   (813) 666-2330

2. **Micro-SIMS**

   Package features include:

   - work request
   - work orders
   - equipment history management
   - preventive maintenance scheduling

   Available from:

   Energy Incorporated
   Facility Management Systems
   P.O. Box 738
   Idaho Falls, ID 83402
   (208) 529-1000

3. **FamTrac**

   Package features include:

   - work orders
   - inventory control
   - equipment ID and history records
   - preventive maintenance scheduling
   - reporting
   - cost analysis

Available from:

Syska and Hennessy
Facilities Management Group
11 West 42 Street
New York, NY 10036
(212) 921-2300 or (212) 556-3495

4. Plant Maintenance Management System (Plant)

Package features include:

- work orders
- equipment inventory and history
- activity definition
- inventory control
- reporting

Available from:

Hansen Software, Inc.
1745 Markston Road
Sacramento, CA 95825
(916) 921-0883 or (800) 821-9316

5. Water Distribution Management System (WDMS)

Package features include:

- work orders
- equipment inventory and history
- activity definition
- inventory control
- reporting
- area scheduled maintenance
- water line leaks
- water test results
- vendor and manufacturer file

Available from:

Hansen Software, Inc.
1745 Markston Road
Sacramento, CA 95825
(916) 921-0883 or (800) 821-9316

6. Maintenance Management System

Package features include:

- work orders
- inventory control
- manufacturer's information
- preventive maintenance
- equipment run hours
- work history

Available from:

Jentech Controls Inc.
Rt. 1, Box 93
Gresham, WI 54128
(715) 787-3795

7. Operator 10 - Inventory/Maintenance

Package features include:

- work order generation/printing
- equipment inventory
- material inventory
- equipment history
- cost reporting
- elapsed time meter log
- maintenance forecasts
- manufacturer and vendor list

Available from:

MACOLA, Incorporated
196 South Main Street
P.O. Box 485
Marion, OH 43302-0485
(614) 382-5999

APPENDIX C

Maintenance System Evaluation Questionnaire

MAINTENANCE SYSTEM EVALUATION QUESTIONNAIRE

Name:_____ Date:_____

This questionnaire will aid maintenance managers with evaluating an existing or a proposed maintenance management system. Its purpose is to help identify problem areas so they can be corrected or improved.

People using this questionnaire may find that their maintenance program has many of the necessary features. However, there will probably be some deficiency in many of the items. This is true because the features of many maintenance systems are either incomplete or are not performing their intended function.

The questions are categorized according to the management functions of planning, organizing, staffing, directing and controlling. Use your best judgment to answer each question. There are no right or wrong answers to the questions. If you are not sure about the response to any question just write the response you think is most appropriate in light of how you feel about the system.

	YES	NO	NEED TO FIND OUT
PLANNING:			
1. The maintenance program has clear cut goals and objectives?			
2. Recommendations for preventive maintenance are presently accomplished for major equipment.			
3. The maintenance program is planned to maximize scheduled maintenance.			
4. The maintenance program is planned to minimize unscheduled repairs or maintenance.			
5. Each piece of equipment is identified with a number or other well understood identification.			

	YES	NO	NEED TO FIND OUT
6. Manufacturer's technical data for each piece of equipment is accessible to maintenance personnel.			
7. Specific preventive maintenance requirements for each piece of equipment are documented and accessible.			
8. Historical records are maintained for each major piece of equipment.			
9. Annual preventive maintenance needs are anticipated.			
10. Annual corrective maintenance needs are anticipated.			
11. The annual budget provides sufficient resources to meet maintenance needs.			
12. A computer is used to help manage the maintenance program.			
13. Provisions have been made to contract for maintenance where your organization does not have the manpower, skills or equipment needed to perform the work.			
14. The feasibility of contracting maintenance has been explored as an alternative to in house maintenance.			

ORGANIZING:

15. The existing maintenance organization permits manpower to be allocated effectively to the major maintenance tasks.			
16. Preventive maintenance is scheduled for all major items of equipment.			
17. Provisions are made in maintenance planning and scheduling to accomplish potential corrective maintenance tasks.			

STAFFING:

18. Existing job descriptions for your maintenance personnel reflect the current needs of your maintenance program.
19. Training is provided to improve the knowledge and skills required by your maintenance employees.
20. Performance appraisals are conducted with employees with respect to their maintenance responsibilities.
21. Job standards and expectations are clearly defined for each maintenance employee.

YES	NO	NEED TO FIND OUT

DIRECTING:

22. Maintenance supervisors maintain good working relationships with maintenance employees.
23. Maintenance supervisors maintain good working relationships with others in the organization.
24. Maintenance employees are regularly motivated to high levels of performance.
25. There is regular, open exchange of information, know how and ideas between employees at all levels.
26. Effective interpersonal relationships exist in the organization.

CONTROLLING:

27. Work requests are prepared for all maintenance work.
28. Actual labor and materials used are compared to estimates for all maintenance work.

	YES	NO	NEED TO FIND OUT
29. Budgets are compared to accounting reports to identify and take action on variances.			
30. Materials and spare parts are controlled and accounted for.			
31. Controls focus on the vital few key areas rather than on the trivial many.			
32. Significant deviations from the maintenance plan are detected in time to make appropriate adjustments to the program.			
INSPECTION:			
33. Equipment inspection detects potential problems in time to schedule repairs before a major breakdown occurs.			
34. Materials and spare parts used most frequently are readily available from stock on hand.			
35. The most critical spare parts are readily available.			

APPENDIX D

Contracting Maintenance Activities

CONTRACTING MAINTENANCE ACTIVITIES

WHY CONTRACT-OUT?

The contracting of maintenance activities to external private firms can offer a number of advantages, and potentially some disadvantages. These are listed on the next page, and discussed below.

Overall the use of private contractors gives an agency great of flexibility in carrying out its work, and can produce cost savings. In general, private firms compete for business and thus tend to be more efficient, and less costly that public agencies. Private firms often work on a fixed price basis, simplifying budgeting for agencies who contract to them. Governments can tap into specialized expertise or tools and equipment which it cannot afford to develop or own by itself. Contractors can be called on as needed, for specific jobs, without adding a greater burden to the civil service payroll. Using contractors should allow agencies to reduce the stock of parts, tools and equipment it must purchase, store and maintain, lowering costs. Similarly, using contractors can reduce the labor supervisory needs of an organization.

The main disadvantage of using outside private firms is that unit labor cost and material may be higher. If contracts are not well designed overall costs can be higher. Proper contract management will be needed to ensure good performance and proper accountability increasing management needs in the agency.

Generally, contracting-out makes sense under the following conditions:

- reliable experience contractors are available;
- service is only needed occasionally, or in widely variable amounts;
- specialized expertise is required or desireable;
- commercial competition forces contractors to be more efficient and less costly;
- civil services are overburdened and slow to respond.

A key factor will be the existence of experienced qualified contractors. In many places, such as outside of the capital cities, reliable contractors with the necessary personnel, skills, tools and equipment, and experience may not exist. Government agencies often build equipment maintenance facilities specifically because such private services do not exist. On the other hand in more developed areas where such contractors abound, it would be irresponsible not to consider the costs, and advantages and disadvantages of contracting out.

ADVANTAGES AND DISADVANTAGES OF CONTRACTING OUT:

Advantages:

(1) Can be cost-effective if there is true competition, prudent procurement procedures and qualified supervision.

(2) Puts pressure on the direct labor organization to improve its efficiency.

(3) Gives the local authority more flexibility to cope with seasonal variations and other changes in the scale of O&M program and respond based on needs rather than based on manpower and equipment at hand.

(4) May reduce the authority's management burden, personnel administration and training.

(5) Can limit the authority's needs for new capital investment in maintenance equipment.

(6) Can develop useful benchmarks in terms of cost and performance of O&M tasks.

(7) May provide special skills and innovative methods of work and management.

(8) Can help develop the local contracting industry, particularly small scale entrepreneurs.

Disadvantages:

(1) Is not cost-effective if local contracting industry is not truly competitive.

(2) Demands qualified preparation of tender documents and close and qualified supervision.

(3) May stimulate fraud and corruption in the procurement process and during supervision.

(4) May displace civil servants and consequently meet resistance from unions.

(5) May result in delays if procurement procedures are cumbersome which is often the case in local authorities in developing countries.

(6) Increase vulnerability to noncompletion of works due to contractors' financial problems, strikes among contractors' personnel etc.

(7) May lower quality of service to the public because contractors may tend to be less sensitive to the authority's objectives and public demands than civil servants.

(8) Acceptance of low bids may lead to inferior quality of work.

(9) Does not provide hands-on experience in the direct labor force so that in-house backup capabilities may deteriorate.

Source: Lorentzen J. Overview of Issues and Strategic Options in Operations and Maintenance. Analysis and Synthesis Report, Draft, UNCHS / HABITAT Support Program for Urban Management. November 1988

EXAMPLES OF CONTRACTING-OUT MAINTENANCE

Some examples of possible uses of private contractors for maintenance services in the water and sanitation sector in developing countries include:

General maintenance services.

Contractors could be retained to provide specific services, on a case by case basis, in support of maintenance activities being conducted by the utility itself. Use of contractors makes sense when the utility uses these services in greatly varying amounts. Quick access to supplemental labor for repairs can be highly useful for a maintenance department. A good example would be the contract hiring of manual labor for excavation during pipeline repairs. Such labor can be called in as needed, keeping overall costs down. Some maintenance activities are done only occasionally, such as painting elevated steel water storage tanks, so these lend themselves to contract work as well.

Repairs or preventive maintenance on selected equipment.

A utility may not find it worthwhile to purchase expensive tools and equipment to maintain a relatively small number of specialized pieces of equipment. Similarly it may not be cost effective to train personnel in these complex procedures which they will only perform occasionally. If available, contractors could be employed to do these jobs. For example private well drillers could be used for corrective maintenance in the case of major well/pump problems that require heavy lifting equipment. Private firms could be used for major overhauls on diesel engines or electric motors. Such firms may do this work for a variety of public and private clients and thus have the volume of business to develop the specialized skills, and purchase the required tools and equipment.

Other Special Services.

Certain other specialized services, outside of the domain of normal water/sanitation utility expertise, may best be procured from outside contractors. For example, groundskeeping and janitorial services are commonly done by private firms or individuals on a contract basis. Billing, although not a maintenance activity, is another service which is sometimes performed by private contractors.

Water Vending.

In most developing countries water vendors exist, either in the form of small push cart salesmen, or larger tanker truck operations. While the prices of vended water may be high, vendors often help distribute water to areas where distribution networks have not yet reached. Many utilities may dislike the presence of vendors, but on the other hand, in countries where capital resources are limited they can provide a valuable service. Utilities often have nothing to do with vendors, but in other areas they sell directly to vendors, and account for their activities in their planning.

Full O&M Services.

In a couple of developing countries, government agencies have contracted out the entire operations and maintenance of water/sewer utilities. In Ivory Coast, SODECI, a private firm, runs all the and piped distribution water systems, under contract to the relevant Ministry. With careful contract negotiation, and direct oversight, the Government obtains a very reliable and high quality service.

CONTRACT CONSIDERATIONS

The details of contract development and management, are beyond the scope of this manual. There are a number of good texts on the issue. Yet a brief introduction to a few of the key points is given below.

There are many different type of contracts, but commonly contracts fall into one of the following categories:

Fixed Price.

Contractor provides a specific service for a precise predetermined cost. If plenty of competition exists low costs can result, but if not, contractors may take plenty of profit. Such contracts are usually written and executed on a case by case basis.

Cost plus Fee.

This type of contract is used when the work cannot be specifically defined, emergency repairs occur, or other factors may interfere with the work. A maintenance contract on a particular piece of hardware, combining preventive and corrective maintenance is usually written this way. This type of contract gives maximum flexibility, saving time. A fee, sometimes as a fixed amount, or as a fixed percentage of the cost of the work is added as profit. The issuing agency is necessarily far more involved in this type of contract.

Unit Price.

Some contracts for specific measurable services, such as excavation, concrete work, etc, are written with compensation based on the registered amount of work done.

The cost items covered in a contract may also vary depending on the type of work to be conducted and the type of contract. Some will include just labor, some labor and materials. Some contracts could be issued just for repairs, some for corrective and preventive maintenance, and some just for preventive work.

Every contract is different, but there are certain key items included in most any contract, such as:

- Statement of work
- Personnel involved
- Period of performance
- Recordkeeping required
- Compensation
- Performance monitoring procedures
- Payment schedule
- Performance Incentives
- Termination clauses

The clauses associated with compensation and statement of work will, of course, be of primary importance. A basis of compensation which ensures both an acceptable cost to the utility, and an interesting margin of profit for the contractor is perhaps difficult, but essential, to achieve. Without an acceptable cost, the utility will be uninterested, without a reasonable profit the contractor will see no reason to be involved. The statement of work must be sufficiently detailed to correctly instruct the contractor, and to allow means of quickly and simply verifying performance. Some flexibility in the wording of the statement of work will be useful in cost plus type contracts.

APPENDIX E

Maintenance Task Description Sheets

MAINTENANCE PROCEDURE SHEET	Page 1 of 1	MPS No. 41310SM1

EQUIPMENT NAME Chlorinator #1 and #3			Average Time
Plant Area Secondary	Level Ground Level	Location Chlorine Building	90 minu

MAINTENANCE DESCRIPTION

Clean gas inlet heater

SAFETY PRECAUTIONS

Observe standard safety precautions
De-energize unit, lock and tag "out of service".

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

Lock
Safety tag
Screwdriver
Adjustable wrench
Rags
Scraper
Brush

PROCEDURE

Preliminary - De-energize unit, lock and tag "out of service".

To clean inlet heater:

1. Drain all gas from the chamber, be sure it is empty.
2. Remove heater.
3. Clean heater.
4. Replace heater.
5. Remove lock and safety tag and return unit to service.

MAINTENANCE PROCEDURE SHEET	Page 1 of 2	MPS No. 41310SA1

EQUIPMENT NAME				Average Time
Chlorinator #1 and #3				
Plant Area Secondary	Level Ground Level	Location Chlorine Building		100 minut

MAINTENANCE DESCRIPTION

Clean and inspect chlorinator

SAFETY PRECAUTIONS

Observe standard safety precautions
De-energize unit, lock and tag "out of service"

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

Lock	Hoisting chain
Safety tag	Air hose and nozzle
Soft rags	Hammer
Set of combination wrenches	1/4" drill bit
	Screwdriver
Empty container	Bottle filled with wood alcohol (methanol)

Muriatic acid (dilute hydrochloric acid)

PROCEDURE

Preliminary

To clean and inspect chlorinator:

1. Close the gas supply valve.
2. Continue to operate the chlorinator until the gas pressure gauge and flow meter readings drop to zero.
3. Close gas supply shut-off valve at the chlorinator.
4. Remove test plug from vacuum regulator stack allowing air to be pulled in. Operate the chlorinator on air for a few minutes to purge gas from chlorinator components.
5. Close water supply valve.
6. Close valves in chemical solution line.
7. De-energize the power to electrical heater.
8. Deactivate the control system(s).
9. Connect the test plug back on vacuum regulator stack.
10. De-energize unit, lock and tag "out of service".

NOTE 1: Use wood alcohol (methanol) to remove any accumulated organic residues from gas dispenser parts.

2: Muriatic acid (dilute hydrochloric acid) can be used to remove accumulated mineral deposits from parts. Be careful that the acid does not come into contact with the skin or clothing.

To clean vacuum regulating valve and gas filter:

1. Remove the gas filter block.
2. Clean the valve plug.
3. Clean the seat and inspect seat surfaces thoroughly for any scratches or roughness - replace if defective.
4. Unscrew and remove the end plug.
5. Clean gas filter.
6. Inspect "O" rings and replace if required. On reassembly, be sure to replace all gaskets at gas filter block and gas line connections.

To clean and inspect flow rater valve:

1. Disconnect and remove piping from top of flowrater valve.
2. Remove orifice tube and orifice plug - do not drop plug.
3. Clean orifice plug and adapter. Inspect plug for roughness or damage.
4. Inspect "O" ring - replace if necessary.
5. Reassemble - lubricate "O" rings sparingly and make sure "O" rings are properly seated and orifice plug and tube are bottomed.

To clean vacuum stabilizing valve:

1. Disconnect vacuum line from upper valve body. Disconnect piping from lower valve body.
2. Remove bolts and separate valve body halves.
3. Remove diaphram, spring, sleeve and valve plug from the body as one assembly.
4. Inspect diaphragm for cracks or weakness, etc. Replace if necessary.
5. Mark position of valve seat assembly in body.
6. Unscrew valve set assembly.
7. Clean valve seat and plug, inspect for roughness or damage. Replace if required.
8. Renew "O" rings if necessary.
9. Reassemble unit - screw the valve seat assembly to its original position which was marked. (NOTE: Clearance between plug and seat must be 1/4 inch, a 1/4 inch drill bit should be used to set this up.)

To clean vacuum relief valve:

1. Disconnect the tubing from the vacuum relief valve.
2. Remove valve from chlorinator.
3. Unscrew coupling nut and separate the valve body halves, and remove the spring.
4. Clean valve seat and plug. Inspect contacting surfaces for scratches, nicks, breaks or roughness. Inspect the diaphragm for cracks, rips or weakness, replace parts as required.
5. Unscrew plug on upper valve body and remove dampening ball.
6. Clean the ball and inspect it for chips or cracks.
7. Reassemble vacuum relief valve.

To clean drain relief valve:

1. Remove piping from bottom of drain relief valve, and unscrew coupling nut at tee and remove valve.
2. Remove bolts from valve body, and separate the body halves.
3. Clean valve seat and plug. Inspect diaphragm for cracks, tears, deterioration or weakness. Replace any defective parts.
4. Reassemble drain relief valve.

To inspect all hose lines:

1. Inspect all hoses for cracks, breaks or weak spots that may develop with aging. Faulty lines should be replaced.
2. Reassemble all hoses.
3. Remove lock and energize unit.
4. Restart chlorinator in accordance with current instructions. Remove safety tag.
5. Calibrate flowrater valve (zero adjustment) before resuming normal operations.

To measure voltage and current:

1. After ensuring the unit may be operated, energize the unit by turning breaker at the motor control console to "on".
2. At the terminals at the very bottom of the motor control console, measure the voltage and current for each of the three legs (for 3-phase motors). Record these readings on the PM work record.

NOTE 3: TAKE CORRECTIVE ACTION SHOULD ANY DISCREPANCIES BE OBSERVED.

3. De-energize unit at the local electrical controller.
4. Replace access panel on the motor control console.
5. Remove safety tag and return unit to service.

MAINTENANCE PROCEDURE SHEET	Page 1 of 1	MPS No. 41310SS1

EQUIPMENT NAME			Average Time
Chlorinator #1 and #3			
Plant Area Secondary	Level Ground Level	Location Chlorine Building	60 minut

MAINTENANCE DESCRIPTION

Clean and Inspect Flow Meters

SAFETY PRECAUTIONS

Observe standard safety precautions
De-energize unit, lock and tag "out of service".

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

Lock
Safety tag
Set of O rings
Bottle filled with Xylenes
Empty container
Rubber gloves
Silicone valve grease
Soft rags
Brush, tube

PROCEDURE

Preliminary - De-energize unit, lock and tag "out of service".

To clean and inspect flow meter:

1. Close the gas supply valve shut-of valve at chlorinator.
2. Continue to operate chlorinator until gas pressure gauge and flow meter readings drop to zero, indicating that gas supply line has been evacuated.
3. Remove metering tube assembly - do not use excessive force on the tube itself.
4. Disassemble and clean all parts with tube brush and exylenes.
5. Inspect all parts for wear or damage -- replace if necessary. Replace any "O" rings showing signs of brittleness, cuts or abrasion.
6. Reassemble, lubricate "O" rings sparingly.
7. Insert metering tube assembly into chlorinator. Make sure adaptor "O" rings are properly seated.
8. Open gas supply shut-off valve at chlorinator.
9. Remove lock and safety tag and energize and return to service.

MAINTENANCE PROCEDURE SHEET	Page 1 of 1	MPS No. 32220SS1

EQUIPMENT NAME Motor, Air Blower 1 - 6			Average Time
Plant Area Secondary	Level Lower Level	Location Pipe Gallery	18

MAINTENANCE DESCRIPTION Change Oil

SAFETY PRECAUTIONS

Observe Standard Safety Precautions

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

Lock
Safety tag
Rags
Empty Container
Fresh Lubricant - Texaco Regal B or 46
8" - 10" Adjustable Wrench
SAE 5 Mineral Oil

PROCEDURE Preliminary -- Lock and tag "out of service".

1. Remove bottle from oiler body
2. Remove drain plug and drain oil into container. Also, remove top plug (has hose connected to oiler)
3. Flush bearing with SAE 5 Mineral Oil
4. Install drain plug
5. Add fresh lubricant until oil level is halfway up in sight glass
6. Install top plug
7. Add fresh lubricant to bottle if required and place on oiler body
8. Remove any spilled oil and check for leaks
9. Return to service.

MAINTENANCE PROCEDURE SHEET	Page 1 of 1	MPS No. 32220SQ1

EQUIPMENT NAME			Average Time
Motor, Blowers 1-6			
Plant Area Secondary	Level Ground Level	Location Operations Pipe Gallery	25 minu

MAINTENANCE DESCRIPTION

Clean motor, inspect and meg motor.

SAFETY PRECAUTIONS

Observe standard safety precautions
De-energize unit, lock and tag "out of service"

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

Rags
Safety tags
500 volt megger
Volt meter
Ammeter
Ohmmeter
Screwdriver
Thermometer
Non-flammable solvent (lix cleaning solvent or equivalent)

PROCEDURE

Preliminary - De-energize unit, lock and tag "out of service" Allow motor to cool to ambient temperature.

To clean motor:

1. Clean exterior of motor of all foreign matter. For open or drip-proof motors, make note of extremely dirty condition and take corrective action if necessary.

To test insulation resistance:

1. Turn circuit breaker at motor control console to "off".
2. Turn local electrical control (at motor) to "on". Measure the ambient temperature at the motor in degrees fahrenheit.
3. Remove access panel at the very bottom of the motor control console, exposing terminals.
4. Meg the motor circuits at these terminals, after application of a 500-volt direct current for one minute.

NOTE 1: USE AN OHMMETER ON THOSE CIRCUITS WHICH WOULD BE DAMAGED BY A 500-VOLT MEGGER.

5. Correct the insulation resistance measurement to a standard 75°F and record the corrected reading on the PM work record.

NOTE 2: IF THE CORRECTED READING SHOWS A SIGNIFICANT DROP FROM PREVIOUS READINGS, OR IF THE CORRECTED READING IS LESS THAN 40 MEGOHMS (CLASS A) OR 8 MEGOHMS (CLASS B), CORRECTIVE ACTION SHOULD BE TAKEN.

MAINTENANCE PROCEDURE SHEET	Page 1 of 1	MPS No. 32210SA1

EQUIPMENT NAME BLOWERS 1-6			Average Time
Plant Area Secondary	Level Lower Level	Location Operations Pipe Gallery	15 minute

MAINTENANCE DESCRIPTION

INSPECT FOUNDATION BOLT TIGHTNESS

SAFETY PRECAUTIONS

OBSERVE STANDARD SAFETY PRECAUTIONS

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

WRENCHES 1-1/2, 1-1/8 OPENINGS

PROCEDURE

1. INSPECT FOR SOUNDNESS OF ANCHOR BOLTS IN CONCRETE
2. CHECK FOR UNIFORM TIGHTNESS OF BLOWER - MOTOR FRAME TO CONCRETE PAD
3. CHECK FOR UNIFORM TIGHTNESS OF BLOWER TO FRAME
4. CHECK FOR ANY CRACKED WELDS ANCHORING MOTOR TO FRAME.

APPENDIX F

Estimating Resource Requirements

Form No. 6/W

WORK QUANTITY PLANNING CRITERIA FOR ANNUAL MAINTENANCE PROGRAMME

SHEET 1 OF 4

ACTIVITY		WORK	INVENTORY	ANNUAL PLANNING CRITERIA	PLANNING
[illegible]	DESCRIPTION	MEASUREMENT	ITEM		FACTOR
11/W	Clean intake externally	No. of intakes	No. of intakes	360 times a year	360
12/W	Clean intake adjacent area	No. of intakes	No. of intakes	12 times a year	12
21/W	Check and tighten gland packings of pumps	No. of pumps	No. of pumps	4 times a year	4
22/W	Grease pumps bearings	No. of pumps	No. of pumps	4 times a year	4
23/W	Clean pump suction strainers	No. of pumps	No. of pumps	180 times a year	180
24/W	Clean pump drain lines and gland feeder lines	No. of pumps	No. of pumps	4 times a year	4
25/W	Record readings of suction and delivery gauges	No. of pumps	No. of pumps	360 times a year	360

Form No. 6/W

WORK QUANTITY PLANNING CRITERIA FOR ANNUAL MAINTENANCE PROGRAMME

SHEET 2 OF 4

ACTIVITY CODE	ACTIVITY DESCRIPTION	WORK MEASUREMENT	INVENTORY ITEM	ANNUAL PLANNING CRITERIA	PLANNING FACTOR
26/W	Check alignment of pumps and hold down bolts	No. of pumps	No. of pumps	2 times a year	2
27/W	Strip down pump and clean inside	No. of pumps	No. of pumps	B1 annually	0.5
28/W	Test pressure gauges on pumps	No. of pumps	No. of pumps	Annually	1
29/W	Grease motor bearings	No. of motors	No. of motors	4 times a year	4
30/W	Clean and check inside of motors	No. of motors	No. of motors	2 times a year	2
31/W	Exercise valves	No. of valves	No. of valves	4 times a year	4
41/W	Clean adjacent area and exercise [illegible] of front-	No. of plants	No. of plants	180 times a year	180

Form No. 6/W

WORK QUANTITY PLANNING CRITERIA FOR ANNUAL MAINTENANCE PROGRAMME

SHEET 3 OF 4

ACTIVITY CODE	ACTIVITY DESCRIPTION	WORK MEASUREMENT	INVENTORY ITEM	ANNUAL PLANNING CRITERIA	PLANNING FACTOR
42/W	Clean and lubricate equipments of treatment plant	No. of plants	No. of plants	4 times a year	4
51/W	Service air valves of p. main	No. of valves	No. of valves	2 times a year	2
52/W	Open wash outs of p. main	No. of valves	No. of valves	4 times a year	4
53/W	Check leaks of p. main	km	km of main	52 times a year	52
61/W	Service air valves of distribution	No. of valves	No. of valves	2 times a year	2
62/W	Open wash outs of distribution	No. of valves	No. of valves	3 times a year	3
63/W	Check leaks of distribution	im		36 times a year	36

Form No. 6/W

WORK QUANTITY PLANNING CRITERIA FOR ANNUAL MAINTENANCE PROGRAMME

SHEET 4 OF 4

ACTIVITY		WORK	INVENTORY	ANNUAL PLANNING CRITERIA	PLANNING FACTOR
CODE	DESCRIPTION	MEASUREMENT	ITEM		
64/W	Check and test meters	No. of meters	No. of meters	Every 5 years	0.2

ANNUAL MAINTENANCE PROGRAMME WORKSHEET

Form No. 7/W

PROGRAMME YEAR _____ SHEET 1 OF 3

ACTIVITY		INVENTORY	Inventory	Planning	Annual		PRODUCTIVITY	=	MAN DAYS		
			×	=	work	÷					
CODE	DESCRIPTION	ITEM	Amont	Factor	Quantity			Crew Days	Total	Equip. Oper.	Maint. Worker
11/W	Clean intake externally	No. of intakes	2	360	720		2 per crew day	360	720	-	720
12/W	Clean intake adjacent area	No. of pumps	2	12	24		½ per crew day	48	192	-	192
21/W	Check and tighten gland packings of pumps	No. of pumps	4	360	1440		15 per crew day	96	192	-	192
22/W	Grease pump bearing	No. of pumps	4	4	16		4 per crew day	4	8	-	8
23/W	Clean pump suction strainer	No. of pumps	180	180	720		12 per crew day	60	120	-	120
24/W	Clean pump suction lines and gland feeder lines	No. of pumps	4	4	16		6 per crew day	3	6	-	6
25/W	Record readings of suction and delivery gauges	No. of pumps	4	360	1440		40 per crew day	36	72	-	72

ANNUAL MAINTENANCE PROGRAMME WORKSHEET

Form No. 7/W

PROGRAMME YEAR_____ SHEET 2 OF 3

ACTIVITY		INVENTORY	Inventory	×	Planning	=	Annual work	+	PRODUCTIVITY	=	Crew Days	MAN DAYS		
CODE	DESCRIPTION	ITEM	Amont		Factor		Quantity					Total	Equip. Oper.	Maint. Worker
29/W	Grease motor bearings	No. of motors	4		4		16		4 per crew day		4	8		8
30/W	Exercise valves	No. of valves	12		4		48		24 per crew day		2	4		4
41/W	Clean adjacent area and exercise valves of treatment plant	No. of plants			180				2 per crew day					
42/W	Clean and lubricate all equipments in treatment plant	No. of pl ts			4				2 per crew day					
51/W	Service all the air valves of pumping/ gravity main	No. of valves	11		2		22		4 per crew day		5	15		15
52/W	Open washout valves and flush pumping/ gravity mains	No. of valves	6		4		24		3 per crew day		8	16		16
53/W	Check leaks of pumping/ gravity main	Km of mains	16·4		52		852·8		5km per crew day		171	171		171

ANNUAL MAINTENANCE PROGRAMME WORKSHEET

Form No. 71W

PROGRAMME YEAR _____ SHEET 3 OF 3

ACTIVITY CODE	ACTIVITY DESCRIPTION	INVENTORY ITEM	Inventory Amont	×	Planning Factor	=	Annual work Quantity	÷	PRODUCTIVITY	=	Crew Days	MAN DAYS Total	Equip. Oper.	Maint. Worker
61/W	Service air valves of distribution	No. of valves			2				4 valves per crew day					
62/W	Open washouts and flush distribution system	No. of valves	5		3		15		3 per crew day		5	10		10
63/W	Check leaks of distribution	km of main	24·2		36		871·2		5km per crew day		174	174		174
64/W	Check and test water meters	No. of meters	10		0.2		2		5 per crew day		1	2		2
71/W	Other maintenance											256		256
									Total Requirement			1966	–	1966
	Total mandays for continuous activities 11/W,	21/W, 23/W; 25/W			= 1104									
		Men required			= 1104		= 3·07							
	Total mandays	for other activities			= 360 762									
		Men required			= 762		= 3·39 ≃ 7							

Form No. 8/W

PLANNING CRITERIA FOR MATERIALS QUANTITIES

WORK ACTIVITY		ESTIMATED QUANTITY PER CREW DAY
CODE	DESCRIPTION	
22/W	Grease pump bearings	1kg grease 1kg cotton waste
29/W	Grease motor bearings	1kg grease 1kg cotton waste
42/W	Clean and lubricate all equipment	1kg grease ½ litre oil 2kg cotton waste
51/W	Servicing of air valves gravity/pumping main	1kg cotton waste
61/W	Servicing of air valves distribution system	1kg cotton waste

MATERIAL REQUIREMENT FOR ANNUAL WORK PROGRAMME

Form No. 9/W

PROGRAMME YEAR 1986

WORK ACTIVITY			ANNUAL CREW DAYS	GREASE Kg.	LUBRICANT Ltr.	COTTON WASTE Kg.	TOTAL COST
CODE	DESCRIPTION	UNIT RATE	Rs.	80·00	30·00	2·50	
22/W	Grease pump bearings		4	4		4	
				320·00		10·00	330·00
26/W	Grease motor bearings		4	4		4	
				320·00		10·00	330·00
51/W	Service air valves of gravity/pumping main		5			5	
						12·50	12·50
61/W	Service air valves of distribution		-				
TOTAL ANNUAL REQUIREMENT		MATERIALS		8		13	
		COST		640·00		32·50	672·50

MAINTENANCE PERFORMANCE BUDGET

Form No. 10/W

SHEET 1 OF 2

PROGRAMME YEAR _____

WORK ACTIVITY		ANNUAL WORK PROGRAMME			UNIT COST- RUPPEES		ANNUAL COST - RUPEES			
CODE	DESCRIPTION	CREW DAYS	WORK QUANTITY	WORK UNIT	PER CREW DAY	PER WORK UNIT	LABOUR	EQUIPMENT	MATERIAS	TOTAL
11/W	Clean intake externally	360	720	no of Intakes	100.00	50.00	36000.00			36000.00
12/W	Clean intake adjacent area	48	24	no of Intakes	200.00	400.00	9600.00			9600.00
21/W	Check and tighten pump gland packings	96	1440	no. of pumps	125.00	8.33	12000.00			12000.00
22/W	Grease pump bearings	4	16	no of pumps	182.50	45.63	400.00		330.00	730.00
23/W	Clean pump suction strainer	60	720	no. of pumps	100.00	8.33	6000.00			6000.00
24/W	Clean pump suction lines and gland feeder lines	3	16	no. of pumps	100.00	16.66	300.00			300.00
25/W	Record readings of pressure gauges	36	1440	no. of gauges	100.00	2.50	3600.00			3600.00
26/W	Grease motor bearings	4	16	no. of motors	182.50	45.63	400.00		330.00	730.00
31/W	Exercise valves	2	48	no. of valves	100.00	4.17	200.00			200.00
41/W	Clean and flush treatment plant	-	-	no. of plants	150.00	75.00				
42/W	Clean and lubricate all equipments of treatment plant	-	-	no. of plants	123.06	61.50				
51/W	Service air valves of pumping/gravity main	5	22	no. of valves	152.50	38.13	750.00		12.50	762.50
52/W	Open washouts and flush pumping/gravity main	8	24	no. of valves	100.00	33.33	800.00			800.00
53/W	Check leaks of pumping/gravity main	171	2.8	KM	50.00	10.00	8550.00			8550.00
61/W	Service air valves of distribution			no of valves	152.50	38.13				

Form No. 10/W

SHEET 2 OF 2

PROGRAMME YEAR _____

MAINTENANCE PERFORMANCE BUDGET

WORK ACTIVITY		ANNUAL WORK PROGRAMME			UNIT COST- RUPEES		ANNUAL COST - RUPEES			
CODE	DESCRIPTION	CREW DAYS	WORK QUANTITY	WORK UNIT	PER CREW DAY	PER WORK UNIT	LABOUR	EQUIPMENT	MATERIAS	TOTAL
62/W	Open whashouts and flush distribution	5	15	no. of valves	100·00	33·33	500·00			500·00
63/W	Check leaks of distribution	174	871·2	KM	50·00	10·00	8700·00			8700·00
64/W	Check water meters	1	2	no. of meters	100·00	33·33	100·00			100·00
	Allow for items marked with asterisks						20,000·00		10,000·00	30,000·00
	in Fig.4									
	Allow for other maintenance						16185·00		1600·88	17785·88
	Total direct cost						124085·00		12273·38	136358·38
	Maintenance Engineering						21600·00	20,000·00		41600·00
	Engineering management						9320·00	2080·00	2020·00	12420·00
	Total budget requirement						154005·00	22080·00	14293·38	190378·38

MAINTENANCE PERFORMANCE BUDGET

Form No. 10/W

SHEET 2 OF 2

PROGRAMME YEAR

WORK ACTIVITY		ANNUAL WORK PROGRAMME			UNIT COST- RUPPEES		ANNUAL COST - RUPEES			
CODE	DESCRIPTION	CREW DAYS	WORK QUANTITY	WORK UNIT	PER CREW DAY	PER WORK UNIT	LABOUR	EQUIPMENT	MATERIAS	TOTAL
62/W	Open whashouts and flush distribution	5	15	no. of values	100·00	33·33	500·00			500·00
63/W	Check leaks of distribution	174	871·2	KM	50·00	10·00	3700·00			8700·00
64/W	Check water meters	1	2	no. of meters	100·00	33·33	100·00			100·00
	Allow for items marked with asterisks						20,000·00		10,000·00	30,000·00
	in Fig.4									
	Allow for other maintenance						16185·00		1600·88	17785·88
	Total direct cost						124085·00		12273·38	136358·38
	Maintenance Engineering						21600·00	20,000·00		41600·00
	Engineering management						9320·00	2080·00	2020·00	12420·00
	Total budget requirement						154005·00	22080·00	14293·38	190378·38

EXAMPLE

Programme Year 1986

DIRECT COSTS

Direct

2481 Man Days at 50·00 per day 124 050·00

Direct

	Days		Rate/Day		Annual Cost
_____	____	x	____	=	_____
_____	____	x	____	=	_____
_____	____	x	____	=	_____
_____	____	x	____	=	_____
_____	____	x	____	=	_____
_____	____	x	____	=	_____
_____	____	x	____	=	_____
_____	____	x	____	=	_____
_____	____	x	____	=	_____
_____	____	x	____	=	_____

Sub-Total, Equipment Cost —

Direct

	Unit	Amount		Unit Cost		Annual Cost
Grease	kg	8	x	80·00	=	640·0
Cotton	kg	13	x	2·50	=	32·50
other	N/A	____	x	_____	=	11 600·00
_____	____	____	x	_____	=	_____
_____	____	____	x	_____	=	—
_____	____	____	x	_____	=	_____
_____	____	____	x	_____	=	_____
_____	____	____	x	_____	=	_____
_____	____	____	x	_____	=	_____

Sub-total, Materials Cost 12 272·50

Estimated Total Direct Cost 136 322·50

MAINTENANCE ENGINEERING

1	General Forman Rs 1800/month	21600.00	
	Sub-Total, Labour Cost		21600.00

Equipment:

1	Pick-up truck for parttime	20,000.00	
	use		
	Sub-total, Equipment Cost		20,000.00

Associated Costs:

	Sub-total, Associated Cost		0
	Estimated Maintenance Engineering		41 60
	Percent of Direct Cost		

ENGINEERING MANAGEMENT

Labour:

Percentage of head office		8320.00	
staff partially on maint.			
work			
	Sub-total, Labour Cost		8320.00

Equipment:

Part office of municipal	2080·00	
Engineer apportioned to		
maintenance		
Sub-total, Equipment Cost		2080·00

Associated Costs:

Office operation costs	2020·00	
(elec. telephone etc.)		
Sub-total, Associated Cost		2020·00
Estimated Engineering Management		12420·17
Percent of Direct + Maintenance Engineering		
ESTIMATED TOTAL COSTS		176[illegible]92·50

APPENDIX G

Example PM Schedules

PREVENTIVE MAINTENANCE CHECK LIST FOR WATER SUPPLY SYSTEMS BUILDINGS, STRUCTURES AND EQUIPMENT

GROUP		DESCRIPTION	MAINTENANCE PERIOD	RESPONSIBILITY LEVEL	RESPONSIBILITY CREW	TASK TO BE PERFORMED	MATERIALS, SPARE PARTS, LUBRICANTS ETC, REQUIRED
I SOURCE OF SURFACE-WATER	A	Impounding Reservoir	3 months	L	o,a	Clean intake and adjacent area, cut tall grass	
			1 year	D,L	e,m,o	Inspect sanitary conditions, inspect structure and repair as necessary	Building materials
	B	Mountain stream	3 months	L	o,a	Clean intake and adjacent area, cut tall grass near access road.	
			1 Year	D,L	e,m,o	Inspect sanitary condition, inspect structure and repair as necessary.	Building materials
	C D	Lake River	3 months	L	o,a	Clean intake and adjacent area, cut tall grass near access road, clean intake channel, clean collection chamber and disinfect with chlorine	HTH solution
			1 year	D,L	e,m,o	Inspect sanitary condition, inspect structure and repair as necessary.	Building materials
	E	Coarse Screens	1 day	L	o	Remove floating material attached to screen	
			6 months	L	o	Inspect lifting gear and oil or grease as required	Oil and grease
			1 year	D,L	e,m,o	Inspect for signs of corrosion and paint if necessary. Inspect lifting gear for signs of wear and repair if necessary.	Anti corrosion paint
	F	Fine Screens	1 day	L	o	Remove floating material attached to screens	
			6 months	L	o	Inspect lifting gear and oil or grease as required	Oil and grease
			1 Year	D,L	e,m,o	Inspect for signs of corrosion and paint if necessary. Inspect lifting gear for signs of wear and repair if necessary.	Anti corrosion paint
	G	Penstocks/Valves	6 months	L	o	Open and close, apply grease to spindles and guide surfaces above water level	Grease
			1 year	D,L	m,o	Inspect for signs of wear and repair if necessary.	

KEY:

Level: L = Local, D= District, R= Region

Crew: e = engineer/technical officer, m= maintenance team, o= plant operator, a = additional labour (or contract labour) as required

PREVENTIVE MAINTENANCE CHECK LIST FOR WATER SUPPLY SYSTEMS BUILDINGS, STRUCTURES AND EQUIPMENT

GROUP		DESCRIPTION	MAINTENANCE PERIOD	RESPONSIBILITY LEVEL	RESPONSIBILITY CREW	TASK TO BE PERFORMED	MATERIALS, SPARE PARTS, LUBRICANTS ETC, REQUIRED.
I - SOURCE OF SUPPLY GROUND	H	Boreholes	3 months	L	o,a	Clean adjacent area, cut tall grass near access road.	
	I	Dug Wells	1 year	R,L	e,w,m,o,a	Clean casing and screens with appropriate tools and chemicals. Measure well output before and after cleaning, recording total flow and specific capacity. Check pipes and guide bearings	Chemicals, special tools and equipment
			3 years	R,D,L	e,w,m,o	Remove pumping unit for complete overhaul at Regional workshops. Replace with spare unit	Spare parts as required. Spare pumping unit of similar type.
	J	Infiltration Gallery	5 years	D,L	e,m,o,a	Examine pipes and repair if necessary	

KEY:

Level: L= Local, D= District, R= Region

Crew: e= engineer/technical officer, m= maintenance team, o = plant operator, el= motor/switchgear electrician, a= additional labour(or contract labour) as required, w= special team for servicing deep wells/boreholes.

PREVENTIVE MAINTENANCE CHECK LIST FOR WATER SUPPLY SYSTEMS BUILDINGS, STRUCTURES AND EQUIPMENT

GROUP		DESCRIPTION	MAINTENANCE PERIOD	RESPONSIBILITY LEVEL	RESPONSIBILITY CREW	TASK TO BE PERFORMED	MATERIALS, SPARE PARTS LUBRICANTS, ETC REQUIRED
II RAW WATER PUMPING	A	Pump House	1 day	L	o	Clean and sweep floor, wipe and clean walls and piping clean and sweep exterior site, tend lawn and garden.	Cleaning materials
			2 years	D,L	e,m,o,a	Check and repair any leaks in roof. Paint inside and outside walls and piping.	Building materials, Paint
	B	Fuel tanks	1 day	L	o	Check fuel level and refill if necessary. Record fuel consumed during previous day. Clean outside.	
			6 months	L	o	Drain and wash fuel tank, wash and clean filter, clear fuel tank vent pipe.	
	C	Pumps	1 day	L	o	Record readings of suction and delivery gauges. Check packing glands to leak slightly during operation. Check tightness of nuts and bolts, check lubrication of bearings	
			6 months	D, L	m, p, o	Replace grease/oil in bearings without disassembly check alignment of coupling, replace packing in glands.	Grease/oil packing material
			* 3 years (depending on circumstances)	R,D,L	e,m,p,a	Remove pump for complete overhaul in Regional workshops. Replace defective parts as necessary	spare parts as required.

KEY :

LEVEL : L = Local, D, = District, R, = Region

CREW : e = Engineer/technical Officer, m = maintenance team

o = plant operator, p = pump mechanic

PREVENTIVE MAINTENANCE CHECK LIST FOR WATER SUPPLY SYSTEMS BUILDINGS, STRUCTURES AND EQUIPMENT

GROUP		DESCRIPTION	MAINTENANCE PERIOD	RESPONSIBILITY LEVEL	RESPONSIBILITY CREW	TASK TO BE PERFORMED	Materials, spare parts, Lubricants, etc, required
II RAW WATER PUMPING	D	Diesel Engines	1 day	L	o	Check oil level and top up if necessary Lubricate all lubrication points, Record oil pressure, temperatures, speed and battery charge. Record working hours and total since last oil change/last overhaul. Clean outside parts, check nuts and bolts for tightness.	lubricating oil
			1 week	L	o	Wash and clean air filter	
			1 month	D,L	m,o	Dismantle injectors and test spray, replace defective nozzles if necessary. Check and adjust V belt tension /coupling alignment as applicable.	Injector nozzles as necessary
			3 months	D,L.	m,p,o.	Clean and inspect injectors and valve clearances, check and clean oil filters. Fit new fuel elements. Check starting system, Change engine oil or in accordance with manufactures manual.	Fuel filter elements, engine lubricating oil.
			1 year	D,L	m,p,o.	Check and regrind valves and adjust valve clearances. Clean deposits from cylinder head and pistons. Disassemble and check clutch system, if applicable.	
			2 years	R,D,L.	m,p,o.	Remove engine for complete overhaul in Regional workshops. Replace with spare reconditioned engine.	Spare parts as required

KEY:

Level: L = Local, D= District, R = Region

Crew: e = engineer/technical officer, m = maintenance team, o = plant operator, p = pump/engine mechanic

PREVENTIVE MAINTENANCE CHECK LIST FOR WATER SUPPLY SYSTEMS BUILDINGS, STRUCTURES AND EQUIPMENT

GROUP		DESCRIPTION	MAINTENANCE PERIOD	RESPONSIBILITY LEVEL	RESPONSIBILITY CREW	TASK TO BE PERFORMED	MATERIALS, SPARE PARTS, LUBRICANTS, ETC. REQUIRED
II	E	Electric Motors	1 day	L	O	Check motor bearings	
			6 months	D, L	m,o,el	Check alignment of coupling, change lubricating oil/grease without dismantling	Lubricating oil/grease
			5 years	R,D,L	m,el,o	Remove motor for complete overhaul at regional workshops. Replace motor of similar type, if available.	Ball/roller bearings, if necessary.
	F	Switchgear	1 day	L	O	Record voltage, current and KW hr meters	
			3 months	D, L	m,el	Check starter and clean contacts. Check setting of overload relays.	
			1 year	D	m,el	Clean/replace contacts as necessary. Calibrate measuring instruments	Starter contacts, if necessary
	G	Measuring Instruments	3 years	R,D	e,m.	Dismantle and send to specialised contractor for calibration and/or repair	
	H	Water master meters	3 years	R, D,	m	Dismantle and send to Regional workshops for checking and calibration	
	I	Mains	1 year	L	O	check for leaks and repair if necessary	
			3 years	D,L	m,o	Paint exposed pipes with anti-corrosive paint	Anticorrosive paint
	J	Valves	1 year	L	O	Check valve gland and repack if necessary Close fully and open	Packing materials

KEY :

LEVEL : L = Local, D = District, R = Regional

CREW : e = engineer/technical Officer, m = maintenance team,

c = plant operator, el = motor, switchgear electrician.

DIRECTORATE OF WATER DEVELOPMENT

PREVENTIVE MAINTENANCE CHECK LIST FOR WATER SUPPLY SYTEMS BUILDINGS, STRUCTURES AND EQUIPMENT

GROUP		DESCRIPTION	MAINTENANCE PERIOD	RESPONSIBILITY LEVEL	RESPONSIBILITY CREW	TASK TO BE PERFOMED	MATERIALS, SPARE PARTS, LUBRICANTS, ETC. REQUIRED
III CHEMICALS	A	Chemicals store	1 week	L	O	Clean and sweep floor, clean outside, replenish stocks.	Chemicals
			1 year	D,L	e,m,o	Inspect structure, check all lifting gear	
	B D F	Alum preparation tanks Hypochlorite (HTH) Prep. tanks Soda Ash Preparation Tanks	1 day	L	O	Prepare correct strength solutions, clean outside of tanks and valves	
			1 year	D,L	m,o	Inspect structure and protective paint /lining and repair as necessary. Examine valves, pipe connections and repair as necessary	Paint, lining material.
	C E	Alum Dosing Hypochlorite (HTH) Dosing	6 months	D,L	m,o	Dismantle gravity feed doser, clean and reassemble	
	G	Soda Ash Dosing	1 year	R,D,L	e,m,el	Overhaul: dismantle dosing pumps and replace defective parts. Examine electric motors and switchgear. Paint all metal surfaces	Spare parts as necessary, Paint
III SEDIMENTATION	H I	Flocculators Sedimentation Tanks	1 year	D,L	e,m,o	Inspect structure, clean walls inside and outside, disinfect inside walls, paint metal surfaces, paint outside walls	HTH solution, paint
III FILTRATION	J	Slow Sand Filters	1 year	D,L	e,m,o,a	Inspect sanitary condition, inspect structure. Clean adjacent sres, close valves fully and open, tighten valve glands and add packing material, if necessary	Packing material
			5 years	R,D,L	e,m,o,a	Stop filter, rake off top filtering sand layer and replace with new filter sand of correct grade, disinfect and run filtered water to waste for 1day using enough HTH solution	

KEY:
Level: L= Local, D= District, R= Region
Crew: e= engineer/technical officer, m = maintenance team, O = operator, el-motor/switchgear electrician, a = additional labour (or contract labour) as required.

PREVENTIVE MAINTENANCE CHECK LIST FOR WATER SUPPLY SYSTEMS BUILDINGS, STRUCTURES AND EQUIPMENT

GROUP		DESCRIPTION	MAINTENANCE PERIOD	RESPONSIBILITY LEVEL	CREW	TASK TO BE PERFORMED	MATERIALS, SPARE PARTS, LUBRICANTS ETC, REQUIRED
III FILTRATION	K L	Rapid gravity Filters Pressure Filters	3 months	L	o	Inspect sanitary condition, disinfect inside of structure above level of sand bed	Hypochlorite (HTH) solution
			5 years	R,D,L	e,m,o,a	Overhaul: Remove filtering media, inspect laterals and strainers and repair as necessary. Disinfect inside walls. Wash, screen, disinfect filtering media and replace in filter adding new filtering media as necessary	Hypochlorite(HTH)solution, filter laterals and strainers as necessary, filtering media.
	M M	Filter valves & control Loss of Head Gauges	6 months	L	O	Examine filter valves and controls for correct functioning,repack glands as necessary.	Gland packing material
			2 years	R,D	e,m	Calibrate loss of head gauges and flow recorders by specialized contractor,paint all valves	Paint
	O	Air Blowers/ Compressors	1 day	L	O	Check motor and compressor bearings	
			1 year	D,L	m,el,o	Change lubricating oil/grease without dismantling, check alignment of coupling, examine and clean motor and switchgear contacts.	Lubricating oil/grease
			5 years	R,D,L	e,m el,O	Overhaul: Complete dismantling, cleaning and replacement of defective parts	Spare parts as required

KEY:

Level: L = Local, D = District, R= Region
Crew: e =engineer/technical officer, m = maintenance team, O = Plant operator , el = motor/switchgear electrician.

PREVENTIVE MAINTENANCE CHECK LIST FOR WATER SUPPLY SYSTEMS BUILDINGS, STRUCTURES AND EQUIPMENT

GROUP		DESCRIPTION	MAINTENANCE PERIOD	RESPONSIBILITY LEVEL	RESPONSIBILITY CREW	TASK TO BE PERFORMED	MATERIALS, SPARE PARTS, LUBRICANTS, ETC, REQUIRED
IV TREATED WATER PUMPING	A	Pump House	1 day	L	O	Clean and sweep floor, wipe and clean walls and piping, clean and sweep exterior site, tend lawn and garden	Cleaning materials
			2 years	D,L	e,m,o,s	Check and repair any leaks in roof, paint inside and outside walls and piping.	Building materials, paint.
	B	Fuel tanks	1 day	L	O	Check fuel level and refill if necessary.Record fuel consumed during day. Clean outside.	
			6 months	L	O	Drain and wash fuel tank, wash and clean filter, clear fuel tank vent pipe	
	C	Pumps	1 day	L	O	Record readings of suction and delivery gauges. Check packing glands to leak slightly during operation. Check tightness of nuts and bolts. Check lubrication of bearings	
			6 months	D,L	m,p,o.	Replace grease/oil in bearings without dismantling Check alignment of coupling. Replace packing in glands	Grease/oil Packing material
			3 years	R,D,L	e,m,p,o	Complete overhaul: Remove pump for overhaul in Regional workshops. Clean and replace all defective parts.	Spare parts as required

KEY:

Level: L= Local, D= District, R= Region
Crew: e= engineer/technical officer, m= maintenance team, o=plant operator, p=pump mechanic.

GROUP		DESCRIPTION	MAINTENANCE PERIOD	RESPONSIBILITY LEVEL	RESPONSIBILITY CREW	TASK TO BE PERFORMED	MATERIALS, SPARE PARTS, LUBRICANTS ETC, REQUIRED
IV TREATED WATER PUMPING	D	Diesel Engines	1 day	L	O	Check oil level and top up if necessary Lubricate all lubrications points. Record oil pressure, temperatures, speed and battery charge. Record working hours and total since last oil change/last overhaul. Clean outside parts, check nuts and bolts for tightness.	Lubricating oil
			1 week	L	O	wash and clean air filter	
			1 month	D,L	m,o	Dismantle injectors and test spray. Replace defective nozzles if necessary. Check and adjust V belt tension/ coupling alignment as applicable	Injector nozzles as necessary
			3 months	D,L	m,p,o	Clean and inspect injectors and valve Clearances. Check and clean oil filters. Fit new fuel filter elements. Check starting system. Change engine oil or in accordance with manufactures manual.	Fuel filter elements, engine lubricating oil.
			1 year	D,L	m,p,o	Check and regrind valves and adjust valve clearances. Clean deposits from cylinder heads and pistons. Dismantle clutch system,if applicable.	
			2 years	R,D,L	m,p,o	Remove engine for complete overhaul in Regional workshops. Replace with spare reconditioned engine	Spare parts as required

KEY:

Level: L= Local, D = District, R = Region
Crew: e = engineer/technical officer, m - maintance team, o = plant operator, p = pump/engine mechanic

PREVENTIVE MAINTENANCE CHECK LIST FOR WATER SUPPLY SYSTEMS BUILDINGS, STRUCTURES AND EQUIPMENT

GROUP		DESCRIPTION	MAINTENANCE PERIOD	RESPONSIBILITY LEVEL	RESPONSIBILITY CREW	TASKS TO BE PERFORMED	MATERIALS, SPARE PARTS, LUBRICANTS, ETC. REQUIRED
IV	E	Electric Motors	1 day	L	O	Check motor bearings	
			6 months	D,L	m,o	Check alignment of coupling, change lubricating oil/grease without dismantling.	Lubricating oil/grease
			5 years	R,D,L	m,el,o	Remove motor for complete overhaul at Regional workshops, replace with motor of similar type, if available.	Ball/roller bearings if necessary.
	F	Switchgear	1 day	L	O	Record voltage, current and kWhr meter	
			3 months	D	m,el	Check starter and clean contacts. Check setting of overload relays.	
			1 year	D	m,el	Clean/replace contacts as necessary. Calibrate measuring instruments	Starter contacts, if necessary.
	G	Measuring Instruments	3 years	R,D	e,m	Dismantle and send to specialized contractor for repair and calibration	
	H	Water meter meters	3 years	R,D	m	Dismantle and send to Regional workshops for repair and calibration	
	I	Mains	1 year	L	O	Check for leaks and repair, if necessary	
			3 years	D,L	m,o	Paint exposed pipes with anticorrosive paint	Anticorrosive paint
	J	Valves	1 year	L	O	Check valve gland and repack, if necessary.	Packing material

TREATED WATER PUMPING

KEY:

Level: L = local, D = District, R = Regional

Crew: e = engineer/technical officer, m = maintenance team, O = plant operator, el = motor/switchgear electrician.

PREVENTIVE MAINTENANCE CHECK LIST FOR WATER SUPPLY SYSTEMS BUILDINGS, STRUCTURES AND EQUIPMENT

GROUP		DESCRIPTION	MAINTENANCE PERIOD	RESPONSIBILITY LEVEL	RESPONSIBILITY CREW	TSAK TO BE PERFORMED	MATERIALS, SPARE PARTS, LUBRICANTS ETC REQUIRED
V STORAGE	A C D	Service Reservoirs Valves and Level gauges	1 month	L	O	Check float vlave, check leaks in piping and repair if necessary	
			1 year	D,L	m,o,a	Inspect structure. Drain reservoir, wash and clean inside and outside. Disinfect floor and walls with hypochlorite(HTH) solution. Check all valves, open and close and repair, if nece-sary. Check level gauges. Paint outside of steel reservoirs.	Hypochlorite (HTH) solution.Gland packing. Paint.
	B C D	Elevated Reservoirs Valves and Level gauges	1 month	L	O	Check float valve, check leaks in piping and repair, if necessary	
			1 year	D,L	m,o,a	Inspect structure. Drain reservoir, wash and clean inside and outside. Disinfect floor and walls with hypochlorite (HTH) solution. Check all valves, open and close and repair, if necessary. Check level gauge. Paint outside and supporting structure of steel reservoirs.	Hypochlorite (HTH) solution. Gland packing. Paint
	E	Water Master Meters	3 yeers	R,D	m	Dismantle and send to Regional workshops for repair and calibration	

KEY:
Level: L = Local, D= District, R = Regional
Crew: s= engineer/technical officer, m= maintenance team, o= plant operator, a = additional labour (contract labour), as necessary.

PREVENTIVE MAINTENANCE CHECK LIST FOR WATER SUPPLY SYSTEMS BUILDINGS, STRUCTURES AND EQUIPMENT

GROUP		DESCRIPTION	MAINTENANCE PERIOD	RESPONSIBILITY		TASK TO BE PERFORMED	MATERIALS, SPARE PARTS, LUBRICANTS, ETC, REQUIRED
				Level	Crew		
VI DIESEL ENGINE GENERATING SETS	A B C	Diesel engine Generator Switchgear	1 day	L	o	Check oil level and top up, if necessary Lubricate all lubricantion points. Record oil pressure, temperatures, speed and battery charge. Record working hours and total since last oil change/last overhaul. Clean outside parts. Check nuts and bolts for tightness. Check alternator bearings. Check fuel level in fuel tank and refill	Lubricating oil Fuel oil
			1 week	L	o	Wash and clean air filter	
			1 month	D,L	m,o	Dismantle injectors and test spray, Replace defective nozzles if necessary.	Injector nozzles
			3 months	D,L	m,p,el,o	Clean and inspect injectors, check valve clearances. Check and clean oil filters. Fit new fuel filter elements. Check starting system. Change engine oil or in accordance with manufacturers manual. Check switchgear and setting of overload relays	Fuel filter element Engine oil
			1 year	D,L	m,p,o	Check alignment of coupling. Check and regrind valves and adjust valve clearances. Clean deposits from cylinder heads and pistons	
			2 years depending on running hours	R,D,L	e,m,p,el,o	Overhaul: Complete dismantling, cleaning and replacement of defective parts	Spare parts as necessary

KEY:

Level: L=Local, D=District, R=Region
Crew: e=engineer/technical officer, m=maintenance team, p= engine/pump mechanic, el= electrician, o=plant operator.

PREVENTIVE MAINTENANCE CHECK LIST FOR WATER SUPPLY SYSTEMS BUILDINGS, STRUCTURES AND EQUIPMENT

GROUP	DESCRIPTION	MAINTENANCE PERIOD	RESPONSIBILITY LEVEL	RESPONSIBILITY CREW	TASK TO BE PERFORMED	MATERIALS, SPARE PARTS, LUBRICANTS ETC, TO BE USED
VII	Wind Mills	3 months	L	O	Clean adjacent area, cut tall grass	
		1 year	H,D,L	e,m,w,o,a	Clean casing and screens with appropriate tools and chemicals. Measure well output before and after cleaning, recording total flow and specific capacity. Change oil in gearbox. Examine superstructure for signs of corrosion and paint	Lubricating oil. Anti corrosion paint
		5 years	H,D,L	e,m,o,a	Complete overhaul: Dismantle pump and gearbox and recondition at Regional workshops	Spare parts, as necessary.

KEY:

Level: L = Local, D = District, H = Region.

Crew: e = engineer/technical officer, m = maintenance team, o = plant operator, a = additional labour (or contract labour) as required, w = special team for servicing deep wells.

WORKLOAD DISTRIBUTION BY QUARTERS

Form No. 12/W SHEET 1 OF 1

PROGRAMME YEAR 1986

WORK ACTIVITY		ANNUAL PROGRAMME			PLANNED MAN DAYS			
CODE	DESCRIPTION	CREW SIZE	CREW DAYS	MANDAYS	1st QUARTER	2nd QUARTER	3rd QUARTER	4th QUARTER
11/W	Clean intake externally	2	360	720	180	180	180	180
12/W	Clean intake adjacent area	4	48	192	48	48	48	48
21/W	Check and tighten gland packing	2	96	192	48	48	48	48
22/W	Grease pump bearings	2	4	8	2	2	2	2
23/W	Clean pump suction strainer	2	60	120	30	30	30	30
24/W	Clean pump suction lines	2	3	6	2	1	2	1
25/W	Record readings of pressure gauges	2	36	72	18	18	18	18
29/W	Grease motor bearings	2	4	8	2	2	2	2
31/W	Exercise valves	2	2	4	1	1	1	1
41/W	Clean and flush treatment plant	3						
42/W	Clean and lubricate all equipment in treatment plant	2						
51/W	Service air valves of pumping main	3	5	15	3	4	3	5
52/W	Open washouts of pumping main	2	8	16	4	4	4	4
53/W	Check leaks of pumping main	1	171	171	43	42	43	43
61/W	Service air valves of distribution	3						
62/W	Open washouts of distribution	2	5	10	3	3	2	2
63/W	Check leak of distribution	1	174	174	43	44	44	43
64/W	Check meters	2	1	2	1	1	-	-
71/W	Other maintenance			256	64	64	64	64
Total man days				1966	492	492	491	492
Required number of employees				7	7	7	7	7

Calculation of 220 working days per year and 56 working days per quarter except for continuous activities . see Form 7

QUARTERLY WORK SCHEDULE

Form No. 13/W PROGRAMME YEAR 1986

SHEET 1 OF 1

CODE	DESCRIPTION	CREW SIZE	QUARTERLY PROGRAMME		SEMI-MONTHLY MAN DAYS ASSIGNMENT					
			CREW DAYS	MAN DAYS	MONTH		MONTH		MONTH	
					1st 1/2	2nd 1/2	1st 1/2	2nd 1/2	1st 1/2	2nd 1/2
11/W	Clean intake externally	2	90	180	30	30	30	30	30	30
12/W	Clean intake adjacent area	4	12	48	8	8	8	8	8	8
21/W	Check and tighten gland packing	2	24	48	8	8	8	8	8	8
22/W	Grease pump bearings	2	1	2	2					
23/W	Clean pump suction strainer	2	15	30	5	5	5	5	5	5
24/W	Clean pump suction lines	2	1	2		2				
25/W	Record readings of pressure gauges	2	9	18	3	3	3	3	3	3
29/W	Grease motor bearings	2	1	2			2			
31/W	Exercise valves	2	0·5	1				1		
41/W	Clean and flush treatment plant	3	–	–						
42/W	Clean and lubricate equipment of plant	2	–	–						
51/W	Service air valves of pumping main	3	1	3					3	
52/W	Open washouts of pumping main	2	2	4				2		2
53/W	Check leaks of pumping main	1	43	43	7	7	7	8	6	8
61/W	Service air valves of distribution	3	–	–						
62/W	Open washouts of distribution	2	1·5	3		3				
63/W	Check leaks of distribution	1	1	43	8	6	8	6	9	6
64/W	Check meters	2	0·5	1			1			
71/W	Other maintenance			64	11	10	10	11	10	12
	Total			492	82	82	82	82	82	82

SEMI-MONTHLY ASSIGNMENT AND REPORT
(WORK SHEET)

Form No.14/W

ACTIVITY NO	QUARTER: / MONTH: 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		TOTAL DAYS
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
* 11/W	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2		30 of 2 crew
12/W										4	4						8 of 4 "
21/W 22/W 23/W	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2		15 of 2 "
22/W														2			2 of 2 "
53/W			1	1	1	1						1	1	1			7 of 1 "
63/W			1	1	1	1						1	2	1			8 of 1 "
other			2	2	2	2						2	1				11
TOTAL DAYS	3	3	7	7	7	7	3	3	3	7	7	7	7	7	3		

* These activities to be carried out by two crew throughout the year.

SEMI-MONTHLY WORK ASSIGNMENT AND REPORT

Form No. 15/W

QUARTER: FIRST MONTH: FIRST (JANUARY) SHEET 1 OF 2

WORK ACTIVITY / LOCATION	DATE		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		TOTAL	REMARK
			16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31		
CODE NO. 11/W DESCRIPTION: Clean Intake externally LOCATION :	Man-days	Maint. Crew	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2		30	To be carried daily
		Equip. opers.																		
	ACCOMPLISHMENT																		Nos.	
CODE NO: 21/W 23/W 25/W DESCRIPTION: Check gland packings Clean p. strainers Record readings of pressure gauges LOCATION :	Man-days	Maint. Crew	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2		15	These to be ed by single in mo of eve day
		Equip. opers.																		
	ACCOMPLISHMENT																		Nos.	
CODE NO: 22/W DESCRIPTION: Grease pump bearings LOCATION :	Man-days	Maint. Crew														2			2	
		Equip. opers.																		
	ACCOMPLISHMENT																		Nos	
CODE NO: 53/W DESCRIPTION: Check leaks of pumping main LOCATION :	Man-days	Maint. Crew			1	1	1	1						1	1	1			7	
		Equip. opers.																		
	ACCOMPLISHMENT																		KH	
TOTAL MAN DAYS	Man-days	Maint. Crew	3	3	4	4	4	4	3	3	3	3	3	4	4	6	3		54	
		Equip. opers.																		

SEMI-MONTHLY WORK ASSIGNMENT AND REPORT

Form No. 16/W

QUARTER: FIRST MONTH: FIRST (JANUARY) SHEET 1 OF 2

WORK ACTIVITY / LOCATION		DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15			TOTAL	REMARK
			16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31			
CODE NO. 11/W DESCRIPTION: Clean Intake externally LOCATION :	Man-days	Maint. Crew	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2			30	
		Equip. opers.																			
	ACCOMPLISHMENT																			30	
CODE NO: 21/W 23/W 25/W DESCRIPTION: Check gland packings clean p. strainer Record readings of pressure gauges LOCATION :	Man-days	Maint. Crew	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2			15	
		Equip. opers.																			
	ACCOMPLISHMENT																			15	
CODE NO: 22/W DESCRIPTION: Grease pump bearings LOCATION :	Man-days	Maint. Crew														2				2	
		Equip. opers.																			
	ACCOMPLISHMENT																			2	
CODE NO: 53/W DESCRIPTION: Check leaks of pumping main LOCATION :	Man-days	Maint. Crew			1	1	1	1						1	0 X	1				X 6	
		Equip. opers.																			
	ACCOMPLISHMENT																			30 KM	
TOTAL MAN DAYS	Man-days	Maint. Crew																			
		Equip. opers.																			

APPENDIX H

Training Resources on Maintenance Management

TRAINING RESOURCES ON MAINTENANCE MANAGEMENT

SELF STUDY COURSES ON MAINTENANCE MANAGEMENT

1. American Management Association

   Course Titles:

   1. How to Manage Maintenance
   2. Fundamentals of Inventory Management and Control

   Available From:

   American Management Association
   P.O. Box 319
   Saranac Lake, NY 12983
   (518) 891-5510

2. California State University

   Course Titles:

   1. Small Water System Operation and Maintenance
   2. Water Distribution System Operation and Maintenance
   3. Water Treatment Plant Operation
   4. Operation of Wastewater Treatment Plants
   5. Operation and Maintenance of Wastewater Collection Systems

   Available From:

   Office of Water Programs
   CSU, Sacramento
   6000 J Street
   Sacramento, CA 95819-2694
   (916) 278-6142 or 6366

3. Michigan State University

   Course Titles:

   1. Supervisory Management in the Water/Wastewater Field.
   2. Maintenance Management in the Water/Wastewater Field.

   Available From:

   Self-Study Course Coordinator
   7 Olds Hall
   Michigan State University
   East Lansing, MI 48824-1047
   (517) 353-8711

SOURCES OF TRAINING MATERIALS / BOOKS ON MAINTENANCE MANAGEMENT

1. American Water Works Association

American Water Works Association
6666 W. Quincy Avenue
Denver, Colorado 80235
(303) 794-7711

2. National Environmental Training Association

NETA
8687 Via de Ventura
Suite 214
Scotsdale, AZ 85258
(602) 951-1440

3. U.S. Environmental Protection Agency - Instructional Resource Center

Instructional Resource Center
1200 Chambers Road
Third Floor
Columbus, OH 43212
(614) 292-6717

4. Water and Sanitation for Health Project

1611 N. Kent Street
Arlington, VA 22209
(703) 243-8200

5. Water Pollution Control Federation

601 Wythe Street
Alexandria, VA 22314-1994
(703) 684-2400

APPENDIX I

Equipment/Distribution Inventory Worksheets--Sri Lanka

Form No. 3B

DATE 1-1-

INVENTORY SUMMARY SHEET : DISTRIBUTION SYSTEM

NAME OF THE SCHEME

NAME OF ROAD	LENGTH	PIPE		SPECIALS (NOS)							SERVICE CONNECTIONS									No of SP	No of sign boards
											DOMESTIC			COMMERCIAL			INDUSTRIAL				
	m.	Type	Dia mm	DIA inm.	SV	GV	WSV	DAV	SAV	FH	No	Size mm	No of meters	No	Size mm	No. of meters	No	Size mm	No of meters		
Noyse Rd.	1000	C.I	100	100	1		2				88	50		2	75	1				4	
														2	50						
Colombo Rd.	3100	C.I.	150	150	1						115	50		6	75					6	
														89	50						
St. Mary's Rd.	2780	C.I.	150	150	1		1				50	50								2	
Barbar Rd.	2360	C.I.	150	150	1						31	50		3	50					2	
Coraya Rd.	3640	C.I.	100	100	1		1				28	50		2	50					2	
Ferry Rd.	2260	C.I.	150	150	1						16	50		1	50					1	
Lane Rd.	2280	C.I.	150	150	1						18	50								1	
2nd Cross St.	2210	C.I.	150	150	1						15	50		3	50					1	
Bridge Rd.	4570	C.I.	100	100	1						23	50		2	50					2	
TOTAL	9210	C.I.	100	100	3						328	50		8	75					21	
	14990	C.I.	150	150	6									102	50						

50

INVENTORY WORK SHEET: DISTRIBUTION SYSTEM

NAME OF THE SCHEME :
NAME OF ROAD : Noyse Rd.

Form No. 3A/W

DATE : 1-1-86

DISTANCE		LENGTH	PIPE		SPECIALS (NOS)							SERVICE CONNECTIONS									No. of S.P	No of sign boards
												DOMESTIC			COMMERCIAL			INDUSTRIAL				
From	To	m	Type	Dia. mm	DIA mm	SV	GV	WSV	DAV	SAV	FH	No.	Size mm	No. of meters	No.	Size mm	No. of meters	No.	Size	No. of meters		
0	300	300	C.I.	100	100	1						25	50	-	2	75	1				2	
300	600	300	C.I.	100	100			1				30	50								1	
600	900	300	C.I.	100																		
900	1000	100	C.I.	100	100			1				33	50		2	50					1	
TOTAL		1000	C.I.	100	100	1		2				88	50		2 2	75 50	1				4	

INVENTORY WORK SHEET: DISTRIBUTION SYSTEM

NAME OF THE SCHEME :

NAME OF ROAD : Colombo Rd.

Form No. 3A/W

DATE: 1-1-86

DISTANCE		LENGTH	PIPE		SPECIALS (NOS)							SERVICE CONNECTIONS									No. of S.P	No of sign boards
												DOMESTIC			COMMERCIAL			INDUSTRIAL				
From	To	m	Type	Dia. mm.	Dia. mm.	SV	GV	WSV	DAV	SAV	FH	No.	Size	No. of meters	No	Size	No. of meters	No.	Size	No. of meters		
0	300	300	C.I.	150								10	50	—	6	75	-	-	-	-		-
300	600	300	C.I.	150	150			1				22	50	—	9	50	-	-		-	1	-
600	900	300	C.I.	150								15	50		7	50	-	-		-	1	
900	1200	300	C.I.	150								8	50		9	50	-	-		-	1	
1200	1500	300	C.I.	150	150	1						11	50		12	50	-	-		-	-	
1500	1800	300	C.I.	150								8	50		14	50					1	
1800	2100	300	C.I.	150								7	50		11	56					1	
2	2400	300	C.I.	150								10	50		12	50					1	
2400	2700	300	C.I.	150								13	50		7	50					1	
2700	3000	300	C.I	150								11	50		8	50					1	
3000	3100	100																				
TOTAL		3100	C.I.	150	150	1		1				115	50		6 99	75 50					6	

INVENTORY SUMMARY SHEET : GRAVITY / PUMPING MAIN

Form No. 2B / W

NAME OF THE SCHEME :

DATE : 1-1-86

LOCATION	LENGTH (m)	PIPE		SPECIALS (NOS)							SIGN BOARDS (NOS.)	REMARKS
		Type	Dia. (mm.)	DIA mm	SV	GV	BV.	WSV	DAV	SAV		
Dadunu Oya - Chillaw	7300	C.I.	175	175				3		3		
Eba-tank - Chillaw	9150	A.C.	200	200				3		8		

Form No. 2A/W

INVENTORY WORKSHEET : GRAVITY/ PUMPING MAIN

NAME OF THE SCHEME :

LOCATION : Eba tank to Chillaw town

DATE : 1-1-86

DISTANCE		LENGTH	PIPE		SPECIALS (NOS)							SIGN	REMARKS
From	To	(m)	Type	Dia. mm	DIA mm	SV	GV	BV	WSV	DAV	SAV	BOARDS	
0	2000	2000	A.C.	200	200				1		2		
2000	40000	2000	A.C.	200	200						1		
4000	6000	2000	A.C.	200	200				1		2		
6000	8000	2000	A.C.	200	200				1		2		
8000	9150	1150	A.C.	200	200						1		
TOTAL :		9150	A.C	200	200				3		8		

Form No. 2A/W

INVENTORY WORKSHEET : GRAVITY/ PUMPING MAIN

NAME OF THE SCHEME : -

LOCATION : Daduru Oya to chillaw town

DATE : 1-1-86

DISTANCE		LENGTH	PIPE		SPECIALS (NOS)							SIGN	REMARKS
From	To	(m)	Type	Dia. mm	DIA mm	SV	GV	BV	WSV	DAV	SAV	BOARDS	
0	2000	2000	C.I.	175					1		1		
2000	4000	2000	C.I.	175									
4000	6000	2000	C.I.	175					1		1		
6000	7300	1300	C.I.	175					1		1		
TOTAL :		7300	C.I.	175					3		3		

Form No. 1/W

INVENTORY NO.1 : HEAD WORKS AND STORAGE

NAME OF THE SCHEME :

DATE : 1-1-86

INTAKE	PUMP HOUSES Eba High Lift Pump House				TREATMENT PLANT	STORAGE FACILITIES
Location :	LOCATION AND TYPE :				Location :	Location :
Type :	PUMPS	NO. 1	NO. 2	NO. 3	NO. 4	Type :
Capacity:	Make	Sigmond	Sigmond			Capacity :
Other details	Model					Details of equipment :
	Total head (m)	110	110			Year of construction :
	Capacity (1) $m^3/hr.$	100	100			
	(11) kw					Location :
	Year of Install.	1968	1968			Type :
Location:	MOTOR / ENGINE	NO. 1	NO. 2	NO. 3	NO. 4	Capacity :
Type :	Make	Brooks	Brooks			Year of construction :
Capacity:	Model					Location:
Other details	Capacity (kw)	30	30			Type :
	Year of Install.	1968	1968			Capacity :
	OTHER EQUIPMENTS: 6 Nos. Valves					Details of equipment :
						Location:
						Type :
						Capacity:
						Year of construction :

INVENTORY NO.1 : HEAD WORKS AND STORAGE

Form No. 1/W

NAME OF THE SCHEME : _ .

DATE : 1-1-86

INTAKE

Location : Eba tank

Type : Direct

Capacity : 2200 M^3

Other details

Location : Daduru Oya

Type : Direct

Capacity : 3500 M^3

Other details

PUMP HOUSES

LOCATION AND TYPE : Daduru Oya High Lift Pump House

PUMPS	NO. 1	NO. 2	NO. 3	NO. 4
Make	Sigmond	Sigmond		
Model				
Total head (m)	95	95		
Capacity (1) $m^3/hr.$	90	90		
(11) kw				
Year of Install.	1962	1962		

MOTOR / ENGINE	NO. 1	NO. 2	NO. 3	NO. 4
Make	Brooks	Brooks		
Model				
Capacity (kw)	22	22		
Year of Install.	1962	1962		

OTHER EQUIPMENTS : 6 Nos Valve

TREATMENT PLANT

Location :

Type :

Capacity :

Details of equipment :

Location :

Type :

Capacity :

Details of equipment :

STORAGE FACILITIES

Location : Chillaw town

Type : Tower

Capacity : 1000 M^3

Year of construction : 1968

Location : Daduru Oya

Type : 3 Nos Sumps

Capacity : 250 M^3

Year of construction : 1967

Location :

Type :

Capacity :

Year of construction :

APPENDIX J

Equipment ID Numbering System
Used in U.S. Wastewater Treatment Plants

Table 1. FUNCTIONAL NUMBER SYSTEM

100 Raw Wastewater Station
- 110 Screening
  - 111 Bar Screens
  - 112 Conveyors
- 120 Grinding
  - 121 Grinders
- 130 Wastewater Flow
  - 131 Pumping
  - 132 Valves and Gates
  - 133 Wet Well Level Control
  - 134 Flow Measurement
  - 135 Pump Seal Water
  - 136 Compressed Air
- 140 Auxiliary Services
  - 141 Sump Pumping
  - 142 Ventilation
  - 143 Hoists
  - 144 Electrical Supply

200 Primary Treatment
- 210 Primary Settling
  - 211 Tanks and Gates
  - 212 Sludge Collectors
  - 213 Scum Launders
- 220 Sludge Handling
  - 221 Pumping
  - 222 Pump Seal Water
  - 223 Flow Measurement
  - 224 Sludge Degritting
- 230 Scum Handling
  - 231 Pumping
  - 232 Pump Seal Water
  - 233 Scum Well Level Control
- 240 Auxiliary Services
  - 241 Sump Pumping
  - 242 Ventilation
  - 243 Hoists
  - 244 Electrical Supply

300 Secondary Treatment
- 310 Aeration
  - 311 Tanks and Gates
  - 312 Adjustable Weirs
  - 313 Tank Air Diffusers
  - 314 Incremental Feed Channel Air Diffusers
  - 316 Tank and Feed Channel Water Sprays
  - 316 Mixed Liquor Flow Measurement
  - 317 Diffuser Sock Washing
- 320 Air Delivery
  - 321 Filters
  - 322 Blowers
  - 323 Flow Measurement
  - 324 Pressure Relief
  - 325 Channel Sparger Air Delivery
  - 326 Compressed Air
- 330 Secondary Clarifiers
  - 331 Mixed Liquor Channel Air Spargers
  - 332 Mixed Liquor Channel Water Sprays
  - 333 Clarifier Mechanism and Gates
- 340 Chemical Treatment
  - 341 Flocculant Mixing
  - 342 Flocculant Pumping
- 350 Return Sludge
  - 351 Pumping
  - 352 Pump Seal Water
  - 353 Return Sludge Wet Well Level
  - 354 Dewatering
  - 355 Flow Measurement
- 360 Excess Sludge
  - 361 Pumping
  - 362 Pump Seal Water
  - 363 Flow Measurement
  - 364 Dilution
- 370 Scum
  - 371 Scum Well Level Control
  - 372 Scum Pumping
- 380 Auxiliary Services
  - 381 Sump Pumping
  - 382 Ventilation
  - 383 Hoists
  - 384 Electrical Supply

400 Chlorination and Effluent Flow
- 410 Chlorination
  - 411 Chlorine Handling and Weighing
  - 412 Evaporation
  - 413 Chlorinators
  - 414 Chlorine Detection and Venting
  - 415 Injectors and Diffusers
  - 416 Contact Chambers
- 420 Residual Chlorine Analysis
  - 421 Analyzers
  - 422 Influent Sampling
  - 423 Effluent Sampling
- 430 Effluent Water
  - 431 Weirs and Gates
  - 432 Level Measurement
  - 433 Return Water Pumping, High Lift
  - 434 Return Water Pumping, Low Lift
  - 435 Pump Seal Water
- 440 Auxiliary Services
  - 441 Sump Pumping
  - 442 Ventilation
  - 443 Hoists
  - 444 Electrical Supply

Table 1 (continued). FUNCTIONAL NUMBER SYSTEM

500 Sludge and Scum Processing
- 510 Auxiliary Services
  - 511 Sump Pumping
  - 512 Ventilation
  - 513 Hoists
  - 514 Electrical Supply
- 520 Sludge Thickening
  - 521 Thickeners
  - 522 Pumping
  - 523 Flow Measurement
  - 524 Chlorination
  - 525 Compressed Air
- 530 Sludge Storage and Handling
  - 531 Sludge Storage Tank
  - 532 Screw Feeders
  - 533 Pumps
  - 534 Conveyors
  - 535 Flow Measurement
  - 536 Flushing Water
  - 537 Hydraulic Power
  - 538 Sump Pumping
- 540 Scum Handling
  - 541 Weir Control
  - 542 Pumping
- 550 Lime Treatment
  - 551 Dry Lime Storage Tank
  - 552 Level Indication
  - 553 Vibration
  - 554 Dust Collection
  - 555 Dry Lime Feeding
  - 556 Lime Mixing
  - 557 Lime Slurry Pumping
- 560 Ferric Chloride Treatment
  - 561 Storage Tanks
  - 562 Compressed Air Supply
  - 563 Day Tanks
  - 564 Pumping
- 570 Polymer Treatment
  - 571 Mixing
  - 572 Pumping
- 580 Sludge Conditioning
  - 581 Conditioning Tanks
- 590 Vacuum Filtration
  - 591 Vacuum Pumping
  - 592 Filtering
  - 593 Filter Agitation
  - 594 Filtrate Pumping

600 Incineration
- 610 Incinerators
  - 611 Mechanisms
- 620 Gas Supply
  - 621 Oil Supply
  - 631 Shutoff
  - 632 Filtration
  - 633 Pumping
  - 634 Flow Rate
- 640 Air Supply and Foul Gases
  - 641 Cooling Air
  - 642 Combustion Air
  - 643 Fuel Gas Delivery
- 650 Scrubbing
  - 651 Scrubbers
  - 652 Flush Water
  - 653 Exhaust Fans
- 660 Ash Handling
  - 661 Elevators
  - 662 Conveyors
  - 663 Storage
  - 664 Conditioning
  - 665 Feeding
- 670 Auxiliary Services
  - 671 Sump Pumping
  - 672 Ventilation
  - 673 Hoists
  - 674 Electrical Supply

700 Utilities and Services
- 710 Recorders and Meters
  - 711 Flow
  - 712 Pressure
  - 713 Level
  - 714 Concentration
  - 715 Electrical and Position
- 720 Laboratory Facilities
  - 721 Lab Equipment
- 730 Plant Service Equipment
  - 731 Plant Water
  - 732 Heating
  - 733 Hot Water
  - 734 Lighting
- 740 Outside Utility Supply
  - 741 Electricity
  - 742 Gas
  - 743 County Water
- 750 Maintenance & Repair Facilities
  - 751 Machine Shop
  - 752 Mechanical Shop
  - 753 Electrical Shop
- 760 Buildings and Grounds
- 770 Safety Equipment
  - 771 Fire Extinguishers
  - 772 Hydrants
  - 773 Emergency Lighting
  - 774 First Aid Equipment

Table 2. SAMPLES FROM EQUIPMENT CONFIGURATION LIST

ID	Equipment Name	Type	Location	
520 SLUDGE THICKENING				
521 Thickeners				
52111	Sludge Thickener No. 1	11	J	N
52112	Sludge Thickener No. 2	11	J	S
52121	Gear Motor No. 1	31	J	N
52122	Gear Motor No. 2	31	J	S
52131	Chain Drive No. 1	41	J	N
52132	Chain Drive No. 2	41	J	S
52141	Gear Reducer, No. 1	41	J	N
52142	Gear Reducer, No. 2	41	J	S
52151	Ventilator, No. 1 Thickener	72	J	N
52152	Ventilator, No. 2 Thickener	72	J	S
52161	Control, No. 1	33	J	N
52162	Control, No. 2	33	J	S
522 Pumping				
52211	Duplex Plunger Pump No. 1	22	J L	NW
52212	Duplex Plunger Pump No. 2	22	J L	NE
52213	Duplex Plunger Pump No. 3	22	J L	SW
52214	Duplex Plunger Pump No. 4	22	J L	SE
52221	Motor, Pump No. 1	31	J L	NW
52222	Motor, Pump No. 2	31	J L	NE
52223	Motor, Pump No. 3	31	J L	SW
52224	Motor, Pump No. 4	31	J L	SE
52231	Variable Speed Reducer, No. 1	41	J L	NW
52232	Variable Speed Reducer, No. 2	41	J L	NE
52233	Variable Speed Reducer, No. 3	41	J L	SW
52234	Variable Speed Reducer, No. 4	41	J L	SE
52241	Gear Drive, No. 1	41	J L	NW
52242	Gear Drive, No. 2	41	J L	NE
52243	Gear Drive, No. 3	41	J L	SW
52244	Gear Drive, No. 4	41	J L	SE
52251	Reduction Gear No. 1	41	J L	NW
52252	Reduction Gear No. 2	41	J L	NE
52253	Reduction Gear No. 3	41	J L	SW
52254	Reduction Gear No. 4	41	J L	SE
52261	Control, No. 1	33	J L	NW
52262	Control, No. 2	33	J L	NE
52263	Control, No. 3	33	J L	SW
52264	Control, No. 4	33	J L	SE
523 Flow Measurement				
52311	Thickened Sludge Magnetic Flowmeter	61	J L	
52321	Flow Transmitter	61	J L	
52331	Influent Sludge Channel Level Recorder	63	J O	W

Location areas (refer to pages 5 and 6):

J = sludge thickening
L = plant shop and service building
O = outside

Table A-1. EQUIPMENT TYPE CLASSIFICATION

10	Tanks and Tank Equipment
11	Tanks, Channels, Bins
12	Slide Gates, Sluice Gates
13	Sludge and Scum Collectors
14	Weirs
20	Pumps, Compressors, Blowers
21	Centrifugal Pumps
22	Piston Pumps
23	Gear, Vane, Screw, Diaphragm Pumps
24	Air Compressors
25	Air Blowers
26	Sump Pumps
27	Submersible Pump/Drive Assemblies
28	Vacuum Pumps
30	Electrical Equipment
31	Motors, Motor and Drive Assemblies
32	Supply Panels and Boxes
33	Controls
34	Transformers, HV Power Supplies
35	Delays, Relays, Timers
40	Mechanical Equipment
41	Drives and Bearings
42	Hoists and Cranes
43	Conveyors
44	Special Equipment
50	Hydraulic and Pneumatic Components
51	Strainers, Filters, Screens
52	Heat Exchangers, Evaporators
53	Diffusers, Injectors, Nozzles
54	Valves, Dampers
55	Pressure Reducers, Relief Devices
56	Silencers, Scrubbers
57	Mixers, Agitators, Vibrators
58	Chlorinators, Feeders
59	Hydraulic Power Components
60	Measurement and Control
61	Flowrate Transducers
62	Pressure Transducers
63	Level Transducers and Controls
64	Analyzers
65	Scales
66	Meters, Alarms, Recorders
67	Float, Pressure, and Limit Switches
70	Plant Service Equipment
71	Fire Extinguishers
72	Heaters, Ventilators
73	Laboratory Equipment

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67	Float, Pressure, and Limit Switches
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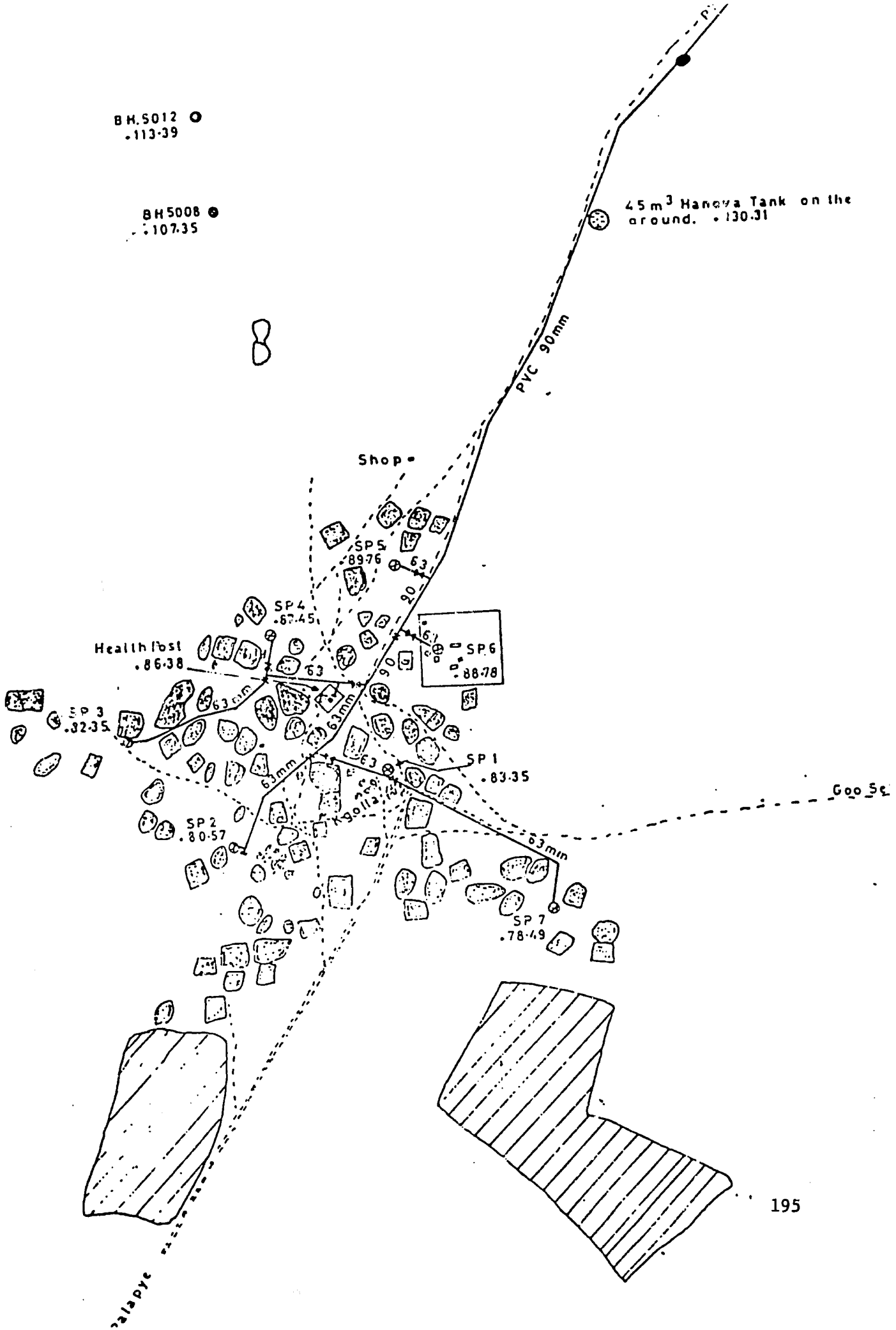
72	Heaters, Ventilators
73	Laboratory Equipment

APPENDIX K

Distribution System Maps


BH.5012
.113·39
BH5008
.107.35
45 m3 Hanova Tank on the
ground. .130.31
PVC 90mm
Shop
SP5
.89·76
63
90
SP4
.87.45
Health Post
.86·38
63
90
SP6
.88·78
63mm
SP3
.82·35
63mm
63mm
63
SP1
.83·35
90
SP2
.80·57
63mm
SP7
.78·49
Goo Se

COMPREHENSIVE MAPS

PURPOSE:

An overall view of the water system

TYPES:

1. Distribution
2. Transmission
3. Pressure
4. Index
5. Combination (one or more of the above)

MATERIAL:

Original - Heavy tracing cloth
Prints - Black line preferred

USE ACCURATE BASE - EXAMPLE:

County plats, U.S. geological survey quadrangle maps

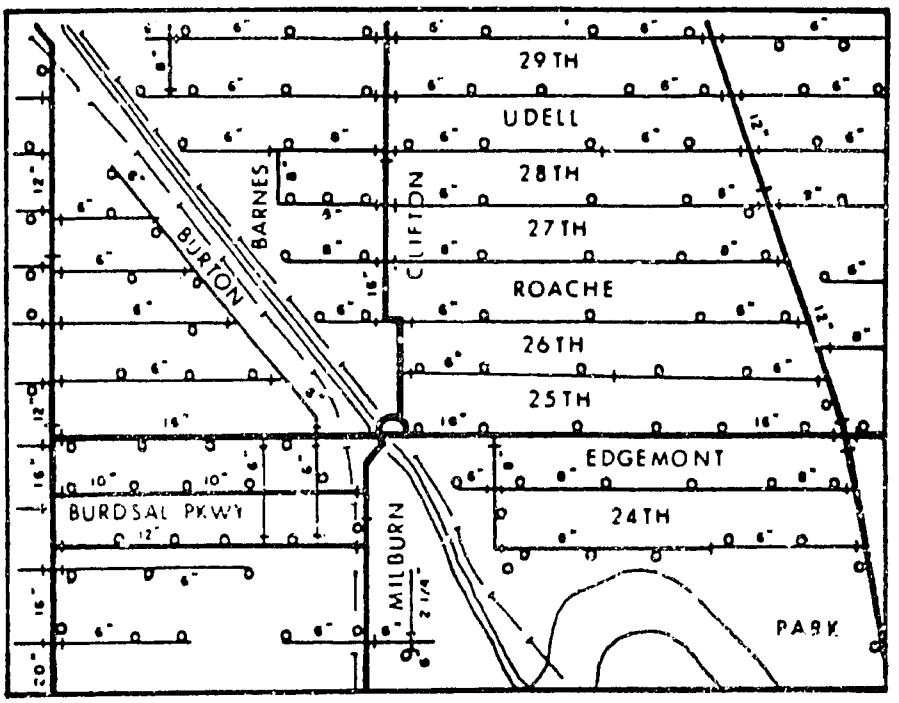
SCALE:

Preferred scale - 500 ft. per in.
Maximum scale - 1,000 ft. per in.

ITEMS TO BE SHOWN ON MAP:

Street names
Sizes of mains
Fire hydrants
Valves
Wells & sources
Tanks & storage
Orientation arrow
Scale
Date last corrected
Index key for sectional maps
Reproducible

PORTION OF COMPREHENSIVE MAP



SECTIONAL MAPS

PURPOSE:

A more detailed picture of the Distribution System. Area covered will range from 1/8 to 1/2 section.

MATERIAL: Original - heavy tracing cloth; Prints - black line preferred

SIZE OF PLATS:

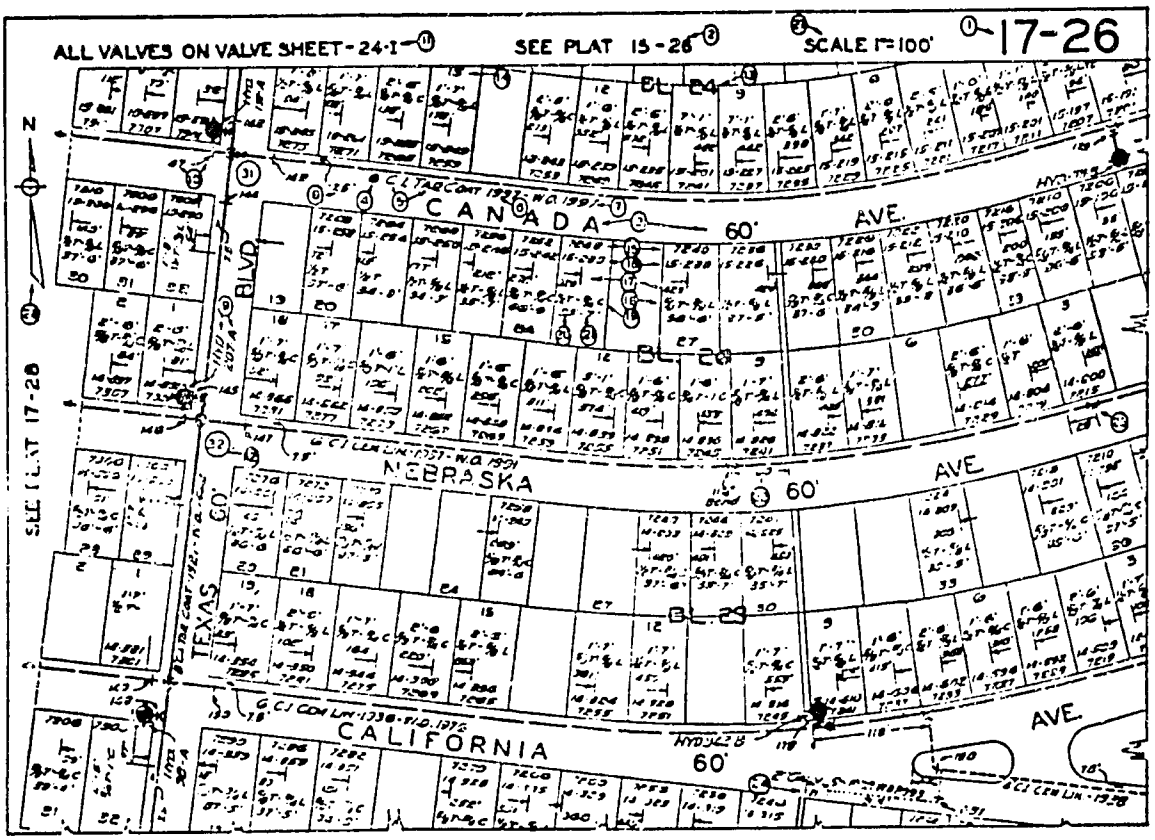
20 x 25 in. or 26.4 x 26.4 in., plus margins 2 to 3 in. wide
50 ft. per in. in congested areas
100 ft. per in. in residential areas
200 ft. per in. in rural areas

ACCURATE BASE - EXAMPLE: County Assessor's maps

ITEMS TO BE SHOWN ON PLATS:

- Plat designation or number
- Adjacent plat numbers
- Street names
- Mains and sizes
- Material of main
- Fire hydrants, numbers and classifications
- Valves and numbers (omit valve sheet designation)
- Valve sheet designation shown in margin
- Intersection numbers (if valve intersection plats are used)
- Block numbers
- Lot numbers
- House numbers
- Water account numbers
- Sizes of taps
- Sizes and materials of service lines
- Date last corrected
- Orientation or north arrow
- Scale
- Additional information if space allows:
  - Distance from property line to mains and services
  - Distance from mains to property stor

PORTION OF SECTIONAL PLAT



VALVE, HYDRANT AND INTERSECTION RECORDS

PURPOSE:

Provide detail information of an installation

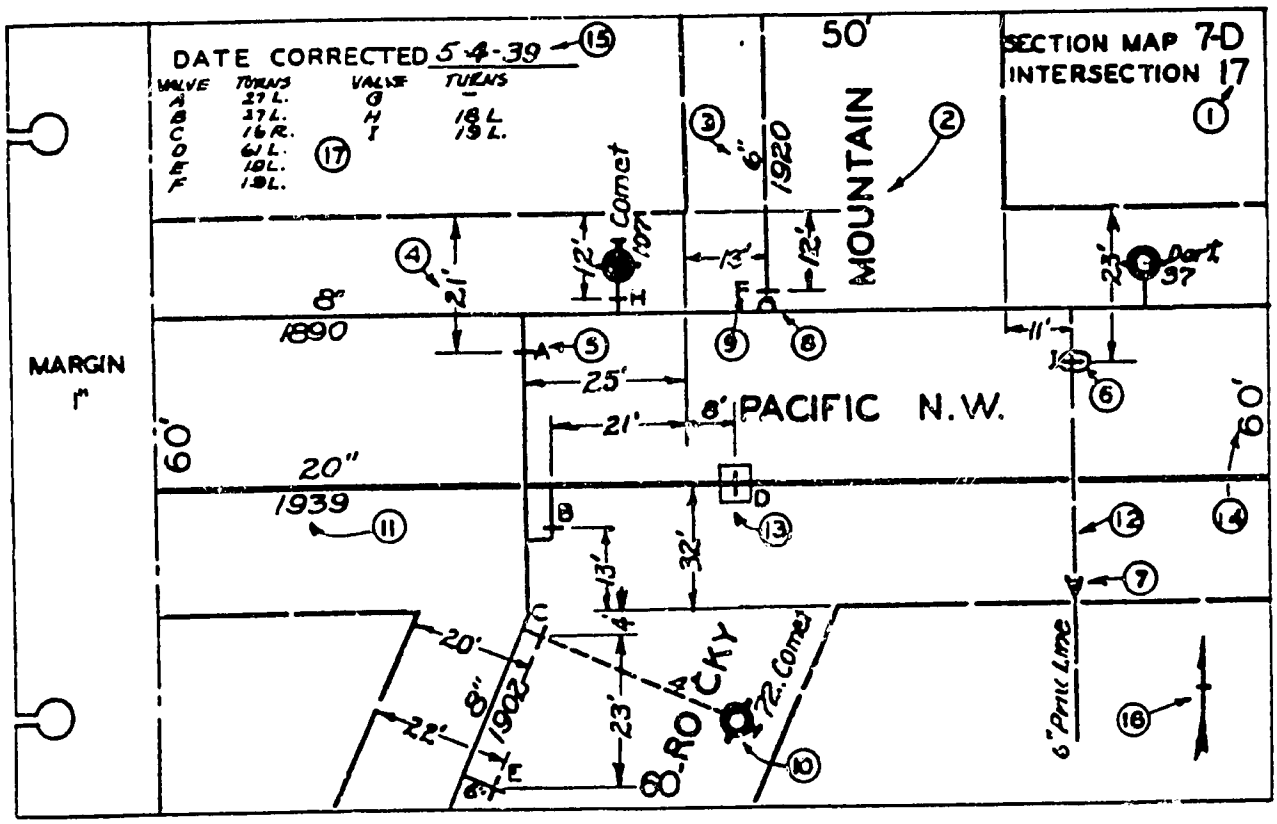
TYPES:

1. Cards:
   - Card for each
   - Location, size, brand and model
   - Installation date
   - Number of turns
   - Maintenance and inspection record

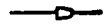
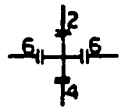
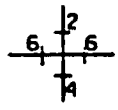
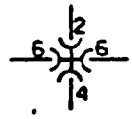
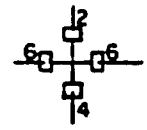
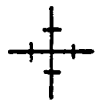
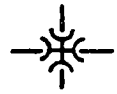
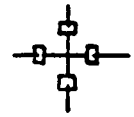
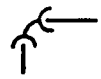
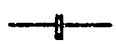
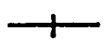
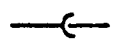
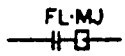
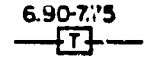
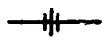
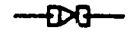
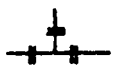
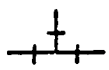
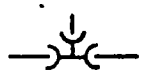
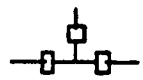
2. Maps:
   - Detail drawing of each
   - Scale: 2' to 20' = 1"
   - Engineer and profile "as builts" can be utilized
   - Photographs

3. Combination:
   - Cards and maps

VALVE INTERSECTION PLAT



PIPE SYMBOLS — MODERN ELECTRIC WATER COMPANY

FITTING	FLANGED	SCREWED	A.C. (BELL & SPIGOT)	MECHANICAL JOINT
BUSHING				
END CAP				
CROSS				
REDUCING				
STRAIGHT				
ELLS				
45°				
90°				
JOINTS (COUPLINGS)				DRESSER 
VARIATIONS	 FL-MJ		 FL-AC (ADAPTER)	 6.90-7.15 (TRANSITION)
UNION				
REDUCING FLANGE				
REDUCER				
TEES				
REDUCING				
STRAIGHT				
VALVES				
GATE				
			FL AC	FL MJ
COCK				
FIRE HYDRANTS				
4"				
6"				
6" WITH PUMPER PORT				

APPENDIX L

System Equipment Forms--Botswana

DEPARTMENT OF WATER AFFAIRS

	Area Service Station	104 B
To be filled in triplicate		

BOREHOLE EQUIPMENT SPECIFICATION (to be attached to each application form)

	Official Use
A Borehole owner's Name ..... B H/Official No..... or Syndicate Chairman Location ..... District	
B ENGINE Year of manufacture..... Model/Make ..... Serial No..... HP/kw ..... R.P.M ..... Shaft dia ..... Pulley dia.....	
C POWER HEAD Rising Main dia ..... Model/Make ..... Number of Pipe..... Pulley dia ..... Cylinder size ..... Strokes/min'..... Pump Rod size.....	
D MONO HEAD Raising Main dia ..... Type ..... Number of Pipe..... Pulley dia ..... Pump Elements size..... Mono shaft size.....	
E PUMP Type ..... Make..... Size	
F BELT Type of Belt ..... Size	
G RESERVOIR Tank capacity ..... m³ Type	
H WATER METER Fitted ☐ Yes ☐ No Type Working ☐ Yes ☐ No	

Please fill in as accurately as possible. Correct information is of the utmost importance. Add supplementary information about borehole history if any.

_____ DISTRICT WATER DEPARTMENT.

Engine History sheet

Engine type:_____ Number:_____ R.P.M.:_____ year:_____

Date	Place	Bh. no.	Hours run	Nature of work	Parts	no.	office us

DISTRICT COUNCIL WATER MAINTENANCE UNIT

Place _____ Borehole No _____

Month _____ 19 Type of engine _____

Operator _____ Engine No. _____

LOG OF PUMPING PLANTS

Date	OPERATION OF ENGINE							Received quantity		Consumption		Delivery of water			Remarks, work carried out, breakdowns etc
	Start	Stop	Start	Stop	Start	Stop	Hours of operation	Diesel l	Oil l	Diesel l	Oil l	Water meter before start	Water meter after stop	Pumped Quantity	
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
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24															
25															
26															
27															
28															
29															
30															
31															
GRAND TOTAL															

CONSUMPTION OF DIESEL & OIL	DIESEL	OIL
Balance from previous month		
Received during the month		
Total		
Total used during the month		
Balance		

OPERATION AND YIELD	
Delivery of water m³	
No. of hours operated this month	
Yield (m³ water — hours operated)	
Consumption of fuel (ml ÷ m³ water)	
Consumption of oil (ml ÷ hours operated)	

WATER LEVEL		
Date	During Operation	After stop (3 hours)

Remarks by San Operator		Remarks by OH in charge	
Sign	Date	Sign	Date

Figure 2.