FEDERAL DEMOCRATIC REPBULIC OF ETHIOPIA

MINISTRY OF WATER AND ENERGY

OPERATION AND MAINTENANCE MANUAL

For

Urban WATER UTILITIES

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1 INTRODUCTION

1.1 GENERAL

Experiences indicate that failure to give sufficient consideration for operation and maintenance during **planning**, **construction** and **operation** stages resulted in early system failure and rapid deterioration of many water supply schemes. To improve the existing weak operation and maintenance systems of the water supply services, the water supply and sanitation improvement program has given due attention. In line with this, this manual for the Operation and Maintenance of the major components of the Utility has been prepared.

The manual contains all round tasks related to the improvement of operation and maintenance management of water supply schemes categorized under urban water supply utilities. The purpose of this manual is to provide an official guidance for the utilities on concepts, practices and procedures that apply to the operation and maintenance of town water utilities.

The majority of the contents are extracted from standard manuals widely practiced for Urban Water Supply systems, which are adjusted to suit common water works and applicability of responsibilities to the system parts and components in the country. Every town water supply utility shall improve the knowledge of the personnel and formally verify that the user has conceived the manual through formal and informal trainings.

This manual briefly describes objectives, scope, definitions, procedures and overall activities involved in the operation and maintenance of urban water supply system units, parts and equipment.

1.2 OBJECTIVES OF OPERATION AND MAINTENANCE

The objective of an efficient operation and maintenance of a Water Supply System is to provide safe and clean drinking water in adequate quantity and desired quality, at adequate pressure at convenient location and time and as economically as possible on a sustainable basis.

1.3 NATIONAL WATER RESOURCES MANAGEMENT POLICY AND STRATEGY

1.3.1 Policy Provisions Related to Operation and Maintenance

The major provisions in National Water Resource Management policy which directly or indirectly affect Operation maintenance are as indicated under the following points.

1. General Goal of the policy

i. The overall goal of Water Resources Policy is to enhance and promote all national efforts towards the efficient, equitable and optimum utilization of the available Water Resources of Ethiopia for significant socioeconomic development on sustainable basis.

2. Allocation and apportionment of Water

i. Recognize that the basic minimum requirement, as the reserve (basic human and livestock needs, as well as environment reserve) has the highest priority in any water allocation plan.
ii. Ensure that water allocation gives highest priority to water supply and sanitation while apportioning the rest for uses and users that result in highest socio-economic benefits.
iii. Enhance and encourage water allocation that is based on efficient use of water resources that harmonizes greater economic and social benefits.

3. Watershed Management

i. Promote practices of efficient and appropriate watershed management to maximize water yields and quality.
ii. Ensure that watershed management practices constitute an integral part of the overall water resources management.

4. Water Resources Protection

i. Create appropriate mechanisms to protect the water resources of the country from pollution and depletion so as to maintain sustainable development and utilization of water resources.
ii. Establish standards and classification for various uses of water in terms of quality and quantity for different scenarios including limits and ranges for desirable and permissible levels.
iii. Establish procedures and mechanisms for all actions that are detrimental to water resources including waste discharges, source development, catchment management etc.

5. Water Resources Conservation

i. Conserve water resources through the integration of appropriate measures in the main water use categories.

6. Standards and Design Criteria

i. Formulate and adopt national standards and criteria for the design, installation, construction, operation, maintenance, inspection and other activities in all water resources management undertakings.

7. Ownership, Operation and Maintenance

i. Promote the establishment of integrated operation and maintenance framework that provide reliable and sustainable water supply systems in all the regions.
ii. Ensure that all studies and development activities undertaken by External Support Agencies, Loans, Non-Governmental Organizations and Government incorporate self-

financing plans and self-supporting budget for reliable operation and maintenance purposes.

iii. Develop guidelines and procedures for inspection, preventive, routine and curative maintenance services and for training of technicians as well as develop a network of monitoring systems.

iv. Promote the direct involvement of communities, particularly women, in the operation and maintenance of water systems.

v. Promote that operation and maintenance of water systems is based on decentralized approach, which enhances sustainability.

vi. Ensure that the system of ownership of water supply systems recognizes the local objective realities on the ground, and involvement of the users and other stakeholders, as well as be based on conducive conditions for sustainable management.

8. Development of Information Management System

i. Develop a coherent, efficient and streamlined process of information management in the water sector consisting of:-

a. defining and incorporating:- data collection, processing, analysis and dissemination,

b. determine the requirements of:- human, technology, data and financial resources,

c. identifying the users typography, information requirements,

d. defining information requirements of users,

e. identifying sources of information

ii. Recognize the link between properly managed water resources and the availability of viable information systems and to develop a practical, coherent, well designed and smoothly functioning Ethiopian Water Resources Information Systems (EWRIS), by establishing the Ethiopian Water Resources Information Center (EWRIC).

9. Water Pricing

i. Recognize water as a vulnerable and scarce natural resource and ensure and promote that all pricing systems and mechanisms should be geared towards conservation, protection and efficient use of water as well as promote equity of access.

ii. Promote that tariff setting shall be site specific, depending on the particulars of the project, location, the users, the cost and other characteristics of the schemes.

iii. Ensure that pricing for urban water supplies shall aim at full cost recovery and develop cross-subsidization strategies and promote credit services.

iv. As willingness to pay by users of water systems is a powerful impetus for financial sustainability of water resources systems, willingness to pay shall be promoted by, stating the main objectives, instituting fairness in water systems, promoting transparency and communications.

10. Ground Water Resources

i. Identify the spatial and temporal occurrence and distribution of the country's ground water resources and ensure its utilization for the different water uses. provide special focus for those areas vulnerable to drought and water scarcity.
ii. Ensure that the exploitation of ground water shall be based on abstraction of the maximum amount equal to the sustainable yield as determined by competent authorities and establish regulatory norms.
iii. Establish and develop norms, standards and general guidelines for sustainable and rechargeable management of ground water .
iv. Foster conjunctive use of surface and groundwater as appropriate.
v. Promote implementation of appropriate technologies suitable for water deficient areas in order to mitigate water scarcity problems.

11. Water Quality Management

i. Develop water quality criteria, guidelines and standards for all recognized uses of water and ensure their implementation.
ii. Formulate receiving water quality standards and legal limits for pollutants for the control and protection of indiscriminate discharges of effluents into natural water courses.
iii. Develop appropriate water pollution prevention and control strategies pertinent to the Ethiopian context.

12. Institutional Framework.

i. Promote appropriate linkage mechanisms for the coordination of water resources management activities between the Federal and Regional Governments.
ii. Establish water resources management institutions for sustainable development and management of the water sector.
iii. Avoid or minimize institutional instability in order to maintain sufficiently skilled manpower and as appropriate, to enhance a coherent institutional framework that allows the necessary flexibility and accommodates continuity in times of change.
iv. Foster the participation of user communities in water resources management by supporting the establishment of appropriate institutional framework from regional to the lowest administrative structure and promote decentralized management.
v. Establish phase-by-phase Basin Authorities, for efficient, successful and sustainable joint management of the water resources of the basins through concerted efforts of the relevant stakeholders.
vi. Put in place conducive situations for the establishment and sustainability of appropriate Federal level agencies for study, design, and engineering and construction supervision.

vii. Create conducive environment for the enhancement of linkages and partnership between the Federal and Regional states on the basis of the constitution for the realization of efficient, sustainable and equitable water resources management.

13. Capacity Building

i. Provide sustainable and objective oriented training on the relevant areas of water resources management as well as develop and implement effective means in order to efficiently utilize and sustainable retain trained manpower.

ii. Device appropriate strategies for the development and enhancement of local capacity in consultancy and construction through different incentive mechanisms.

iii. Provide the necessary capacity building, as much as conditions permit, to the regions, with special emphasis to the underdeveloped regional states, for efficient and equitable water resources management.

iv. Build policy review, reform and implementation capacity on sustainable basis.

14. Legislative Framework

i. Water being the common property of all Ethiopians, to formulate water resources legislation that allows all citizens to have access for water based on the rules and regulations of the government.

ii. Provide the legal basis for active and meaningful participation of all stakeholders, including water users' associations, the community and particularly for women to play the central role in water resources management activities.

iii. Provide the necessary legal framework for penalties commensurate with the violation of legal provisions relating to water resources in order to produce deterrent effects.

1.3.2 Strategy Provisions Related to Operation and Maintenance

Similar to provisions in National Water Resource Management policy, major points in the Ethiopian Water Resources Sector Strategy specially indicted in Water Supply and Sanitation Strategy which directly or indirectly affect Operation maintenance are as indicated under the following points.

1. Objectives Water Supply and Sanitation Strategy

i. The principal objective of the strategy is to secure basis for the provision of sustainable, efficient, reliable, affordable and users-acceptable WSS services to the Ethiopian people, including livestock watering, in line with the goals and objectives of relevant national and regional development policies.

2. Main Elements of the Water Supply and Sanitation Strategy

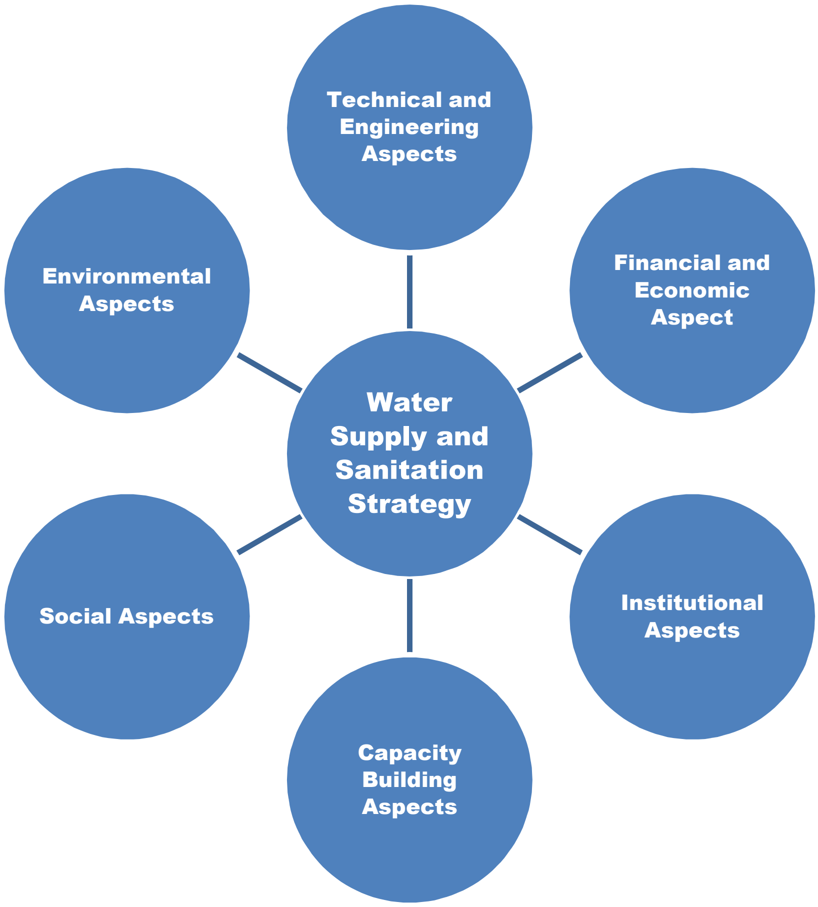


Figure 1: Diagrammatical Representation for Pillars of strategy for Water Supply and Sanitation

Major points which are related to Operation and Maintenance under each of the above elements are as indicated here below;

3. Technical and Engineering Aspects

i. Identify and promote the development of appropriate, efficient, effective, reliable and affordable WSS technologies which are demand driven and have great acceptability among the local communities. Facilitate local level decision making in choice of technology by presenting a comprehensive analysis and evaluation of available technological options to the local populations.

ii. Develop national standards, specifications and design criteria which are rational, affordable, acceptable, implementable and sustainable for the design, installation, implementation, operation, maintenance and inspection of the WSS systems. These are to be based on internationally recognized norms and to be in conformity with the socio-economic, historical, geographical and cultural factors of Ethiopia.

iii. Develop appropriate procedures and standards to determine and evaluate water requirements, types of water sources and services that can be made available, and service levels to be achieved by taking into account parameters related to desirable levels, permissible limits, specifications, minimum and maximum levels, etc. Describe these procedures in the form of manuals for ease of application.

iv. Formulate procedures and processes to carry out routine and specialized O&M activities for different types of WSS systems. Prepare manuals to facilitate and guide the implementation of these procedures.

v. Conduct studies and research on traditional WSS technologies (indigenous technology, culturally and socially acceptable) and alternative appropriate and low-cost WSS technologies (including: systems, equipment and materials) to promote the acceptability of most suitable technologies for given site specific conditions.

vi. Develop and enforce standards and guidelines for maintaining water quality in all recognized water uses; eg., water supply (domestic, industrial, livestock, others etc.) and sewerage and sanitation.

vii. Promote and encourage water conservation through regulatory and demand management measures in those existing systems where efficient utilization of water is as feasible as development of new schemes.

4. Financial and Economic Aspects

i. Subsidize the capital costs only for communities that are unable to cover the cost of the basic services so as to ensure social equity; establish financial resource allocation criteria to access these subsidies based on local socio-economic factors, and implement phasing out mechanisms of such programs (to promote self-reliance).

ii. Establish and implement cost-sharing arrangements to share the capital, O&M and capacity building costs between government, local communities, consumers, external support agencies and non-governmental organizations.

iii. Ensure transparency, fairness, responsibility and accountability in the utilization and management of the WSS funds, namely through Community Water Committees (rural) and Consumers' Councils (urban), and by conducting regular audits and inspections by community members who are not members of the water committees/councils. Establish line of responsibility and authority within these community-based structures. Institute good contracting arrangements to engage the consultants and private firms to perform planning, design, implementation and O&M tasks, and effectively administer these arrangements to ensure quality control.

iv. Promote rational subsidization norms based on the severity of local problems, focusing on the direct beneficiaries and promoting localized initiatives as well as water use efficiency. Determine a 'social tariff' for poor communities which minimally covers operation and maintenance costs. Develop special flat rate tariffs for communal services like hand pumps and public stand posts. Consider providing support to cover "connection fee" in areas where it turns out to be beyond the reach of local communities.

5. Institutional Aspects

i. Reorganize and strengthen the role of public sector institutions in the provision of WSS services. Ensure that public institutions (at higher level decision making) are continuously engaged in the formulation and enforcement of policies, strategies, regulations, and legislation, as well as in development and implementation of information management systems and capacity building programs. On the other hand, assign more responsibilities to the local level institutions concerning implementation, management, monitoring and supervision of WSS schemes, as well as to secure local level inter-sectoral co-ordination.

6. Capacity Building Aspects

i. Develop and implement a comprehensive and well coordinated training plan to strengthen the technical capacities of national professionals, both in formal and informal sectors, to enable them to deal with different aspects of WSS systems. The training plan should support the mandates of the institution, and be in conformity with needs of the staff.

ii. Strengthen the capacity of water users associations (water committees/water councils) so that they may make independent informed choices, and remain and serve as a focal point in the WSS management structure which can ensure autonomous decentralised management of the WSS systems.

iii. Establish viable public information management systems (including conventional, electronic and internet-based systems) that could be used to access and disseminate the technical information, documentation, and analysis of data on various aspects of WSS systems.

7. Social aspects

i. Establish and legalise a process for the participation of all stakeholders (formal and informal) to ensure efficient management of WSS systems, and promote participatory, consultative and consensus building methodologies so as to enhance the involvement of users at different levels of decision making.

ii. Launch public awareness campaigns to educate people about important WSS issues and related environmental health risks.

iii. Pay special attention to the role of women while establishing community based structures for the management of localized WSS systems. Contribute to the holistic well being of the community by educating women in water-environment-health issues. Strengthen the role and technical capacities of women in O&M and management of WSS schemes.

8. Environmental Aspects

i. Define parameters for the definition of access to safe and adequate water supply. Conduct sound water quality analysis before construction of WSS schemes to ensure that the water is potable.
ii. Protect water bodies from pollution by industrial wastewater and other wastes through strong enforcement of legislative measures so that people have access to safe drinking water.
iii. Integrate and co-ordinate the development of industrial water supply and waste water treatment with other water sector development objectives including, irrigation, hydro-power, etc. Recycle wastewater when it has been found to be safe for health and the environment.
iv. Promote improvement of environmental sanitation in urban centres and rural areas and protect water bodies from being polluted and contaminated.

1.4 DEFINITION OF OPERATION AND MAINTENANCE

In an engineering sense, operation refers to hourly, daily, monthly, quarterly, annually, and other timely defined operations of the components of a system such as plant, machinery and equipment (valves etc.) which is done by an operator, his assistant or any relevant defined body. This is a routine work.

The term maintenance is defined as the art of keeping the plant, equipment, structures and other related facilities in optimum working order.

For better understanding, the definition of Operation and Maintenance is as outlined here below;

a. **Operation** is a series of actions done by operators so that the equipment and systems parts could render the intended service**.** The process of operation includes operating generator set, water pumps opening valves, cleaning all areas inspecting electrical and electronic equipment, including motors, controllers and taking records.

In general operation is a series of actions by operators on water supply elements so that every element could render its intended service properly.

Hence, every operator first must know the capacity ranges and function of each element in the water supply system and operation procedures with some maintenance works, within their capacity.

b. **Maintenance** - a series of activities intended to ensure that the equipment, systems, and facilities are able to perform as intended or to provide an environment conducive to effective the work.

Two types of maintenance tasks are identified to be carried out by maintenance teams.

i. **Preventive maintenance**; is the actions that performed on a regular schedule to keep equipment or structures operating effectively and to minimize unforeseen failures. These actions consist of inspections and/or maintenance tasks.

ii. **Curative maintenance;** Actions performed to either repair or restore malfunctioning equipment or structures to effective operating conditions through either scheduled or unscheduled work. These actions may result from problems discovered during preventive maintenance or as a result of failures during operation.

The Objective of operation and Maintenance defined here above cannot be achieved unless it also comprises actions which minimize the impact of the environment on quality and quantity of water sources.

Regular improvement on the Performance of Operation and Maintenance can only be achieved if recording of the events is done and evaluated using properly set standards. Hence, planning, recording, reporting, monitoring and evaluation of Operation and maintenance actions is also the part of this manual. The Manual also includes, the need for implementation of MIS for efficient and effective storing, and analyzing of information for immediate decision making.

1.5 STAGES IN OPERATION AND MAINTENANCE

There are four stages in the implementation of Operation and Maintenance action under a Utility. These stages are;

1. **Establish Operation and Maintenance System**

   This is the stage at which a Utility establishes its operation and Maintenance system related to its nature starting from the source up to the outlet water points.

2. **Implement the System**

   Once the system is established, implementation of the actions as per the time frequency set in the manual is important. Implementation of the system requires regular upgrading of the skill of the staffs of the Utility.

3. **Recording of the Actions**

   Recording of the events and results of the actions is major stage of operation and Maintenance as per the time frequency set in the manual and as their occurrence in day to day events. Recording is required to be done using the standard formats prepared for that particular event. In addition to recording, the records need to be filed using separate folders. These records are required to prepare reports which is the next stage as indicated here below.

4. **Preparation of Report**

   Records need to be used to prepare regular reports. Preparation of report for decision makers' major outcome of the operation system. Reports also need to be prepared using the standard format prepared for this purpose.

5. **Existence for Monitoring and Evaluation of the O&M System**

   Town Water boards of the respective towns are required to monitor the operation by visiting sites of operation and its recording. In addition, decision makers are also required to give zero tolerance for dalliance in preparation and timely submission of reports. The report needs to be evaluated by decision makers related to the required standards to improve performance. For example levels of performance efficiency of pumps and level of UFW are the major areas of monitoring related to the required standards for decision making if their limit is beyond what is acceptable. By monitoring and evaluation we easily learn that each Operation and Maintenance action needs to be done following annual plan approved by the higher management bodies of the Utility as monitoring and Evaluation of events follows planning.

1.6 OBJECTIVE OF THE MANUAL

The Manual on Operation and Maintenance is intended to serve as a guide to strengthening the technical, operational and managerial capabilities required of the concerned personal to operate and maintain water supply services as per acceptable norms of quantity, quality, sustainability, reliability and cost.

The manual also helps to:-

- Identifying human, equipment and material resources required to ensure operation and maintenance of the systems.
- Prepare detailed schedule for operation and maintenance activities.
- To give clear procedure and tact of operation and maintenance.

The whole effort of operation and maintenance management improvement program is to make water supply systems sustainable, a global term which has to be clearly understood by the staffs of water supply systems. Hence, although sustainability is not only a technical issue, the definition of the term sustainability is situated at the front of this manual for having clear demonstration of the whole issue as follows: -

A water supply service is sustainable when: -

a. It functions and is being used
b. It is able to deliver an appropriate level of benefits (quality, quantity, convenience, comfort, continuity, affordability, efficiency, reliability, equity, health)
c. It continuous over a prolonged period of time (which goes beyond the life-cycle of the equipment)
d. Its management is institutionalized (community management, gender perspective, partnership with local authorities, involvement of formal/informal private sector)
e. Its operation, maintenance and administrative and replacement costs are covered at local level
f. It can be operated and maintained at local level with limited external support like technical assistance, training and monitoring.
g. It does not affect the environment negatively

Hence, in order to make a system sustainable, at least it requires the consideration and the achievement of the above issues, which is a long process. The definition of the term sustainability is included in here that technical personnel also get wider range of concept and vision on important issues related to improvement of operation and management system.

In addition to sustainability the system has to deliver adequate water to all categories of the users. The supply is said adequate is the production of water is compatible to domestic (HC, YC, PTU etc.), industrial users, commercial users and public users available in the town up to design period set for the system.

The other major requirement for the given water supply system related to its objective is it being safe. At any instant of the service, the water must be free of any water borne diseases. This can be achieved by implementation of Operation and Maintenance system. In general implementation of proper Operation and Maintenance system enables utilities to deliver the required service in the process of achieving full cost recovery.

1.7 OPERATION & MAINTENANCE SCENARIO IN THE COUNTRY

Despite, the above objectives, Operation and maintenance, is given less attention. Hence interruption of services, uneconomical operation of systems, and inequitable distribution of water during shortage, prevailing of water born diseases, and prevailing of continuous shortages of water are the common phenomenon in most towns of the country.

Most Utilities are not staffed with skilled and experienced personnel to operate and maintain their system. Adequate tools and equipments are not also available in most utilities. The day to day actions by most utilities are not well planned and are not according to the required standard to achieve the objective of the service. Almost all utilities in the country do not reach to the full cost recovery level.

It has been observed that lack of attention to the important aspect of Operation & Maintenance (O&M) of water supply schemes in several towns often leads to deterioration of the useful life of the systems necessitating premature replacement of many system components. As such, even after creating such assets by investing millions of Birr, they are unable to provide the services effectively to the community for which they have been constructed, as they remain defunct or underutilized most of the time.

Some of the key issues contributing to the poor Operation & Maintenance have been identified as follows:

i) Lack of finance, inadequate data on Operation & Maintenance

ii) Inappropriate system design; and inadequate workmanship

iii) Multiplicity of agencies, overlapping responsibilities

iv) Inadequate training of personnel
v) Lesser attraction of maintenance jobs in career planning
vi) Lack of performance evaluation and regular monitoring
vii) Inadequate emphasis on preventive maintenance
viii) Lack of operation manuals
ix) Lack of appreciation of the importance of facilities by the community
x) Lack of real time field information etc.

1.8 SCOPE AND APPLICATION OF THE MANUAL

This manual is applicable to urban water supply utilities operation and maintenance activities for schemes ranging from simple spring water sources with scheme components to those having huge water abstraction structures with complex treatment system and complex distribution systems. The manual gives general guidance to the integrated approach for utilities to carry out planned operation and maintenance activities in order to ensure sustainable and efficient service. This manual is not intended to be a substitute to the operation and instruction procedures made available by manufactures or installers during the construction or installation of the system or a particular component or part. Hence, it shall be used in conjunction with such instructions and operation procedures available with the utilities. It should be noted that if such instructions and procedures are not available with the utilities, they shall be collected and availed for immediate reference.

The manual does not include all the currently available scheme types in the world. Some components which are not considered in this manual may be operated using the manufacturers guide while the Operation and Maintenance system for other unforeseen components may be included as time, resource and capacity permits in the future.

1.9 UPDATING THE MANUAL

This manual is prepared to be used as a base for Operation and maintenance of scheme components mostly used in water supply systems. However, all elements covered in this document can not be available in every water supply system of every town in the country. Hence, updating the technical manual is mandatory so as to fit the technical issue overlooked and to suite to the particular nature of the system for the town. Hence, the UTILITY in consultation with REGION, shall update its manual so as to suit the operation and maintenance activities and achieve the following three basic measuring gauges:

- Less costly
- Prompt

- Better service or quality

Updating can be made to this technical manual due to the following reasons.

- ✓ Update the tasks and responsibilities listed in this manual so as to include new installations or exact recommendation of manufacturers.
- ✓ Update the maintenance management system as per the realistic path.
- ✓ Update the procedures for procurement and store keeping meeting the service scope.
- ✓ Update the system components in the manual to suit the prevailing water supply system components.

As indicated under chapter 3 of this manual, updating of the Operation and Maintenance manual by UTILITIES shall strictly comply with the arrangements of the available components stipulated in the drawing(sketches) with all the information about the scheme components described. In other words preparation of town specific Operation and Maintenance follows preparation of sketches most preferably GIS based drawings with all the required geographical, physical and capacity related etc. information included.

1.10 WHO WILL USE THE MANUAL

This manual is intended primarily for the managers and technician in-charge of the operation and maintenance of the urban drinking water supply systems. In addition it is also a useful tool for higher management bodies to monitor and evaluate the plan and implementation of the O&M functions to achieve its objective stipulated above.

2 STRATEGY

2.1 INTRODUCTION

Effective and efficient implementation of Operation and Maintenance can only be achieved if and only if systematic approach is followed and fulfillments of basic requirements are done. Hence, the strategy in implementation of proper operation and maintenance system shall be done according to the strategies listed here below.

2.2 STRATEGY FOR GOOD OPERATION AND MAINTENANCE

The minimum requirements for good operation and maintenance are:

i) Preparation of GIS based maps of the system

ii) Preparation of a plan for operation and maintenance.

iii) Providing required personnel to operate and maintain the system.

iv) Providing Capacity building programmes for the O&M

v) Availability of spares and tools for ensuring proper O&M

vi) Preparation of a water audit and leakage control plan

vii) Action Plan for energy audit for saving on energy

viii) Establishing a sound financial management system.

ix) Maintaining MIS records on the system including history of equipment, costs, life etc.

3 OPERATION AND MANITENANCE FOR WATER SUPPLY SYSTEMS

3.1 General

This chapter is the section in which the central objective of the manual is included. It contains the actions required with their frequency and proposed resources. Hence the Operation and Maintenance plan of utilities to operate and maintain system components is mainly based on this chapter of the manual.

3.2 Preparation of GIS based maps of the system

The operation and maintenance of a water supply system starts from understanding the general components that physically make up a system. These components with their physical and geographical information are sources to prepare a general layout. The general layout of the scheme is normally prepared and submitted to utility at the completion of construction of the water supply system as as-built drawings. If such layout does not exist, schematic layout needs to be prepared by utility. System layout should be affixed at a visible position in the room of technical personnel which helps the operation of technical personnel by: -

- Providing general concept on the feature of the system components and their relative location on one paper.
- For discussion among technical personnel and informal training
- To indicate the pipe material, size, location and connection details
- To assist the quick decision of technical personnel for providing service or solve distribution problems by zoning or by shift in case of water supply deficit.
- Provides a base for comparing and planning the area of service with the development plan and size of the town.

The layout can be sketched on existing administrative maps or schematically on A1 size (594x841 mm) paper with information including, name of water system, scale (if scaled), north direction, boundaries of the municipality or area to be served, date, location and size of existing pipes, location of existing structures and notes. A layout can be made to scale or schematic depending on the technical capability of the technical personnel of the Urban Water Supply Service or the availability of as-built drawings.

System lay out map shall be detail in all technical terms including the elevations of all components such that any technical improvement activity can be based on correct information.

The map of the system is preferable to be with GIS background for broader application. Geographic Information System (GIS) is a computer program that combines mapping with detailed information on physical structures with geographic areas. GIS has also compatibility with auto-cad design systems. The remote sensing maps can be used to prepare base maps of the utilities by using GIS. The GIS creates a database within a mapped area such as streets, valve chambers/manholes, pipe networks and pumping stations. The attributes can be address, number of valve chamber/manhole, pipe length, diameter, invert and quadrant (coordinates) and can also include engineering information, maintenance information and inspection information. The utility staff will get facility to update the maps and retrieve information geographically. These maps can be used to inform the maintenance crew to locate the place of work. The utility can use a work order system for new/repair works so that after completion of the work like a line is added or a valve is fixed or a new connection is given, the work order can be used by the map unit for updating of the map and the attributes also. These maps are used to indicate layers of maps for water lines, sewers, power cables, telecom cables etc.

GIS map of the system is help full in asset management of the utility which is intern a base for implementation of sound financial system leading to full cost recovery. Hence, preparation of GIS maps for their systems shall be either immediate or long term plan of each utility depending their capacity. But in the meantime preparation of map of the water supply system of the town is a major priority in implementation of operation and maintenance. Detail information on sizes, quantity, year of construction, capacity etc. shall be included for each scheme components. This map is also major tool to have specific information for each customer like the line of connections and some more. During the preparation of maps, marker posts, which indicate the name, location and sizes of each scheme components, shall be installed on the ground aside to the element.

3.3 Asset Registration

In addition to preparation of preferably GIS based map for the water supply system of the town, registration of all the assets of the utility including details of the scheme components is required. Registration of the asset shall be periodic including the spares and tools available in the store for day to day maintenance and operation events. Availability of registered asset periodically helps to be a base for calculating annual depreciation costs in financial management on the way to achieve full cost recovery.

3.4 Operation and Maintenance for Sources of Water Supply Systems

3.4.1 Function of Water Sources

The major elements and functions of sources of water supply systems of towns are those indicated in the table here below,

Table 1: Water supply elements at the source

Name of source element	Function
Borehole or well/spring, infiltration galleries, radial wells, etc.	Collects ground water from aquifers. Collects ground water that emerges on surface.
Dam / impoundment reservoir	Reserves river flow or runoff water
River / dam/ lake intake	A structure to guide abstracted water to a wet well or treatment units

3.4.2 Objective of O&M for Water Sources

The objectives of operation and maintenance for sources of water supply systems are:

- The water sources should be able to supply water which is safe to drink after treatment.
- The water sources should be perennial and should ensure sustainable yield.
- The quality of water should not be allowed to deteriorate.
- There should be least or no disruption in water supply systems due to depletion of water sources.
- There should be least possible expenditure on the repair and maintenance of the water sources.
- Proper record of the water sources should be maintained so that their time to time performance could be known.
- A methodical long-range programme of source inspection and monitoring should be introduced to identify problems so that a regular programme of preventive maintenance can guarantee reliability and continuity.
- Survey maps shall be obtained or prepared for all possible sources of water like rivers, reservoirs, lakes, canals, wells, and springs etc. The maps already available should be updated from time to time

3.4.3 Types and Classifications of Water Sources

Ground and surface water are the most common water sources for developing water supply requirement of towns.

a. Ground water is tapped from aquifers through wells, springs and infiltration galleries. The yield depends on the depth, type of aquifer and ground water table gradient. Good yielding aquifers can be considered as reliable sources of water supply for community purposes. Spring is points at which groundwater comes to surface naturally. It is not always reliable sources of water supply because the shallow water tables that supply the spring are usually subject to rise and fall in elevation during rainy and dry season.

b. **Surface water** is perennial streams, lakes, rivers and canals. It also includes stored floods by constructing impoundments.

Ground water is generally preferred, because usually it is lower in bacterial count, is cleaner, cooler and more uniform. The lower bacterial count and the greater clarity are due to the filtering action of the soil and sand through which the groundwater flows. Also, the required treatment is minimal.

3.5 Operation and Maintenance Requirements at Water Wells

According to available data the specific capacity of wells should be measured at regular intervals either monthly or bi-monthly and it should be compared with the original specific capacity. As soon as 10 to 15% decrease in specific capacity is observed steps should be taken to determine the cause and accordingly corrective measures should be taken. Rehabilitation procedures should be initiated before the specific capacity has declined by 25%. A check list given below can be used to evaluate the performance of a well:

(a) Static water level in the production well,
(b) Pumping rate after a specific period of continuous pumping,
(c) Specific capacity after a specified period of continuous pumping,
(d) Sand content in a water sample after a specified period of continuous pumping,
(e) Total depth of the well,
(f) Efficiency of the well,
(g) Normal pumping rate and hours per day of operation,
(h) General trend in water levels in wells in the area,
(i) Draw down created in the production well because of pumping of nearby wells.

A significant change in any of the first seven conditions listed above indicates that a well or pumping rate is in need of attention.

Preventive maintenance programme begins with well construction records showing geological condition, water quality and pumping performance. The data of optimum and efficient limit of operation should be available which is created at the time of testing and commissioning of the well. The pump test data is normally in the form of a discharge draw-down curve (called yield draw down curve).

Wells should be pumped within the specified pumping rates, which should have been established during the pumping test of the well. Excess pumping rates may cause sand and silt to pack around the screen, thus clogging it, or fill in the voids of gravel and reduce yield of borehole and causes incrustation. Comparison of the well static water levels, pumping rate and draw down with the original well completion records over a period of time reveals changes in well characteristics and indicates when rehabilitation of the well should be done. The various water levels are measured by using a steel tape, electrodes or an air hose and pressure gauge. Falling static water level may indicate a gradual lowering of ground water table or interference of other wells. An increased draw-down while static water level is unchanged is caused by increased resistance to water inflow and definitely indicates clogging, scaling or corroding of the well screen, the gravel area becoming clogged with sand or silt or cave-in of the stratum.

Ground Water Sources are costly structures which require careful design, construction, operation and timely maintenance. A trouble free service can be ensured by adopting the aforesaid practices. However, it has been experienced that a large number of Ground Water Sources constructed at high costs, operate at very low efficiencies or fail completely. The indication of source failures is either excessive sand pumping or steady decline in well yield. It may often be possible in few cases to rehabilitate the source by carrying out suitable remedial measures, but in most of the cases even the costly operations may not be effective to restore the source. In such cases the source is abandoned and a new source will have to be constructed.

3.5.1 Causes of Well Failure

Wells failure may be due to inadequate design, faulty construction and operation, lack of timely maintenance and repair and failures due to mechanical and chemical agents and adverse aquifer condition. The main causes for source failure are categorized as under:

i) Incorrect design: for instance use of incorrect size of screen and gravel pack, wrong pin pointing of well site resulting in interference.

ii) Poor construction e.g. the bore may not be vertical, the joints may be leaky, wrong placement of well screen, non-uniform slots of screen, improper construction of cement slurry seal to prevent inflow from Saline aquifer.

iii) Corrosion of screens due to chemical action of water resulting in rupture of screens.

iv) Faulty operation e.g. over pumping, poor maintenance.

v) Adverse aquifer conditions resulting in lowering of water table and deterioration of water quality.

vi) Mechanical failure e.g. falling of foreign objects including pumping assembly and its components.

vii) Incrustations due to chemical action of water.

viii) Inadequate development of wells.

Causes of failure of well mentioned above from (i) to (viii) are applicable according to type of source. The correction of the situations mentioned above at (i) to (iii) above is a very difficult and costly affair. Therefore, a decision whether to rehabilitate an old well or construct a new should be based on the cost benefit analysis. Following remedial measures can be taken for correcting situation mentioned at (iv) to (viii).

A. Faulty Operation

Tube well should run in such a way that the pumping water level should always remain above the level of well screen. Over pumping will expose the well screen, which may result in incrustation and corrosion. Over pumping results in excessive draw down which may cause differential hydrostatic pressures, leading to rupture of well screen. Negligence in timely repair and maintenance may result in poor performance of the tube well. Therefore, before any permanent damage is done to tube well it should be ensured that the tube well is operated at its designed capacity and timely repair and maintenance are done.

B. Adverse Aquifer Condition

In adverse aquifer conditions where water table has depleted but the quality has not deteriorated, wells can generally be pumped with considerable reduced discharge.

C. Mechanical Failure

The falling of pumping set assembly and its components into the bore hole can be minimized by providing steel wire holdings throughout around the assembly length including pumping set or by providing and clamping a steel strip around the pumping assembly. However, in spite of proper care sometimes foreign objects and pumping set assembly components may fall in the well. In corrosive water the column pipe joints and pump parts may get progressively weakened due to corrosion, get disconnected and fall into the well. These foreign & falling objects may damage the well screen resulting into failure of the well. However where well screen is not damaged, then by proper fishing the fallen objects can be taken out of the well making it functional again. Detail fishing methods can be provided by contracting firms.

D. Incrustation

DIAGNOSING INCRUSTATION PROBLEM

Chemical incrustation is indicated by a gradual reduction in yield of the well.

However, it can also happen with a gradual lowering of the water table due to over-pumping or inadequate ground water recharge. This fact can be verified by studying the behaviour of the ground water level over the service period of the tube well. Incrustation in the form of slime produced by iron bacteria decreases well yield due to clogging of the well screen and casing. Incrustation also clogs the fractures & fissures of rocky zone of well which is prevalent in bore wells. This trouble can be identified from the performance curves of the well. In this case the reduction in well yield is somewhat more rapid. Water quality analyses are used to identify the type of incrustation.

3.5.2 Types of Incrustation

The various types of incrustation in order of the frequency of occurrence are:

i. Precipitation of carbonates, sulphates and silicates of calcium and magnesium.
ii. Precipitation of hydroxides, oxides and other compounds of iron and manganese.
iii. Slime produced by iron bacteria and other slime producing organisms.
iv. Deposition of soil materials (Mechanical Incrustation).

A. Calcium and Magnesium

Calcium carbonate is one of the most extensively found minerals. Its solubility depends upon the quantity of free carbon dioxide in the water which in turn depends upon the pH, the temperature and the pressure. On pumping, a low pressure zone is created around the well and some of the dissolved carbon dioxide is released from solution. Some calcium bicarbonate is then reconverted into calcium carbonate which is deposited as a cement like material on the screen and in the sand and gravel around it. This incrustation builds up a shell around the screen which may be several centimeters thick. Partial incrustation may extend back as much as a metre into the water-bearing formation. In addition to the sand grains around the well which are cemented together, other substances like aluminium silicates, iron compounds and organic material may also be entrapped in the carbonate scales. Many a time the calcium carbonate may only be a small fraction of the deposit but is usually the basic binder. This type of deposit accounts for about 90 per cent of the cases of incrustation.

B. Iron and Manganese Salts

Bicarbonates of iron and manganese are more soluble in water than their hydroxides. In incrusting regions the ground water is generally charged to its full capacity with these salts. It is believed that an increase of its velocity in the vicinity of the well is enough to upset the balance and precipitate out the insoluble iron and manganese hydroxides. These are jelly like and fluffy.

Oxidation can then occur due to the dissolved oxygen in the water and these are transformed into hydrated oxides. Hydrated ferrous oxide is a black sludge while ferric oxide is reddish brown like common crust. Ferrous bicarbonates are moderately soluble in water, the solubility increasing if the water is acidic. Ferric salts are, however, insoluble in alkaline or weakly acidic water. Thus a reduction of acidity can also cause precipitation of the iron salts. Ferrous bicarbonates also get oxidised when they come in contact with oxygen to form insoluble ferric hydroxide.

$$4Fe(HCO_3)_2 + O_2 + 2\,H_2O = 4Fe(OH)_3 + 8\,CO_2$$

Oxidation is more marked in water table tubewells, which are run intermittently, because air can get into the zone of daily depletion of water table and oxidise the salts there. In such cases sand particles of the aquifer can get progressively coated with iron oxide, thus reducing the void spaces and encroaching upon the storage capacity of the formation. Clogging by manganese occurs much less frequently. Soluble manganese bicarbonates react with oxygen to form insoluble manganese hydroxide which precipitates as a sooty or dark brown deposit. In general, waters containing more than 400 ppm bicarbonates, 100 ppm sulphates, or 400 ppm silicates can be considered incrusting. Water containing 2 ppm iron or 1 ppm manganese can be considered incrusting. Water can also pick up iron from the well casing itself.

C. Bacteria

Iron bacteria such as crenothrix grow attached to the screen or voids of the aquifer, and feed on carbon compounds like bicarbonates and carbon dioxide in addition to the iron in solution. Release of carbon dioxide, deficiency of oxygen, and darkness favour their growth. During their life cycle they change the dissolved iron into the insoluble ferric state. This is deposited in the void of the aquifer surrounding the screen or in a jelly like sheath which surrounds the bacteria. This slime can clog the screen slots and the pores of the aquifer. They may grow in water pipes as well and clog the same. Similar bacteria can also cause oxidation manganese compounds to insoluble form.

Sometimes sulphate reducing bacteria are also found in ground water which reduce the sulphates in the water to hydrogen sulphide. Hydrogen sulphide so formed attacks the iron pipes to form insoluble iron sulphide, which deposits as a scale.

D. Silt and Clay Deposits (Mechanical Incrustation)

Silt and clay material can sometimes move on to the screen and clog the same. This may also clog the fractures & fissures of rocky zone of a well which is prevalent in bore wells. Such clogging may be because of improper development or inadequate design and construction.

3.5.3 Rehabilitation of Incrusted Wells

It is very necessary that the type of incrustation is determined before deciding upon the treatment to be given. This can be done by analysing the water pumped by a well and examining samples of aquifer from around the well screen. Samples of incrustation taken from other wells in the same formation give very good information.

Incrusted wells can be cleaned by acids, chlorine, dispersing agents, etc. Hydrochloric and sulphuric acid are effective in removing carbonates and partially effective in removing iron and manganese oxides. Glassy phosphates are able to disperse iron and manganese oxides, silts and clays. Chlorine is effective in removing bacterial growth and slime.

Procedure and detail method of removing incrustation is beyond the scope of this manual. But if problem of incrustation identified through testing, detail procedure for removing is required.

3.5.4 Inadequate Development

Sometimes due to carelessness at the time of construction proper development of the tubewell is not done which results in constant inflow of the sand particles causing choking of the filtering media and strainers. Such tubewells need redevelopment. The method of redevelopment of tubewell shall also be found from companies licensed for this purpose.

3.5.5 Prevention of Incrustation

In case of wells where the water is charged with undesirable chemicals, incrustation cannot

be prevented entirely, but it can be delayed, and kept in check by keeping the draw-down as small as possible. In this way a considerable release of carbon dioxide does not take place and precipitation of carbonates in well screens is kept in check. In order to reduce the head loss to a minimum, the well should be developed properly so that aquifer losses are reduced to the minimum. A screen having a large open area and fully penetrating the aquifer should be installed. This results in lower entrance velocities as well due to which precipitation of iron salts and carbonates is retarded. The pumping rate should be reduced and the pumping period increased. The required quantity of water may be obtained from several wells rather than pumping a few large wells at excessive flow rates. Lastly, the screen should be cleaned periodically, say once a year, even if the discharge has not fallen off. This last point is very important because if partial choking takes place, it is very difficult to eradicate the same completely.

3.5.6 Prevention of Corrosion

3.5.6.1 Application of Corrosion Resistant Paints and Coatings

Corrosion can be controlled to a large extent by applying anti corrosive paints on the steel pipes at the time of construction of the tube well. Non corrosive casing pipe and strainers (such as PVC pipes and strainers) can also be used at the time of construction of tube well to avoid corrosion. Some commonly used paints/coatings to control corrosion are of aluminium, asphalt, red lead and coal tar. Now a days, a number of epoxy paints for this purpose are also available in the market.

Corrosion can also be prevented by methods for applying cathodic protection against corrosion of mild steel pipes :

- Sacrificial anode
- Impressed current

Detail procedure to apply these methods is also beyond the scope of this manual. it shall be further referred to books if site conditions and test results require this method.

Prevention of contamination of wells by improper environmental handling is treated in separate section in this manual.

Table 2: Operation and Maintenance requirements of Wells

S.N	Task Description	Frequency	Tools /Equipment and Materials	Manpower requirement
1	Clean the compound owned and fenced for the Borehole	Quarterly	Akafa, Doma, Machid etc.	Daily laborer
2	Test the condition of the fence and take corrective measure	Occasionally	Medosha, Mismar, etc	Guard and Carpenter if required
3	Make sure that the concrete apron around the well is water tight and there is not damped water around the well	Daily	Akafa, Doma, masonry, and carpentry tools etc.	Daily laborer, Masons, carpenter,
4	Measure the static water level before the pump starts	Monthly	Deep meter	Motor Operator
5	Measure the dynamic water	Monthly	Deep meter	Motor Operator

S.N	Task Description	Frequency	Tools /Equipment and Materials	Manpower requirement
	level of the Borehole while working and just after stopping			
6	Rehabilitate the well using rig	5 Years	Rig	Drilling Company
7	Record daily water production using	Daily	Format and pen	Motor Operator
8	Summarize monthly water production	Monthly	Format and pen	Technical department
9	Clean and improve the flood protection ditch found on upper side of wells	Monthly	Akafa, Doma, Machid etc.	Daily laborer
9	Survey the existence of environmentally hazardous contaminants around the well	Monthly	Vehicle, fuel, driver , camera, and stationary etc.	Technical department

3.6 Access Roads

Most large utilities have access roads to Borehole and other scheme components to facilitate their operation and maintenance tasks. Hence, they also need to have plan to maintain them to achieve sustainability as indicated in the table here below;

Table 3: Operation and Maintenance requirements of Access Roads

S.N	Task Description	Frequency	Tools /Equipment and Materials	Manpower requirement
1	Inspect for maintenance requirements of access roads	Bi-annually	Pen and paper	Technical team of the utility
2	Maintain access roads	Bi-annually	Akafa, Doma, Machid, heavy duty equipments etc.	Technical team, daily labourer, local contractor if required

3.7 Spring

Springs are enclosed in a watertight concrete chamber or spring box to protect water against surface contamination, to provide storage and to ensure that all water is collected. On the upstream side of the spring the wall of the box is usually left open for collection of spring water. Water from the spring box flows to wet well where it is temporarily stored. The maintenance of spring boxes requires the actions to be taken to ensure that the structure properly collects the available water and protects the water from contamination. On the upstream of the spring cut of drain or ditch should be excavated to protect entering of flood during rainy season.

Table 4: Operation and Maintenance requirements of springs

S.N	Task Description	Frequency	Tools/Equipment and Materials	Manpower requirement
1	Clean the compound owned and fenced for the Spring	Quarterly	Shovel, Pick axe, **Machid** etc.	Daily laborer
2	Test the condition of the fence and take corrective measure	Monthly	Carpenter hammer, wooden saw, etc	Guard and Carpenter if required with daily labourers
3	Drain and clean spring box at the outlet of capping structure and wet well with chlorine	Yearly	Chlorine solution or powder, water, boots, **Tuta**, and material to clean	Technical department and daily laourers
4	Check whether the chamber and capping structures are leaking or not	Monthly		Technical Department
5	Check whether the pipes, water meters, valves etc. are working properly or not	Monthly		Technical Department
6	Record daily water production using	Daily	Format and pen	Motor Operator
7	Summarize monthly water production	Monthly	Format and pen	Technical department
8	Clean and improve the flood protection ditch found on the upper side of the spring	Monthly	Shovel, pick axe, Machid etc.	Daily laborer
9	Rehabilitation (cleaning and placing the filter materials)	Occasionally if the quality and yield falls	Shovel, pick axe, Machid etc.	Technical department, Daily laborer
10	Survey the existence of environmentally hazardous contaminants around the spring	Monthly	Vehicle, fuel, driver , camera, and stationary etc.	Technical department

3.8 Surface Water Sources

Surface waters are made available to urban and rural water supply systems by several different methods, including the following:

- ✓ By direct intake or infiltration from flowing streams or rivers
- ✓ By intake from existing ponds or lakes.
- ✓ By constructing a dam across a stream or river, thus impounding the water.

A. River Abstraction

Water from streams or rivers serves as source of water supply to urban premise where there is sufficient base flow to support projected demand of the town. Such river source is abstracted by intake or diversion structures built along or across the river. Water from stream or river are generally susceptible to contamination and hence require conventional treatment to make it suitable for domestic supply. The abstraction and treatment method broadly vary depending on the size of source, the topographic and geotechnical conditions, the available technology, the raw water characteristics, etc.

B. Impounding Reservoir

Dams are constructed to create artificial lakes or reservoirs. A dam conserves the surplus water brought down by a river during the periods when the supply exceeds the demand, for utilization later on during the periods when demand outstrips the natural flow of the river. Storage is obtained by constructing barriers across a depression receiving runoff from a considerable catchment. The dam is located where the river is narrow but should open out upstream to provide a large basin for a reservoir.

Dams may be classified into two main categories

(ii) Rigid dams: These include dams of concrete, masonry, steel or timber.

(iii) Non Rigid dams: These include a) Rockfill dams b) Earthen dams c) Composite sections having a combination of rockfill and any type of earth fill construction.

By creating reservoirs or ponds, dams save water from periods of high stream flow or surface runoff. Such storage allows some of the impurities to settle out thus reducing the degree of treatment required. Problems with dams are leakage, sanitation and silting. Dams should be inspected every three months and after every heavy rainfall to determine if there is a need for repair. Erosion of the embankment dam caused by rain must be controlled. If there is any seepage or cracks, they should be repaired immediately to prevent the condition from becoming worse. Cracks should be filled with a soil with high clay content and compacted. The regional office should then be consulted regarding methods for permanent correction of the problem. The upstream embankment of the dam should be checked to ensure that the rip rap –a blanket foundation or wall formed by large stones-has remained in place. A grass cover should be maintained on the downstream side.

Water should not be allowed to flow over the top of the dam as this can cause dam failure. The spillway – a channel built to control the level of water – should be checked for signs of erosion and for debris blocking the flow of water. Repair washed out areas with soil and line with stone, remove debris from the channel. Other means of preventing over topping of the dam is the construction of manhole type inlet at the upstream and on the downstream side an outlet, the two structures being connected by large diameter pipe passing through the dam. The inlet structure would be approximately 0.5 meters below the level of the dam.

Following simple sanitary practices can protect the quality of the water in the reservoir or pond. Livestock and other domestic animals must be kept away from both the reservoir and the watershed. Small pond areas should be fenced. Erosion of the slopes of the watershed should be prevented by preserving vegetation (Except vegetation in contact with the stored water) or terracing the slope to stop the flow of sediment into the reservoir. Sediment colors the water and its accumulation reduces the capacity of the reservoir. It may impart bad taste or odor to the water. Such vegetation should be removed when lowered water level permit. Algae growth should be controlled in shallow less than two meters depth, lakes, ponds and reservoirs as its presence also adds bad tastes and odors and makes the water turbid.

Table 5: Operation and Maintenance requirements for Surface Water Sources

S.N	Task Description	Frequency	Tools/Materials, and other resources	Responsible Unit or Team
1	Check dam bodies, diversion weir, spillways, energy dissipaters, etc, perform surveillance task and carry out maintenance activities	Occasionally and after each flood	Camera, Pen, Paper, meter etc., and local or national contractors	utility/technician
2	Inspect dams and river intake structures	Occasionally	Camera, Pen, Paper, meter etc., and local or national contractors	utility/technician
3	Check intake structures and trash racks	Occasionally and monthly	Camera, Pen, Paper, meter etc., mason, carpenters and daily laborers	utility/technician
4	Clean trash racks and wet well	Occasionally and monthly	Camera, Pen, Paper, meter etc., mason, carpenters and daily laborers	utility/technician
5	Check the settlement for embankments and downstream toe areas for any evidence of localized or overall settlement, depressions or sinkholes.	Quarterly	Local or national contractors	Utility Experts
6	Check the slope stability of embankment dams for irregularities in alignment and variances from smooth uniform slopes, unusual	Quarterly	Local or national contractors	Utility Experts

S.N	Task Description	Frequency	Tools/Materials, and other resources	Responsible Unit or Team
	changes from original crest alignment and elevation, evidence of movement at or beyond the toe, and surface cracks which indicate movement.			
7	Check Seepage for downstream face of abutments, embankment slopes and toes, embankment structure contacts, and the downstream valley areas should be examined for evidence of existing or past seepage. The presence of animal burrows and tree growth on slopes which may cause detrimental seepage should be examined.	Quarterly	Local or national contractors	Utility Experts
8	Observe Drainage that the slope protection should be examined to whether the systems could freely pass discharge and that the discharge water is not carrying embankment material.	Quarterly	Local or national contractors	Utility Experts
9	Observe the slope protection against wave, currents and surface runoff that may occur at the site should be evaluated. The condition of vegetation cover should be evaluated.	Quarterly	Local or national contractors	Utility Experts
10	Observe the overall normal functioning of the spillways	Bi annually	Local or national contractors	Utility Experts
	Observe the overall normal functioning of the outlet structures	Monthly	Local or national contractors	Utility Experts
11	Survey the existence of environmentally hazardous contaminants around surface sources	Monthly	Vehicle, fuel, driver , camera, and stationary etc.	Technical department

3.9 Pumps

3.9.1 General

Pumping machinery and pumping station are very important components in a water supply system. Pumping machinery is subjected to wear, tear, erosion and corrosion due to their nature of functioning and therefore are vulnerable for failures. Generally more number of failures or interruptions in water supply are attributed to pumping machinery than any other component. Therefore, correct operation and timely maintenance and upkeep of pumping stations and pumping machinery are of vital importance to ensure uninterrupted water supply. Sudden failures can be avoided by timely inspection, follow up actions on observations of inspection and planned periodical maintenance. Downtime can be reduced by maintaining inventory of fast moving spare parts. Efficiency of pumping machinery reduces due to normal wear and tear. Timely action for restoration of efficiency can keep energy bill within reasonable optimum limit. Proper record keeping is also very important.

Obviously due attention needs to be paid to all such aspects for efficient and reliable functioning of pumping machinery. This chapter discusses procedures for operation and Maintenance and addresses pertinent issues involved in O&M of pumping machinery and associated electrical and mechanical equipment.

3.9.2 Types of Pumps

Following types of pumps are used in water supply systems.

i) Centrifugal pumps

ii) Vertical turbine pumps

_ Oil lubricated

_ Self water (pumped water) lubricated

_ Clear water lubricated

iii) Submersible pumps

_ Vertical bore well type pump-motor set

_ Mono bloc open well type pump-motor set

iv) Pumps

v) Reciprocating pumps

3.9.3 Important Points for Pump Operation

Important points as follows shall be observed while operating the pumps.

a. Dry running of the pumps should be avoided.

b. Centrifugal pumps have to be primed before starting.

c. Pumps should be operated only within the recommended range on the head-discharge characteristics of the pump.

• If pump is operated at point away from duty point, the pump efficiency normally reduces.

• Operation near the shut off should be avoided, as the operation near the shut off causes substantial recirculation within the pump, resulting in overheating of water in the casing and consequently, in overheating of the pump.

d. Voltage during operation of pump-motor set should be within + 10% of rated voltage. Similarly current should be below the rated current as per name plate on the motor.

e. Whether the delivery valve should be opened or closed at the time of starting should be decided by examining shape of the power-discharge characteristic of the pump. Pump of low and medium specific speeds draw lesser power at shut off head and power required increases from shut off to normal operating point. Hence in order to reduce starting load on motor, a pump of low or medium specific speed is started against closed delivery valve.

Normally the pumps used in water supply schemes are of low and medium specific speeds. Hence, such pumps need to be started against closed delivery valve.

The pumps of high specific speed draw more power at shut off. Such pumps should be started with the delivery valve open

f. The delivery valve should be operated gradually to avoid sudden change in flow velocity which can cause water hammer pressures. It is also necessary to control opening of delivery valve during pipeline - filling period so that the head on the pump is within its operating range to avoid operation on low head and consequent overloading. This is particularly important during charging of the pumping main initially or after shutdown. As head increases the valve shall be gradually opened.

g. When the pumps are to be operated in parallel, the pumps should be started and stopped with a time lag between two pumps to restrict change of flow velocity to minimum and to restrict the dip in voltage in incoming feeder. The time lag should be adequate to allow to stabilize the head on the pump, as indicated by a pressure gauge.

h. When the pumps are to be operated in series, they should be started and stopped sequentially, but with minimum time lag. Any pump, next in sequence should be started immediately after the delivery valve of the previous pump is even partly opened. Due care should be taken to keep the air vent of the pump next in sequence open, before starting that pump.

i. The stuffing box should let a drip of leakage to ensure that no air is passing into the pump and that the packing is getting adequate water for cooling and lubrication. When the stuffing box is grease sealed, adequate refill of the grease should be maintained.

j. The running of the duty pumps and the standby should be scheduled so that no pump remains idle for long period and all pumps are in ready-to run condition. Similarly unequal running should be ensured so that all pumps do not wear equally and become due for overhaul simultaneously.

k. If any undue vibration or noise is noticed, the pump should be stopped immediately and cause for vibration or noise be checked and rectified.

l. Bypass valves of all reflux valve, sluice valve and butterfly valve shall be kept in closed position during normal operation of the pumps.

m. Frequent starting and stopping should be avoided as each start causes overloading of motor, starter, contactor and contacts. Though overloading lasts for a few seconds, it reduces life of the equipment.

3.9.4 Undesirable operations

Following undesirable operations should be avoided.

i) Operation at Higher Head

The pump should never be operated at head higher than maximum recommended. Such operation results in excessive recirculation in the pump, overheating of the water and the pump. Another problem, which arises if pump is operated at a head higher than the recommended maximum head, is that the radial reaction on the pump shaft increases causing excessive unbalanced forces on the shaft which may cause failure of the pump shaft. As a useful guide, appropriate marking on pressure gauge be made. Such operation is also inefficient as efficiency at higher head is normally low.

ii) Operation at Lower Head

If pump is operated at lower head than recommended minimum head, radial reaction on the pump shaft increases causing excessive unbalanced forces on shaft which may cause failure of the pump shaft. As useful guide, appropriate markings on both pressure gauge and ammeter be made. Such operation is also inefficient as efficiency at lower head is normally low.

iii) Operation on Higher Suction Lift

If pump is operated on higher suction lift than permissible value, pressure at the eye of impeller and suction side falls below vapour pressure. This results in flashing of water into vapour. These vapour bubbles during passage collapse resulting in cavitations in the pump, pitting on suction side of impeller and casing and excessive vibrations. In addition to mechanical damage due to pitting, discharge of the pump also reduces drastically.

iv) Throttled operation

At times if motor is continuously overloaded, the delivery valve is throttled to increase head on the pump and reduce power drawn from motor. Such operation results in inefficient running as energy is wasted in throttling. In such cases, it is preferable to reduce diameter of impeller which will reduce power drawn from motor. But as the pump operates at low efficiency, the cost for

v) Operation with Strainer/Foot Valve Clogged

If the strainer or foot valve is clogged, the friction loss in strainer increases to high magnitude which may result in pressure at the eye of the impeller falling below water vapour pressure, causing cavitation and pitting similar to operation on higher suction lift. The strainers and foot valves should be periodically cleaned particularly during monsoon.

vi) Operation of the Pump with Low Submergence

Minimum submergence above the bell mouth or foot valve is necessary so as to prevent air entry into the suction of the pump which gives rise to vortex phenomenon causing excessive vibration, overloading of bearings, reduction in discharge and efficiency. As a useful guide the lowest permissible water level be marked on water level indicator.

vii) Operation with Occurrence of Vortices

If vibration continues even after taking all precautions, vortex may be the cause. All parameters necessary for vortex-free operation should be checked.

3.9.5 Starting and stopping Pumps

Starting and stopping of pumps required standard operation and is done following systematical and step wise checking different parameters. Hence the operator need to get on the job and normal training on its operation mainly using the supplied manufacturers' manual.

3.9.6 Preventive Maintenance of Pumps

Appropriate maintenance schedule and procedure need to be prescribed for all electrical and mechanical equipment based on manufacturers' recommendations, characteristics of the equipment, site and environment conditions i.e. temperature, humidity, dust condition, etc. The maintenance schedule also needs to be reviewed and revised in the light of experience and analysis of failures and breakdown at the pumping station. The preventive maintenance

General guidelines for maintenance schedules for pumps and associated electrical and mechanical equipment are enlisted below. The guidelines should not be considered as total,

full-fledged and comprehensive as characteristics of equipment and site conditions differ from place to place. For example, in dust laden environment or places where occurrence of storms are frequent, blowing of dust in motor, renewal of oil and grease in bearing shall have to be done at lesser intervals than specified in general guideline. Schedule shall detail the maintenance to be carried out at regular intervals i.e. daily, monthly, quarterly, half yearly, annually etc. or operation hours. The schedule shall also include inspections and tests to be performed at appropriate interval or periodicity

3.9.6.1 Daily Observations and maintenance

1. Daily Maintenance

(a) Clean the pump, motor and other accessories.
(b) Check coupling bushes/rubber spider.
(c) Check stuffing box, gland etc.

2. Routine observations of irregularities

The pump operator should be watchful and should take appropriate action on any irregularity noticed in the operation of the pumps. Particular attention should be paid to following irregularities.

a) Changes in sound of running pump and motor
b) Abrupt changes in bearing temperature.
c) Oil leakage from bearings
d) Leakage from stuffing box or mechanical seal
e) Changes in voltage
f) Changes in current
g) Changes in vacuum gauge and pressure gauge readings
h) Sparks or leakage current in motor, starter, switch-gears, cable etc.
i) Overheating of motor, starter, switch gear, cable etc.

3.9.6.2 Daily Record of operations and observations

A log book should be maintained to record the hourly observations, which should cover the following items.

a. Timings when the pumps are started operated and stopped during 24 hours.
b. Voltage in all three phases.
c. Current drawn by each pump-motor set and total current drawn at the installation.
d. Frequency.
e. Readings of vacuum and pressure gauges.
f. Motor winding temperature.
g. Bearing temperature for pump and motor.
h. Water level in intake/sump.
i. Flow meter reading.
j. Daily PF over 24 hours duration.

k. Any specific problem or event in the pumping installation or pumping system e.g. burst in pipeline, tripping or fault, power failure.

3.9.6.3 Monthly maintenance

i) Check free movement of the gland of the stuffing box; check gland packing and replace if necessary.

ii) Clean and apply oil to the gland bolts.

iii) Inspect the mechanical seal for wear and replacement if necessary.

iv) Check condition of bearing oil and replace or top up if necessary.

3.9.6.4 Quarterly maintenance

i) Check alignment of the pump and the drive. The pump and motor shall be decoupled while correcting alignment, and both pump and motor shafts shall be pushed to either side to eliminate effect of end play in bearings.

ii) Clean oil lubricated bearings and replenish with fresh oil. If bearings are grease lubricated, the condition of the grease should be checked and replaced/replenished to the correct quantity. An anti-friction bearing should have its housing so packed with grease that the void space in the bearing housing should be between one third to half. A fully packed housing will overheat the bearing and will result in reduction of life of the bearing.

iii) Tighten the foundation bolts and holding down bolts of pump and motor mounting on base plate or frame.

iv) Check vibration level with instruments if available; otherwise by observation.

v) Clean flow indicator, other instruments and appurtenances in the pump house

3.9.6.5 Annual maintenance

A very thorough, critical inspection and maintenance should be performed once in a year.

Following items should be specifically attended.

i. Clean and flush bearings with kerosene and examine for flaws developed, if any, e.g. corrosion, wear and scratches. Check end play. Immediately after cleaning, the bearings should be coated with oil or grease to prevent ingress of dirt or moisture.

ii. Clean bearing housing and examine for flaws, e.g. wear, grooving etc. Change oil or grease in bearing housing.

iii. Examine shaft sleeves for wear or scour and necessary rectification. If shaft sleeves are not used, shaft at gland packings should be examined for wear.

iv. Check stuffing box, glands, lantern ring, mechanical seal and rectify if necessary.
v. Check clearances in wearing ring. Clearances at the wearing rings should be within the limits recommended by the manufacturer.
vi. Check impeller hubs and vane tips for any pitting or erosion.
vii. Check interior of volute, casing and diffuser for pitting, erosion, and rough surface.
viii. All vital instruments i.e. pressure gauge, vacuum gauge, ammeter, voltmeter, watt meters, frequency meter, tachometer, flow meter etc. shall be calibrated.
ix. Conduct performance test of the pump for discharge, head and efficiency.
x. Measures for preventing ingress of flood water shall be examined. Ingress of floodwater in sump, well, tube well or bore well shall be strictly prevented. Seal cap shall be provided above tube well/bore well.
xi. Check vibration level.

3.9.6.6 Overhaul of the Pump

It is difficult to specify the periodicity or interval for overhaul in the form of period of service in months/years or operation hours, as deterioration of pump depends on nature of service, type of installation i.e. wet pit or dry pit, quality of water handled, quality of material of construction, maintenance, experience with particular make & type of pump etc. However generally, following operational hours may be taken as broad guidelines for overhauling.

i. Submersible pump – 5000 – 6000 hours
ii. Vertical turbine pump – 12000 hours
iii. Centrifugal pump – 15000 hours

Different formats need to be used to record all the above maintenance events to be used for future actions.

3.10 Generator

The generator set: -

- Manufactured and mounted only to produce electrical energy. Any other use, even if occasional is forbidden.
- Shall not be wetted, sprinkled water or other liquid on the generating set.
- Should not be touched with moist parts of the body wear, the protection devices and garment required by the rule.
- Children and non-experienced persons should not be allowed to operate.

If generator is on operation: -

- Check if there are any abnormal noises, vibration, over temperature, oil leakage, etc.
- Check the transfer of power to the pump.
- All windows, doors and ventilations shall be opened in order to circulate fresh air in the room. These opening shall produce 20% of the room area and the room area shall be $10m^2$. However, this shall be considered during construction.
- The exhaust gases shall be released out of the room by means of strong sealed steel tubes; cast iron connecting pieces may also be used. The end of the pipe has to be at least 1.50m from windows, doors, opening parts or ventilation air intakes, and at least 3m high from the floor.
- The pipes inside the room have to be wrapped round with non-conducive materials since their external surface temperature has to be less than 100^{oc}.
- The material for heat insulation and protection has to be fireproof or class1 fire reaction fuels.
- Should never come in contact with water during operation. The non-observance of this rule brings the danger of electric shocks and damage to the generating set itself.

Every procedure of putting generating set in to service, starting, working and shut down of generator recommended by the manufacturer shall be respected.

Note: Switch on the generator before turning on the switch on the switchboard.

Lubrication and maintenance of the equipment should also be effected regularly as directed in the manufacturers' instruction. Dates of lubrication and dates on which wear parts are replaced should be recorded in the logbook.
The routine maintenance of the generator can be summarized as follows: (The list is not exclusive, refer in priority to relevant manufacturers manual)

- Check oil level once a weak.
- Check belt tension every month.
- Clean air suction filter every month.
- Clean and remove dust on equipment bodies every month (especially for motor cooling).
- Check bolt tightening every month; tighten if required.
- Refer to lubrication schedule every month.

Table 6: Operation and Maintenance Requirement of Generators

S.N	Task Description	Frequency	Tools/Equipment and Materials	Manpower requirement

S.N	Task Description	Frequency	Tools/Equipment and Materials	Manpower requirement
1	Greasing	Daily	Tools, paper and pen	operator
2	Clean air filter or replace as required, check leakage of fuel and oil, tighten bolts and nuts, check the filter of water radiator for water cooled sets, check the power of the battery and speed of the engine	After every 125 hours of working	Tools, paper and pen	operator
3	To clean the fuel nozzles if the exhaust air is not normal, check the belts and correct is loosen, clean fuel filter if the fuel is not clean, clean oil filter or replace	After every 250 hours of working	tools	operator
4	Replace fuel filter	After 500 hours of working	tools	operator
5	Remove the carbon content in the engine if its power is low, or after 2000 hours of working, correct the valve clearance space, clean the head of the cylinder, and its heat removal part, check the belts and replace is required	After 1000 hours of working	Tools	Technician
6	Service the engine wholly	After 5 years or 15,000hours of working	Tools and engine removing equipments	Company which has complete workshop

3.11 Transmission Pipe

3.11.1 Function

The overall objective of a transmission system is to deliver raw water from the source to the treatment plants and transmit treated water from treatment plants to the storage reservoirs for onward supply into distribution networks. Transmission of raw water can be either by canals or by pipes whereas transmission of treated water is by pipes only. Transmission through pipes can be either by gravity flow or by pumping.

3.11.2 O&M Objective of Transmission Line

The objective of O&M of transmission system is to achieve optimum utilization of the installed capacity of the transmission system with minimum transmission losses and at minimum cost. To attain this objective the utility has to evolve operation procedures to ensure that the system can operate satisfactorily, function efficiently and continuously, and last as long as possible at lowest cost.

3.11.3 Routine Operation at Normal Condition

Normally the operations involve transmission of required water within the available head or within the pumping head. Operations of valves at reservoirs from which transmission channels/mains start and operation of pumps (in case of pumping mains) from which the transmission mains start are the routine operations. Operation of chlorinators where installed are also included in the routine operations.

1. Pumping Transmission Mains

Water levels in the sumps from which the water is being pumped are measured. Critical points are selected in the transmission system for monitoring of pressures by installation of pressure recorders and gauges. In the pumping systems, whenever water pressures in the pumping station drops below the designed system pressure, the operators are alerted to search for possible leaks in the pumping system. Similarly at the receiving end, if the required water levels are not building up at the storage reservoir, it indicates that the required quantity is either not pumped or there may be leakages enroute. At times whenever the maximum levels in the receiving reservoirs are reached the pumps will have to be stopped or the outlet valves of the reservoir have to be opened.

2. Continuity

Operators are required to check that the transmission of water takes place continuously and as per the requirement. Normally, the flow meter readings, water levels in reservoir and pressures in transmission mains are recorded and transmitted to the control room. The operators have to ensure the accuracy of the measuring instruments for flows, pressures and levels so as to perform the operations properly. Analysis of the records will enable the agency to evaluate how well the transmission system is working.

3.11.4 Problems in Transmission lines

1. Leakage

Water is often wasted through leaking pipes, joints, valves and fittings of the transmission system either due to bad quality of materials used, poor workmanship, and corrosion, age of the installations or through vandalism. This leads to reduced supply and loss of pressure. Review of flow meter data will indicate possible leakages. The leakages can be either visible or invisible. In the case of invisible leaks sections of pipeline can be isolated and search carried out for location of leaks.

2. **Leakage Through Appurtenances**

   Most common leaks are through the glands of sluice valves. Leaks also occur through expansion joints where the bolts have become loose and gland packing is not in position. Leaks through air valves occur due to improperly seated ball either due to the damage of the gasket or due to abrasion of the ball, through the gland of the isolating sluice valve or through the small orifice.

3. **Air Entrainment**

   Air in a rising main in free form will collect at the top of pipeline and then run up to higher points. Here it will either escape through air valves or will form an air pocket. With more accumulation of air the size of air pocket will rise. The cross sectional area of the pipe will diminish and the velocity of water will increase. The formation of air pocket will result in an increase of head loss. Other problems associated with air entrainment are: surging, corrosion, reduced pump efficiency and malfunctioning of valves or vibrations. In rare cases bursting of pipes also is likely to occur due to air entrainment.

4. **Water Hammer**

   The pressure rise due to water hammer may have sufficient magnitude to rupture the transmission pipe or damage the valves fixed on the pipeline. Water hammer in water supply systems occurs due to rapid closure of valves and sudden shut off or unexpected failure of power supply to the pumps.

5. **Age of the System**

   With age there is considerable reduction in carrying capacity of the pipelines particularly unlined CI, MS and GI pipes resulting in corroded pipes and leaks and hence in reduced quantity and pressures.

6. **Lack of Records**

   Maps showing the actual alignment of transmission mains are not readily available. The location of pipes and the valves on the ground becomes difficult in the absence of system maps. Some minimum information about the location of pipes and valves and size of pipes and valves and the direction of opening of valves etc. is required, to operate and maintain the system efficiently.

3.11.5 Elements of the transmission pipe

The following indicated in table below are main elements of the transmission pipe:

Table 7: Elements of the Transmission Pipe

Name of element	Function
Pipe	A tube or cylindrical channel through which water is conveyed either by pumping or by gravity
Pressure gauge	A device that tells us the pressure caused by flowing water in the pipe (in bar, m or kgf/cm2)
Bulk water meter	Registers the water being transmitted located at the well outlet & at out let of wet well.
Check valve	Prevents backflow of water in the pipe to protect pump hammering and loss of energy water raised.
Flush valve	It is a valve situated at low points in the transmission pipe to allow washout of sediments or emptying the transmission pie for maintenance
Air valve	A special valve which relief the transmission pipe from compressed air and protects from blocking the flow
River or gully crossing	It is a structure to support a pipe crossing a gully or streams, above ground
Anchor Blocks	Anchor blocks are concrete or masonry blocks situated at the joints of pipe to support and anchor the pipe to the ground from external load or distribute loads from internal pressure at bends and joints

3.11.6 Operation and maintenance requirements for elements of Transmission pipe

Operation and maintenance activities to be undertaken at the transmission pipe by different parties involved in the operation maintenance of Urban Water Supply Services are indicated in table below:

Table 8: Operation and maintenance requirements for elements at the transmission pipe

S.N	Task Description	Frequency	Tools and materials	Manpower requirement
1	Inspect joints and fittings of transmission pipe	Monthly	Wrenches , pick axe, shovel etc	Local operator/techn ician, daily laborer
2	Inspect pipelines and flush by valves at low point			
2.1	If the line is raw water line from surface water sources up to treatment site	Quarterly	Wrenches , pick axe, shovel etc	Local operator/techn ician, daily laborer
2.2	If the line is for clear water from the treatment site up to service reservoir	Annually	Wrenches , pick axe, shovel etc	Local operator/techn ician, daily laborer

S.N	Task Description	Frequency	Tools and materials	Manpower requirement
3	Record readings of water meter and pressure gauge on prepared form and notice if readings are unusual or faulty	Daily	Pen, format	Local operator/technician
4	Overhaul bulk water meter	Every 3-5 year/occasionally	tools	Zonal mechanics
5	Inspect and clean valve chamber from debris. Open valve and flush after repair or inspect if valve is operational by closing and opening. Valves should always be operated slowly to prevent water hammer.	Annually	Wrenches, pick axe, shovel etc	Local operator/technician, daily laborer
6	Open check valve and check condition of facing on swing check valve equipped with leather or rubber seats on disk. If metal seat ring is scarred, smooth with a fine file and emery cloth. A, check pin wear on balanced disk valve since disk must be accurately positioned in the seat to prevent leakage. (For swing type check valves)	Annually	Wrenches, pick axe, shovel etc	Local operator/technician, daily laborer
7	Dismantle air valve from transmission line check float for leakage. Check linkage and pins for corrosion. Clean orifices. Check valve vault or manhole. Note condition of concrete or masonry and make the necessary repairs. Ensure that surface water and dirt cannot enter vault or manhole.	Annually	Wrenches, pick axe, shovel etc	Local operator/technician, daily laborer
8	Inspect river or gully crossing structure for erosion or settlement and maintain after heavy rain or every three months	Quarterly	Wrenches, pick axe, shovel etc	Local operator/technician, daily laborer, mason, carpenter
9	Inspect anchor blocks for erosion or settlement and maintain after heavy rain or every three months	Quarterly	Wrenches, pick axe, shovel etc	Local operator/technician, daily laborer, mason and carpenter

3.12 Treatment

3.12.1 Function

Water to be supplied for public use must be potable i.e., satisfactory for drinking purposes from the standpoint of its chemical, physical and biological characteristics. Drinking water should, preferably, be obtained from a source free from pollution otherwise it will need treatment, before being used. The raw water normally available from surface water sources is, however, not directly suitable for drinking purposes.

A potable water supply is essential for the prevention of water borne diseases. Water that is contaminated by disease causing organisms or that is unacceptable because of taste; color or odor will need treatment, before being used. To determine if a water supply will need treatment, the bacteriological, physical and chemical characteristics of the water must be studied.

Facilities for treating water vary from simple drip feed chlorinators to complete conventional treatment plants for clarification and filtration depending on the characteristics of the raw water. The most commonly employed water treatment processes may entail one or more of the conventional water treatment methods that may include, pre-treatment/ pre-chlorination, coagulation/ flocculation, sedimentation, filtration and disinfection.

Some of the common treatment processes used in the past include Plain sedimentation, Slow Sand filtration, Rapid Sand filtration with Coagulation-flocculation units as essential pretreatment units. Pressure filters and diatomaceous filters have been used though very rarely. Roughing filters are used, under certain circumstances, as pretreatment units for the conventional filters

The treatment processes may need pretreatment like pre-chlorination and aeration prior to conventional treatment. The pretreatment processes comprising of Coagulation and Flocculation are commonly used with Rapid Sand filters.

3.12.2 Groups of Treatment Plants

Treatment plants are majorly grouped under the following,

1. **Slow Sand Filter Plant**

   It may include Plain Sedimentation basins followed by the conventional Filter-Plant.

2. **Rapid Sand Filter plant**

   It can be briefly divided into two main components:

   a. The Pretreatment Works

   These include the (1) Coagulation- Flocculation Units with adequate chemical dosing and rapid mixing facilities, and (2) Sedimentation Units/clarifiers to handle the effluent from the Coagulation-flocculation units.

   b. Filter units.

3. **Other Categories**

   There are a number of other categories of filtration plants but not of common use. Of these Pressure filters are used for small treatment plants or industries. Roughing filters may be used to reduce load on the treatment plants. Small streams of water in the catchment areas may carry large particles and floating matter. Introduction of the roughing filters will ensure entrapping of such undesirable material prior to the storage structures of the treatment units.

3.12.3 Operation and maintenance of Conventional Treatment system

3.12.3.1 Preliminary treatment

The preliminary treatment activities are commonly carried out at water source abstraction sites. Screening, pre-sedimentation and pre-chlorination is the commonly conducted preliminary treatment methods recognized. Pre sedimentation occurs in impoundment reservoirs or wet wells so as to settle large debris to reduce silt load entering conveyance units or treatment plant. Screening is carried out step by step with trash racks and strainers placed at the intake and/or at wet wells and at entrances to pumping units. Pre-chlorination is usually applied to raw water before other physical treatments in order to control growth of bacteria and algae in the treatment system.

The operation procedure for preliminary treatment generally follows the guidance outlined for source elements, but following are additional points.

Table 9: Operation and maintenance requirements for preliminary treatment

S.N	Task Description	Frequency	Responsible Unit or Team	
1	Clean trash racks and screens at intake gates of dams or river diversion structures	Weekly	Utility	Local operator/ technician
2	Inspect mechanical/ manual trash racks	Quarterly	Utility	Local operator /technician
3	Clean strainers at entrance to pumping units	Weekly	Utility	Local operator/ technician
4	Clean and flash wet wells from silts and debris	Weekly	Utility	Local operator /technician
5	Prepare chlorine solution and feed as required	Daily	Utility	Local operator/ technician
6	Clean chemical store	Weekly	Utility	Local operator/ technician

S.N	Task Description	Frequency	Responsible Unit or Team	
7	Inspect equipment in the chemical store	Annually	Utility	Local operator/ technician
8	Clean dosing gravity feeder	Bi- annually	Utility	Local operator/ technician
9	Inspect and overhaul dosing equipment	Annually	Utility	Local operator/ technician

3.12.3.2 Plain Sedimentation

Plain sedimentation is employed for smaller water supply schemes where the raw water is relatively clearer and chemicals are not utilized for coagulation. In the plain sedimentation process, the raw water entering the sedimentation unit is allowed to be detained for the detention time as it passes across the tank ultimately enabling suspended particles to settle. Such sedimentation technique is usually followed by slow sand filters and disinfection.

Table 10: Operation and maintenance requirements for Plain sedimentation

S.N	Task Description	Frequency	Tools/material	Manpower requirement
1	Control quantity of water entering sedimentation tank	Daily	Formats, pen, valve openers	Local operator/technician
2	Inspect turbidity of water leaving the tank	Daily	Laboratory equipment	laboratory technician
3	Inspect level of sludge deposited at bottom of tank	Weekly	Meter and sticks	Local operator/technician
4	Remove sludge from sedimentation tank, flush and rinse	Seasonally, occasionally	Wrench	Local operator/technician, daily laborers
5	Inspect inlet and drain valves, and under drain system.	Quarterly	Wrenches and other tools, and repair	Local operator/technician
6	Inspect interior of tank	Annually	Meter, pen and formats,	Local operator/technician

3.12.4 Coagulation /flocculation

Coagulation is a physical and chemical reaction occurring between the alkalinity of the water and the coagulant added to the water, which results in the formation of insoluble flocs. This process is used to remove non- settleable solids from the water. It involves the feeding and rapid mixing of chemical coagulants into the water to form flocs.

Flocculation is the slow stirring process that causes the flocs to grow and to come in contact with particles of turbidity to form larger particles that will readily settle. The purpose is to produce a floc of the proper size, density, and toughness for effective removal by sedimentation/clarifier and filtration. The stirring process brings the micro-flocs into large and heavy flocs that can settle by gravity or filtered

Depending on the characteristics of water, flocculation chamber may be provided separately where gentle mixing takes place in a tank by mechanical means. As this process is slow compared to coagulation, the flocculation tank must be large enough to provide sufficient detention time. Baffles are used for the purpose of lowering the velocity of the incoming water so that flocs formed by coagulation are not broken.

The jar test has been and is still the most widely used method employed to evaluate the coagulation process and to aid the plant operator in optimizing the coagulation, flocculation and clarification processes. From the turbidity values of the settled water, settling velocity distribution curves can be
drawn. These curves have been found to correlate well with the plant operating data and yield useful information in evaluating pretreatment, such as optimizing of velocity gradient and agitation and flocculation, pH, coagulation dosage and coagulant solution strength. Such curves cannot be generalized and are relevant to the plant for which the data have been collected through the Jar tests.

Table 11: Operation and maintenance requirements for Coagulation/flocculation baffles

S.N	Task Description	Frequency	Tools/material	Manpower requirement
1	Remove sludge/impurities, flush and clean it	Seasonally, occasionally	Wrench	Local operator/technician, daily laborers
2	Inspect inlet and drain valves, and under drain system.	Quarterly	Wrenches and other tools	Local operator/technician
3	Inspect interior of tank	Annually	Meter, pen and formats	Local operator/technician, contractors

3.12.5 Clarifiers

In the coagulant aided water treatment system, the clarifier is a unit in which the processes of sedimentation, sludge re-circulation and sludge removal can be performed. The main advantage of the clarifier is that it saves construction costs by handling several processes in one unit. Several designs are available. For example some of the clarifiers of some urban water supplies inject the chemicals directly into the unit; some units have mechanical agitators and others depend on hydraulic flow for mixing during the flocculation process. Treatment plant operators must consult the manufacturer's instructions and/or the manual provided by the consulting engineers for specific operating and maintenance procedures

1. **Types**

   The basins may be of the following types:

- Rectangular basins.
- Circular and square basins.
- High Rate Settlers (Tube Settlers).
- Solid Contact Units (Up-flow solid-contact clarification and up-flow sludge blanket clarification).

2. **Sludge Characteristics**

   Water treatment sludges are typically alum sludges, with solid concentrations varying from 0.25 to 10% when removed from a basin. In gravity flow sludge removal systems, the solid concentration should be limited to about 3%. If the sludges are to be pumped, solids concentrations as high as 10% can be readily transported. In horizontal flow sedimentation basins preceded by coagulation and flocculation, over 50% of the floc will settle out in the first third of the basin length. Operationally, this must be considered when establishing the frequency of the operation of sludge removal equipment.

3. **Sludge Removal Systems**

   Sludge which accumulates on the bottom of the sedimentation basins must be removed

   periodically for the following reasons:

a. To prevent interference with the settling process (such as resuspension of solids due to scouring).
b. To prevent the sludge from becoming septic or providing an environment for the growth of microorganisms that create taste and odour problems.
c. To prevent excessive reduction in the cross sectional area of the basin (reduction of detention time).

In large-scale plants, sludge is normally removed on an intermittent basis with the aid of mechanical sludge removal equipment. However, in smaller plants with low solid loading, manual sludge removal may be more cost effective. In manually cleaned basins, the sludge is allowed to accumulate until it reduces settled water quality. High levels of sludge reduce the detention time and floc carries over to the filters. The basin is then dewatered (drained), most of the sludge is removed by stationary or portable pumps, and the remaining sludge is removed with squeegees and hoses. Basin floors are usually sloped towards a drain to help sludge removal. The frequency of shutdown for cleaning will vary from several months to a year or more, depending on source water quality (amount of suspended matter in the water).

4. Operation Procedure

From a water quality standpoint, filter effluent turbidity is a good indication of overall process performance. However one must monitor the performance of each of the individual water treatment processes, including sedimentation, in order to anticipate quality or performance changes. Normal operating conditions are considered to be conditions within the operating ranges of your plant, while abnormal conditions are unusual or difficult to handle conditions.

In normal operation of the sedimentation process one must monitor.

1) Turbidity of the water entering and leaving the sedimentation basin and temperature of the entering water. Turbidity of the entering water indicates the floc or solids loading on the sedimentation process. Turbidity of the water leaving the basin reveals the effectiveness or efficiency of the sedimentation process. Low levels of turbidity are desirable to minimize the floc loading on the filter.
2) Temperature of the water entering the sedimentation basin is important. As the water becomes colder, the particles will settle more slowly. To compensate for this change, you should perform jar tests and adjust the coagulant dosage to

produce a heavier and thus a settling floc. Another possibility is to enforce longer detention times when water demand decreases.

3) Visual checks of the sedimentation process should include observation of floc settling characteristics, distribution of floc at the basin inlet and clarity of settled water spilling over the launder weirs. An uneven distribution of floc, or poorly settling floc may indicate that a raw water quality change has occurred or that the operational problems may develop.

Table 12: Operation and maintenance requirements for clarifiers

S.N	Task Description	Frequency	Tools/material	Manpower requirement
1	Control quantity of water entering clarifier	Daily	Laboratory equipment	laboratory technician
2	Conduct jar test, and determine coagulant dosing rate for raw water	Seasonally, occasionally	Laboratory equipment	Local operator/ technician
3	Monitor and control coagulant dosing rate and record amount of chemical consumed	Daily	Laboratory equipment	Local operator/ technician
4	Inspect chemical store and the equipment	Bi-annually	Pen, formats	Local operator/ technician
5	Inspect equipment in water laboratory and clean the laboratory	Daily	Cleaning materials	Local operator/ cleaner
6	Inspect and overhaul dosing equipment	Annually	Pen, formats	Local operator/ technician
7	Clean chemical store	Weekly	Cleaning materials	Local operator/ cleaner
8	Conduct measurement of sludge height in the clarifier	Weekly	Tape meter and sticks, pen and paper	Local operator/ technician
9	Remove or drain sludge accumulated at the bottom	Seasonally, occasionally	Wrench,	Local operator/ technician/daily laborers
10	Drain and clean clarifier	Bi-annually	Wrench, chlorine and cleaning materials	Local operator/ technician
11	Inspect algae and slim growth	Weekly	Pen and paper	Local operator/ technician
12	Inspect walls and bottom of concrete structures	Bi-annually	Pen and paper	Local operator/ technician
13	Inspect inlet and drain valves	Quarterly	Pen and paper	Local operator/ technician

3.12.6 Filtration

A) Slow Sand Filters

1. Process

Slow Sand filtration was the first type of porous media filtration used in water treatment. This process is known for its simplicity and efficiency. During the initial operational period of slow sand filters, the separation of organic matter and other solids generates a layer of biological matter on the surface of the filter media.

2. Filter Controls

The pipe work, valves and devices used to regulate the operation of a filter should be properly planned. Adequate means must be available to:

1. Deliver raw water into the supernatant reservoir,
2. Remove scum and floating matter,
3. Drain off supernatant water prior to filter cleaning,
4. Lower water level in the bed,
5. Control the rate of filtration and adjust it as bed resistance increases,
6. Ensure that negative pressures cannot occur within the bed (the weir is the device usually used for this purpose),
7. Convey filtered water to the filter water tank,
8. Run filtered water to waste or to the inlet side of other filters during the ripening process,
9. Fill sand bed from below with filtered water (from other filters) after cleaning.

3. Operation

The operation of the filter is determined by the filtration rate, which is controlled at the effluent outlet. Inflow, which may be by gravity from a constant level reservoir, or by a pump, is adjusted so that the head of water in the supernatant reservoir remains constant at all times. Excessive raw water delivery will cause overflow through the scum outlets, while a reduction in the rate of inflow will cause the level in the supernatant water reservoir to drop; either condition should alert the operator to a defect in the mechanism controlling the supply of raw water.

The filtration rate is controlled by a single regulating valve on the effluent delivery. At the beginning of the filter run this will be partially closed, the additional resistance thereby provided being equal to that which will later build up within the filter bed. Day by day as the run continues this valve must be checked and opened fractionally to compensate for the choking of the filter and to maintain a constant filtration rate. In the early part of the filter run the daily build up of resistance will be almost imperceptible, calling for very little valve adjustment, but towards the end of the filter run the resistance will increase more

rapidly, necessitating a more positive opening of the valve and signalling the impending need for filter cleaning.
To enable the operator to regulate the valve precisely it is necessary to have some form of measuring device on the effluent outlet.

4. Water Quality

Samples of raw and treated water will be taken at regular intervals for analysis. In a large waterworks with its own laboratory, sampling will almost certainly be carried out daily, since the effluent analysis constitutes the only certain check that the filter is operating satisfactorily and the raw water analysis provides what is possibly the only indication of a change in quality that might adversely affect the efficiency of treatment.

5. Filter Cleaning

While the filter is in operation, a stage comes when the bed resistance increases so much that the regulating valve has to be fully opened and it is the right time to plan the cleaning of the filter bed since any further resistance is bound to reduce the filtration rate. Resistance accelerates rapidly as the time for cleaning approaches.
To clean a filter bed, the raw water inlet valve is first closed, allowing the filter to discharge to the clear water well as long as possible (usually overnight). As the head in the supernatant reservoir drops, the rate of filtration rapidly decreases, and although the water above the bed would continue to fall until level with the weir outlet, it would take a very long time to do so. Consequently, after a few hours, the effluent delivery to the clear water well is closed, and the supernatant water outlet is run to waste through the drain valve provided.
The cleaning of the bed may be carried out by hand or with mechanical equipment. Working as rapidly as possible, they should strip off the Schmutzdecke and the surface sand adhering to it, stack it into ridges or heaps, and then remove the waste material by barrow, hand cart, basket, conveyor belt or other device.
During the cleaning operations precautions must be taken to minimize the chances of pollution of the filter bed surface by the labourers themselves. Such measures as the provision of boots that can be disinfected in a tray of bleaching solution should be taken. Hygienic personal behaviour must be rigidly imposed, and no labourers with symptoms that might be attributable to water borne or parasitic diseases should be permitted to come into direct or indirect contact with the filter medium.

6. Resanding

After several years' operation and, say, twenty or thirty scrapings the depth of filtering material will have dropped to its minimum designed level (usually 0.5 to 0.8 m above the supporting gravel, according to the grain size of the medium). In the original construction, a marker, such as a concrete block or a step in the filter box wall, is sometimes set in the structure to serve as an indication that this level has been reached and that resanding has become due.

During the long period of the filter use/run some of the raw water impurities and some products of biochemical degradation will have been carried into the sand-bed to a depth of some 0.3 to 0.5 m according to the grain size of the sand. To prevent cumulative fouling and increased resistance this depth of sand should be removed before resanding takes place, but it is neither necessary nor desirable that it should be discarded. Instead it is moved to one side, the new sand is added, and the old sand replaced on the top of the new, thus retaining much of the active material to enable the resanded filter to become operational with the minimum re-ripening.

This process (of replacing old sand on the top of the new) known as “throwing over” is carried out in strips. Excavation is carried out on each strip in turn, making sure that it is not dug so deeply as to disturb the supporting gravel layers below.

In areas where sand is expensive or difficult to obtain, the surface scrapings may be washed, stored and used for resanding at some future date. These scrapings must be washed as soon as they are taken from the filter, otherwise, being full of organic matter, the material will continue to consume oxygen, quickly become anaerobic, and putrefy, yielding taste and odour producing substances that are virtually impossible to remove during any washing process.

Sand Washing Machines should be provided for the bigger plants. Wherever provided, these should be operated regularly to prevent accumulation of sand and also to keep the machine in working condition.

Table 13: Operation and maintenance requirements for slow sand filters

S.N	Task Description	Frequency	Tools/material	Manpower requirement
1	Run the filter and record filtration rate	Daily	Pen and formats etc.	Local operator/ technician
2	Monitor turbidity of effluent leaving filter	Daily	Laboratory equipment	Laboratory technician
3	Clean the sand by scraping and removing the top 10-20cm of the sand bed	Seasonally, occasionally	Shovel, scrapers, wheel barrow etc	Local operator/ technician, daily laborers
4	Replace the filter bed by a new or washed sand after 20-30 scraping	Occasionally	Shovel, scrapers, wheel barrow etc	Local operator/ technician, daily laborers
5	Remove and replace the whole sand bed when the bottom becomes septic	Occasionally	Shovel, scrapers, wheel barrow etc	Local operator/ technician, daily laborers
6	Inspect inlet and drain valve	Quarterly	Wrenches and other tools	Local operator/ technician
7	Inspect filter tank walls and bottom	Annually	Meter, pen and paper	Local operator/ technician

B) Rapid Sand Filters

The purpose of filtration is the removal of particulate impurities and floc from the water being treated. In this regard, the filtration process is the final step in the solids removal process which usually includes the pretreatment processes of coagulation, flocculation and sedimentation.

The degree of treatment applied prior to filtration depends on the quality of water.

1. Operation

Filter Operation: A filter is usually operated until just before clogging or breakthrough occurs or a specified time period has passed (generally 24 hours).

Backwashing: After a filter clogs or breakthrough occurs or a specified time has passed, the filtration process is stopped and the filter is taken out of service for cleaning or backwashing.

Surface Wash: In order to produce optimum cleaning of the filter media during backwashing and to prevent mud balls, surface wash (supplemental scouring) is usually required. Surface wash systems provide additional scrubbing action to remove attached floc and other suspended solids from the filter media.

2. Operational Procedures

a. Monitoring process performance is an ongoing activity. You should look for and attempt to anticipate any treatment process changes or other problems that might affect filtered water quality, such as a chemical feed system failure.

b. Measurement of head loss built up in the filter media will give you a good indication of how well the solids removal process is performing. The total designed head loss from the filter influent to the effluent in a gravity filter is usually about 3 meters. At the beginning of the filtration cycle the actual measured head loss due to clean media and other hydraulic losses is about 0.9m. This would permit an additional head loss of about 2.1m due to solid accumulation in the filter.

c. The rate of head loss build up is an important indication of process performance. Sudden increase in head loss might be an indication of surface sealing of the filter media (lack of depth penetration). Early detection of this condition may permit you to make appropriate process changes such as adjustment of chemical filter aid feed rate or adjustment of filtration rate.

d. Monitoring of filter turbidity on a continuous basis with an turbiditimeter is highly recommended. This will provide you with continuous feed back on the performance of the filtration process. In most instances it is desirable to cut off (terminate) filter at a predetermined effluent turbidity level. Preset the filter cutoff control at a point where you experience and tests show that breakthrough will soon occur.

e. In the normal operation of the filter process, it is best to calculate when the filter cycle will be completed on the basis of the following guidelines:

ii. Head loss.

i. Effluent turbidity level.

ii. Elapsed run time.
iii. A predetermined value is established for each guideline as a cut off point for filter operation. When any of these levels is reached, the filter is removed from service and backwashed.

f. At least once a year one must examine the filter media and evaluate its overall condition. Measure the filter media thickness for an indication of media loss during the backwashing process. Measure mud ball accumulation in the filter media to evaluate the effectiveness of the overall backwashing operation.

g. Routinely observe the backwash process to qualitatively assess process performance. Watch for media boils (uneven flow distribution) during backwashing, media carry over into the wash water trough, and clarity of the waste wash-water near the end of the backwash cycle.

h. Upon completion of the backwash cycle, observe the condition of the media surface and check for filter sidewall or media surface cracks. You should routinely inspect physical facilities and equipment as part of good housekeeping and maintenance practice. Correct or report the abnormal equipment conditions to the appropriate maintenance personnel.
i. Never bump up a filter to avoid backwashing. Bumping is the act of opening the backwash valve during the course of a filter run to dislodge the trapped solids and increase the length of filter run. This is not a good practice.
j. Shortened filter runs can occur because of air bound filters. Air binding will occur more frequently when large head losses are allowed to develop in the filter. Precautions should be taken to minimize air binding to avoid damage to the filter media.

3. Back Wash Procedure

i) Filters should be washed before placing them into service.
The surface wash system should be activated just before the backwash cycle starts to aid in removing and breaking up solids on the filter media and to prevent the development of mud balls. The surface wash system should be stopped before completion of the backwash cycle to permit proper settling of the filter media. A filter wash should begin slowly for about one minute to permit purging (removing) of an entrapped air from the filter media, and also to provide uniform expansion of the filter bed. After this period the full backwash rate can be applied. Sufficient time should be allowed for cleaning of the filter media. Usually when the backwash water coming up through the filter becomes clear, the media is washed. This generally takes from 3 to 8 minutes. If flooding of wash water troughs or carryover of filter media is a problem, the backwash rate must be reduced.

ii) Procedure for backwashing a filter is as follows:

- Log length of filter run since last backwash.
- Close filter influent valve
- Open drain valve
- Close filter effluent valve
- Start surface wash system

- Slowly start backwash system
- Observe filter during washing process.
- When wash water from filter becomes clear (filter media is clean), close surface wash system Valve
- Slowly turn off backwash system
- Close drain valve
- Log length of wash and the quantity of water used to clean filter.

Table 14: Operation and maintenance requirements for rapid sand filters

S.N	Task Description	Frequency	Tools/material	Manpower requirement
1	Record the head loss in the filter	Daily	Meter, pen and pencil	Local operator/technician
2	Inspect the turbidity in the effluent	Daily	Laboratory equipment	Laboratory technician
3	Backwash and clean filter media with treated water	Occasionally	Wrenches, and other tools	Local operator/technician/daily laborers
4	Inspect filter bed for unevenness, sink holes or depressions, cracks, mud balls, algae and slime	Monthly	Meter, pen and pencil	Local operator/technician
5	Measure sand level to some convenient reference point to identify whether sand is lost by backwashing or is bulking by incrustation	Monthly	Meter, pen and pencil	Local operator/technician
6	Insert prob in the sand bed up to gravel layer in as many places as possible and note water level to identify uneven gravel bed	Occasionally (after backwash)	Meter, pen and pencil	Local operator/technician
7	Remove sand layer for 0.5sqm area at different spots and observe gravel layer is not moved, incrusted, etc	Quarterly	Shovel, wheel barrow	Local operator/technician/daily laborers
8	Collect representative sample through sieves and check effective sizes and uniformity coefficient	Bi-annually	Sieve, small box and weigh	Region operator/technician/daily laborers
9	Inspect backwash pipe, water pump and air blower systems	Quarterly	Wrenches, pen and pencil, and other tools	Local operator/technician/daily laborers
12	Inspect walls and bottom of concrete structures	Bi- annually	Meter, pen and pencil	Local operator/technician
13	Inspect inlet and drain valves	Quarterly	Meter, pen and pencil	Local operator/technician

C) Pressure Sand filters

The filtering material used in horizontal or vertical pressure filter consists of sand and gravel. It must be kept clean, loose and free from mud balls. Maintenance of the pressure filter is similar to that or gravity filters. The major disadvantage is that the filter bed cannot be observed during operations. Consequently, continuous turbidity monitoring is essential and a great deal of care and thoroughness must be exercised during the monthly internal filter inspections.

Table 15: Operation and maintenance requirements for pressure sand filters

S.N	Task Description	Frequency	Tools/material	Manpower requirement
1	Run the filter and record filtration rate	Daily	Pen and formats etc.	Local operator/ technician
2	Monitor turbidity of effluent leaving filter	Daily	Laboratory equipment	Laboratory technician
3	Backwash filter and examine sand surface for dirt, cracks, mud balls, or unevenness	Monthly, occasionally	Pen and formats etc.	Local operator/ technician
4	Measure sand surface elevation compare with previous measurement	Monthly	Meter, Pen and formats etc.	Local operator/ technician
5	Inspect regularly if sand is found in the filter effluent	Daily	Pen and formats etc.	Local operator/ technician
6	Check the under drain system	Monthly	Wrenches, and other tools	Local operator/technician/daily laborers
7	Clean and apply protective paint or coating to the interior of the filter shell	Annually	Cleaning materials, antirust paints	Local operator/technician/daily laborers, painter
8	Inspect structures for cracks and deteriorations	Bi-annually	Meter, Pen and formats etc.	Local operator/ technician
9	Inspect the under drain system which are subject to corrosion	Quarterly	Wrenches, and other tools	Local operator/technician/daily laborers

3.13 Service Reservoir (SR)

3.13.1 Function

The main function of Reservoirs and Service Reservoir (SR) is to cater for daily demands and especially peak demands of water. Operators/managers must be concerned with the amount of water in the storage reservoir and the corresponding water levels at particular times of the day. Procedures for operating the Service Reservoir will depend upon the design of its storage capacity and on the water demand.

Service Reservoirs have to be operated as per the design requirements. Normally the service reservoirs are constructed to supply water during periods of high water demand and hence the SRs are filled in low water demand period. At times pumps may be used only for filling the SR before the next supply timing or can be used also during supply hours to maintain the levels in the SR.

3.13.2 Abnormal operation of Service Reservoir

Abnormal operating conditions arise:

- Whenever demand for water goes up suddenly due to fire demand, or due to excessive demand on one command area/zone of a system.
- Due to failure or breakdown of water supply of another zone of the distribution system.
- Breakdown or out of service pumps or pipelines or power breakdowns or out of service SRs.

The operator/manager must have a thorough knowledge of the distribution system emanating from the SRs. Closure or adjustment of valves at strategic points in the distribution system can focus or divert the flow of water towards the affected areas. Emergency plans must be developed in advance to cope with such situations.

3.13.3 Storage Level

Most of the distribution systems establish a pattern of levels for assuring the required supplies at the required pressures. A water usage curve over a 24 hour period should be prepared for each SR. It can be seen from the usage curve that the pattern varies not only during the different times of the day but also during different days of the week especially on week-ends, holidays and festivals. Demand pattern also changes during different times of the year depending on the weather conditions such as summer, winter etc. From the usage curve the operator can better anticipate and be ready for the expected high consumption periods. The maximum water levels to be maintained in the SR at each morning should be known to ensure that the system demands are met for the day.

In case of intermittent supply, timings for supply of water in the areas are fixed in advance. In large command areas, the water can be supplied to sub-zones during particular fixed hours

by operation of the necessary valves. The operator should work out a programme for compliance.

3.13.4 Storage Capacity

Capacity of storage reservoir at different levels can be calculated and charts or tables can be prepared and kept at the SR site. Proper functioning of water level indicators is required to read the water level in the SR and assess its capacity. Usually water levels are read at the same time each day and the readings recorded. Checks of water levels at other times of the day will enable to determine if any unusual consumption conditions have occurred. If any significant increase in consumption is anticipated the operations should ensure a corresponding increase in supply into the SR.

Automatic valves are used to prevent overflows from SR and maintain a constant level in the SR as long as the pressure in the distribution system is adequate. Often the pumps feeding into a SR are switched off or switched on as per the water levels in the SR. In some SRs advance warning alarms are provided to signal when water levels in SR are either too low or too high. The operator shall ensure that the automatic operations work as and when needed. Sometimes time clocks are often used to control the water coming into the reservoir. At some places the overflow is connected to the distribution system; in such cases some mechanism must be in place to indicate that the reservoir has started overflowing.

3.13.5 Storage Level Control

A simple system used to read and control the levels in SRs is a gauge/water level indicator. Whenever the SR reaches the maximum water level, the operator informs the pump house to stop pumping. In place of the traditional telephones, mobile phones or dedicated wireless units can also be used. Electrodes, ultrasonic signals or solid state electronic sensors are also used to sense the rise and fall in water levels and send signals to the pumps to be stopped or started through cables or wireless or radio frequencies.

3.13.6 Elements of the Service Reservoir

The following indicated in table below are main elements of the service reservoir:

Table 16: Elements of Service Reservoir

Name of element	Function
Concrete or masonry	To store water without significant leak or loss
Inlet pipe	Conveys water from the transmission to the reservoir
Float valve	Shuts of when the water in the reservoir reaches full level by floating action
Outlet valve and water meter	The outlet valve and water meters are installed at the outlet pipe so as to be used as means of flow control and registering water distributed respectively
Overflow pipe	An open pipe situated at the full level of the reservoir to discharge water safely
Drain pipe and valve	Drain pipe is situated at the bottom level of the reservoir so as to empty the reservoir for inspection and cleaning
Accessories (internal & external ladders and man hole cover)	These accessories can be used during inspection, cleaning and repair
Level indicator	Indicates the level or amount of water in the reservoir
Vent pipe	Provides air ventilation

3.13.7 Operation and Maintenance requirements of reservoir

Operation and maintenance activities to be undertaken at service reservoir are indicated in table below:

Table 17: Operation and maintenance requirements for elements at the Service reservoir

S.N	Task Description	Frequency	Tools/material	Manpower requirement
1	Record readings of water distribution on prepared form and notice if readings are unusual or faulty, Check vent pipe is in good condition and man hole cover is not manipulated by unauthorized intruder	Daily	Pen, and formats	Local operator/technician
2	Check outlet, float and drain valves and leaks on external walls. Check water overflowing is not eroding the area.	Monthly	Pen, and formats	Local operator/technician
3	Check and clean	Annually	Chlorine,	Local operator/technician,

S.N	Task Description	Frequency	Tools/material	Manpower requirement
	structure disinfect with chlorine		cleaning materials, boots etc	daily laborers
4	Inspect for cracks & corrosion	Annually	Pen, and formats	Local operator/technician
5	Check condition of interior paint in steel tank and paint bare spots with primer and finish coat	Annually	Paint, brush, and cleaning materials, chlorine etc	Local operator/technician/painter, daily laborer
6	Check float valves, electrodes and ensure that they are functioning properly	Annually	Pen, and formats	Local operator/technician
7	Check vent screens, replace if necessary	Annually	Wire mesh, wires,	Local operator/technician
8	Check interior and exterior ladders; repair and paint if necessary	Annually	Paint, brush, and cleaning materials, chlorine etc	Local operator/technician/painter, daily laborer
9	Construct pavement around reservoir	Annually	Stone, sand, cement,	Local operator/technician/mason, daily laborer
10	Check the fencing and gates	monthly	Poles, nails, pick axe	Local operator/technician/carpenter, daily laborer

3.14 Distribution System

3.14.1 Objective

The overall objective of a distribution system is to deliver wholesome water to the consumer at adequate residual pressure in sufficient quantity at convenient points and achieve continuity and maximum coverage at affordable cost. To attain this objective the organization has to evolve operating procedures to ensure that the system can be operated satisfactorily, function efficiently and continuously, and as far as possible at lowest cost.

Routine and emergency operating procedures should be in written form and understandable by all operators of the authority to act in emergencies.

3.14.2 Normal operation

Normally, the operations are intended to maintain the required supply and pressure through out the distribution system. Critical points are selected in a given distribution system for monitoring of pressures by installation of pressure recorders and gauges. These pressures are either measured manually and transmitted to the control station or automatically measured and transmitted by telemetry to control station. In the direct pumping systems, whenever water pressures in the distribution system or water levels in the Service Reservoir (SR) drop below the minimum required levels, pumps would be manually or automatically started. In an intermittent water supply system, pumps and valves are operated during fixed hours. These pumps will run till the maximum levels in SR and maximum pressures in the distribution system are reached.

3.14.3 Issues Causing problem in Distribution System

1. Intermittent System

The distribution system is usually designed as a continuous system but often operated as an intermittent system. Intermittent supply creates doubts in the minds of the consumers about the reliability of water supply. This leads to limited use of the water supplied, which does not promote personal hygiene at times. During the supply period the water is stored in all sorts of vessels for use in non-supply hours, which might contaminate the water. Often, when the supply is resumed, the stored water is wasted and fresh water again stored. During nonsupply

hours polluted water may enter the supply mains through leaking joints and pollute the supplies. Further, this practice prompts the consumers to always keep open the taps of both public stand posts and house connections leading to wastage of water whenever the supply is resumed. Intermittent systems and systems which require frequent valve operations are likely to affect equitable distribution of water mostly due to operator negligence.

2. Non-Availability of Required Quantity of Water

Failure of source or failure of power supply may cause reduced supplies. Normally, the distribution reservoirs are designed for filling in about 8 hours of pumping and whenever the power supply is affected the pumping hours are reduced and hence the distribution reservoirs are not filled up leading to reduced supply hours and hence reduced quantity of water.

3. Low pressure at supply point

Normally peak demand is considered ranging from 2 to 3, whereas the water supply is given only for a different duration, leading to large peak factors and hence affecting the pressures in the distribution system. This is a common with most water supply systems.

4. **Leakage of water**

Large quantity of water is wasted through leaking pipes, joints, valves and fittings of the distribution systems either due to bad quality of materials used, poor workmanship, corrosion, age of the installations or through vandalism. This leads to reduced supply, loss of pressure and deterioration in water quality.

5. **Unauthorized connections**

Illegally connected users will contribute to the reduction in service level to authorized users/consumers and deterioration of quality of water. Sometimes, even legally connected users draw water by sucking through motors causing reduction in pressures.

6. **Extension of area of distribution system**

Due to extension of service area without corresponding extension of distribution mains, the length of house connections will be too long leading to reduction in pressures.

7. **Age of the system**

With age there is considerable reduction in carrying capacity of the pipelines due to incrustation, particularly unlined CI, MS and GI pipes. In most of the places the consumer pipes get corroded and leaks occur resulting in loss of water and reduced pressure and pollution of supplies.

8. **Lack of records**

System maps, designs of the network and reservoirs and historic records of the equipment installed in the distribution system are often not available, whereas some minimum information is required to operate and maintain the system efficiently.

3.14.4 Scheduled Maintenances

1. Deterioration of pipes

Pipes deteriorate on the inside due to corrosion and erosion and on the outside due to corrosion from aggressive soil and water/moisture. Depending on the material of pipes, these are subjected to some deterioration, loss of water carrying capacity, leaks, corrosion and pitting, tuberculation, deposition of sediment and slime growth. Preventive maintenance of distribution system assures the twin objectives of preserving the bacteriological quality of water in the distribution system and providing conditions for adequate flow through the pipelines. Incidentally, this will prolong the effective life of the pipeline and restore its carrying capacity. Some of the main functions in the management of preventive maintenance of pipelines are assessment, detection and prevention of wastage of water from pipelines through leaks, maintaining the capacity of pipelines, cleaning of pipelines and relining. The topic of assessment of leaks is dealt in detail in Chapter 15 on Water Audit and Leakage Control in this manual.

2. Cleaning of pipelines

Mechanical cleaning devices such as swabs and pigs are some times used if flushing does not improve the water quality. Scrapers or brushes are used in pipelines with hardened scales or extensive tuberculation. Sometimes scrapers and brushes are used before taking up lining works.

3. Flushing of pipelines

Flushing is done to clean the distribution lines by removing impurities or sediment that may be present in the pipe. Routine flushing of terminal pipelines is often necessary to avoid taste and odour complaints from consumers. It is advisable that a programme for flushing is prepared and followed so that water mains are flushed before consumers start complaining. The routine for flushing can be prepared by taking into consideration the consumer complaints and type of deposits found while cleaning. Since in distribution system flushing is not the only solution for water quality problems, proper operation of treatment process and cleaning of service reservoirs supplying water to distribution system shall also be planned along with the flushing of distribution system. Flushing is usually done during low water demand, when the weather is favourable. Prior planning and good publicity with public will allow the flushing to proceed quickly and without confusion.

3.14.5 Management of Distribution System

Water supply distribution system shall be designed and implemented such that proper operation and maintenance can be done even to share water among users when there is shortage. Management of water supply systems requires the division of zones or District Metering Areas (DMAs) to which water supply can be controlled independently by gate valves.

In determining the size of a single DMA, an aggregate length of distribution pipes of 1 to 3 km would be a reasonable standard. Prior to survey the location of valves and their particular function in the areas of survey must be confirmed in close reference to pipe drawings. Sometimes, repair may be needed to make each zone independent from others. For taking measurement, all the customer meters within the zone of measurement must be ensured for their functionality and bulk water meters need to be installed at inlet and outlet locations.

3.14.6 Elements of the distribution system

The following indicated in table below are main elements of the Distribution System:

Table 18: Elements of the Distribution system

Name of element	Function
Pipe line (Galvanized iron, DCI or PVC or HDPE)	Pressurized Tubes near customers to supply customers by connection
Gate valve	Valves in the distribution system to isolate pipes for controlling flows and isolation during repair.
Flush valves	Valves in the distribution system to flush pipes after repair or as required located at low points
Air release valve	To release air in the distribution system not to block flows or offends customers.
Hydrants	For providing water for fire protection
Public taps	Supply at a point for a number of people
Private connections	Water supply connection points for customers
Water meters	Registers consumption or distribution
Valve chambers	Protection house for valves and easy access

3.14.7 Operation and Maintenance requirements of distribution system

Operation and maintenance activities to be undertaken at distribution system are indicated in table below:

Table 19: Operation and maintenance requirements for elements at the distribution system

S.N	Task Description	Frequency	Tools/material	Manpower requirement
1	Clean public tap, that drains are not clogged	Daily	Cleaning materials, scrapers	Water seller
2	Record water meter reading at every interval of water supply at the public tap and make sure that the water meter is functioning properly.	Daily	Pen and formats	Water seller
3	Inspect fittings of pipe network if there is visible leak	Monthly	Pen and paper	Local operator/technician
4	Check piping installations at the public tap, inspect and repair fence	Monthly	Meter, nails, poles etc	Water seller/carpenter, daily laborer
5	Record water meter readings and check if the water meter is functioning properly, for every connection	Monthly	Pen and bill cards	Water meter reader
6	Inspect pipelines and flush network	Annually	Wrenches, pick axe, shovel	Local operator/technician/daily laborers

S.N	Task Description	Frequency	Tools/material	Manpower requirement
7	Inspect house connections, valves and water meters are functioning appropriately	Annually	Pen and bill cards, containers of known volume	Local operator/technician
8	Inspect isolating valves, air valves and flush valves and that they are functional or replace corroded bolts and repair leaks. Inspect chambers and clean debris from chamber	Annually	Wrenches, pick axe, shovel	Local operator/technician/daily laborers/masons etc
9	Replace water meter for public tap and send to Regional Water Bureau for maintenance and calibration	5 Years	Wrenches and new water meters	Local operator/technician/daily laborer
10	Replace water meter for house connection and send to Regional Water Bureau for maintenance and calibration	5 years	Wrenches	Local operator/technician
11	Measure and quantify the pipes and fittings required for connection requests or extension	Occasionally	Meter, pen and paper	Local operator/technician/daily laborer
12	Inspect river or gully crossing structure for erosion or settlement and maintain after heavy rain or every three months	Quarterly	Wrenches, pick axe, shovel etc	Local operator/technician, daily laborer, mason, carpenter
13	Inspect anchor blocks for erosion or settlement and maintain after heavy rain or every three months	Quarterly	Wrenches, pick axe, shovel etc	Local operator/technician, daily laborer, mason and carpenter
14	Inspect pipelines and flush by valves at low point	Annually	Wrenches, pick axe, shovel etc	Local operator/technician, daily laborer

3.15 Extension/Rehabilitation of the Water Supply System

As the utility existed to serve the demand of the urban community, it is very challenging to satisfy the rapidly growing development activities of the community, which has direct relation with water supply. Hence, the utility has to follow-up, formally notice and perform extension services within its capability or request for assistance of the Zonal and Region Water Bureau.

This section is intended to encourage the utility to handle among its operation and maintenance activities to accept requests or upon recognition of extension or rehabilitation need on the water supply service, which has to be planned and achieved to diminish shortfalls in the system.

Table 20: Possible types of extension or rehabilitation

Component	Possible reasons for extension or rehabilitation or problem to be solved	Remedial action
Power supply (Standby generator)	To make the system more reliable, the community requested and other system components are favorable	Procure standby generator set through the Regional Bureau.
Power supply (Electrification from EEPCO)	To reduce operational cost and make the more comfortable	Get connection from EEPCO grid
Borehole	Yield is too low, needs additional source	To study and recommend feasible actions
Reservoir	Size is too small, the leakage is high and repair cost is so high compared to cost of new one	To study and recommend feasible actions
Transmission pipe	Pipe size is too small to transmit the source capacity, the pipe is too old with unavoidable leak	To study and recommend feasible actions.
Provision of water meter at the reservoir	To measure water distributed or transmitted, no previous installation or malfunctioning meter	To procure and install new or maintain and calibrate old one
Distribution pipe extension	A lot of customers requests are coming but the UTILITY is not sure of the adequacy and pressure and the pipe has to extend with very high cost than normal connection	To study and recommend feasible actions
Private connection	Many customers request for connection and the UTILITY is not sure of the adequacy and pressure	To study and recommend feasible actions
Public tap addition	Community requests and UTILITY not sure about the adequacy and pressure	To study and recommend feasible actions
System expansion	The town is developing, investment and development requires water supply service higher than the capacity of the UTILITY and system extension may require study, planning design and implementation.	Consult with Regional Water Bureau

4 CURATIVE MAINTENANCE AND UFW CONTROL

4.1 Introduction

4.1.1 General

Reduction in water loss enables utilities to use existing facilities efficiently. It significantly contributes to alleviating shortage of water supply, the improvement of the supply capacity to consumers and the reduction of operational expenditures that are related to power and chemical costs to deliver and treat water.

Reduction of water losses extends the service life of existing water supply components to meet increased needs, and that construction of new water facilities such as development of new sources, reservoirs, distribution system and treatment plants could be deferred.

4.1.2 Revenue from Losses

Leakage contributes to loss of revenue from customers who could have been undercharged due to faulty meters, or not charged at all due to illegal connections and unregistered consumption. This has a negative impact on financial improvements of the utilities affecting allocations for wholesale supplies, treatment, pumping and other operation and maintenance expenditures.

4.1.3 Squandering of Resources

Natural resources such as lakes, rivers, springs and subsurface water are limited. The price of energy, chemicals and other items are constantly rising. Therefore, water losses result in wastage of resources unless monitored regularly by establishing better organisations with skilled

4.2 Curative Maintenance

As described under the introductory section of this document, there are two types of maintenances namely preventive and curative maintenances. Preventive maintenance is included under the Operation and Maintenance requirements of system components described under the preceding sections. Besides covering preventive maintenance management of curative maintenance is also important when breakages of system components happen beyond the capacity of the utility to prevent breakage.

In general, to assure proper maintenance of water supply services, the following requirements are required to be fulfilled,

1. Evaluate the report on the preventive maintenance and study if there are proposals for preventive maintenances,
2. Establish system to get information from the users on the breakage of the pipes

3. Handle the information on the preventive maintenances of the system and identify those which can be maintained by the utility and those which needs to be outsourced,
4. Handle records of curative maintenance record orders filling on forms prepared for this purpose,
5. Handle records on the detail of curative maintenance after completed in the formats and main maintenance recording manual

If the type of the maintenance is beyond the capacity of the utility, the following steps needs to be kept;

1. Study the type and detail of curative and preventive maintenance by external sources,
2. Study alternatives for doing maintenance
3. If bidding is required preparer bidding documents with the assistance of the water bureaus and process the procurement. The procurement can be for certain duration of time based on the guidelines,

4.3 Types and occurrence of Leaks

4.3.1 General

Before proceeding to discuss about causes, consequences and other aspects of leakage, it will be good to examine the types of leaks that are commonly encountered and their category of occurrence (where they can be located) in a distribution network of water supply system. Leaks can be classified as:

Physical losses: Physical losses through leaks may occur in any part of the system: transmission pipes, service reservoirs, pumps, distribution networks, and house connections.

Administrative losses: include illegal connections, faulty (under-registering) or broken meters, inaccurate billing, etc.

In this manual the descriptions and control mechanisms are mainly dealing with physical losses or leaks. These kinds of leaks can be categorised into two main types. These are surfacing or visible leaks, and hidden or non-visible leaks.

4.3.2 Types of leaks

4.3.2.1 Surfacing Leaks

Leaks that come out to the surface are called surfacing or visible leaks. They can be seen emerging from the sub-surface to the top ground or pavement. This type of leak normally finds its way through a relatively loose backfill in a trench and will probably surface at the break point. In some cases, however, the source of leak may be at a considerable distance away from the area where it is observed or surfaces out.

Such leaks are usually reported by water customers or the utility's operation and maintenance crew and should be given immediate attention and repaired without delay. Negligence on the part of the water utilities could lead to damage of street pavements and public or other utility properties.

Users' reaction to a neglected or promptly unattended visible leak is serious, often reflecting bias and negative attitude towards the utility, especially in a situation where the water needs of the community could not be satisfied because of inadequacy crisis or service inefficiency. Figure shown here below is typical visible leak from a valve.

Figure 2: Typical visible leaks from a valve (Durame Picture by MCE)

4.3.2.2 Non-visible Leaks

Leaks that do not come out to the surface but percolate to the surrounding ground are called non-visible or hidden leaks. Leaking water will take the path of least resistance and may not necessarily surface. Hidden leaks also find alternative escape routes through other water and wastewater conveyance facilities such as storm water drains, sewers, stream channels or abandoned pipes.

In large water distribution systems, an invisible leak may go undetected for quite a time as the water loss will have little influence when compared to the huge daily water distribution. Even if a number of such leaks develop in a given time, the cumulative effect may not be noticed immediately until an audit (for water) is made at the end of the year to compare water production and consumption. Figure shown here below illustrates underground non-visible leak.

Figure 3: Schematic presentation of Non-visible leaks – usually occur underground

Non-visible underground leaks may not be detected for an average duration of even two years. As the age and size of leak increases, the underground cavity gets larger, increasing the potential for damage to overlaying property and the value of water loss unaccounted. Figure shown here below is typical non-visible leak.

Sign of underground leaks include:

- Usually wet spot in landscaped areas and/or water pooling on the ground surface,
- An area that is green, muddy, soft, or mossy surrounded by drier conditions,
- A notable drop in water pressure/flow volume,
- A sudden problem with rusty water or dirt or air in water supply (there are other causes for this besides a leak),
- Heaving or cracking of paved areas,
- Sink holes or potholes,
- Uneven floor grade or leaning of a structure,
- Unexplained sudden increase in water use, consistently high water use, or water use that has been climbing at a fairly steady rate for several billing cycles.

Figure 4: Typical example of non-visible leak

Most utilities are not aware of the existence of non-visible leaks and the benefits of detecting and repairing them. Leaks in general and hidden ones in particular are one of the major consumers of water in the water system with no contribution to revenue generation. In visible leakage is common when the soil is mostly clay.

4.3.3 Occurrence of Leaks

Generally, leaks can be divided into five main categories depending where they commonly occur or may be located. The five major categories are:

- **Water main leaks** typically range from 0.1 l/s to over 70 l/s. Leaks due to corrosion of water mains usually start through small holes but can grow to very large leaks with time. Excessive pressure and corrosion, poor workmanship, settlement of trenches overloading, and improper materials, and temperature stresses are the major ones. Figures shown here below illustrate typical leaks on water mains.
- **Service Line** leaks typically range from as low as 0.03 l/s to over 1 l/s. The causes for service line leaks are the same as for the mains.
- **Customer Meter Box leaks** (near or within meter boxes of customers) range from 0.1 l/s to 0.7 l/s. Leaks may be caused by loose nuts on the meter, broken or damaged couplings and broken or damaged meters.
- **Customer Connection** Line leaks (customer side of the line) range from 0.1 l/s to 1.0 l/s; holes or breaks in customer connection lines and shutoff valves may cause these leaks.
- **Valves and Appurtenance** leaks in distribution system typically range from 0.07 l/s to as high as 30 l/s; loose connection and broken valves are common causes for this type of leak. Valve leaks in a water supply system may be observed in isolating valves, pressure reducing valves, drains and air-release valves. The

figure shown below also illustrates typical service line and customer connection leaks.

4.4 Causes of Leakage

4.4.1 What Are the Causes of Leaks

There are a number of causes that create leaks in water supply components and mainly in transmission/gravity lines and distribution system. Among others, the major causes can be classified as follows:

- Effects of Excessive Pressure
- Corrosion
- Effects of Soil Condition
- Effect of Quality of Water
- Pipe-Laying Standards
- Age of Pipe

4.4.2 Effects of Excessive Pressure

4.4.2.1 General

The efficiency of a distribution system can be judged on the basis of the pressure available in the system for a specific rate of flow. Pressures should be great enough to adequately meet consumer needs. At the same time they should not be excessive and as pressure increases, leakage increases and money is then spent to transport and process a product that is wasted.

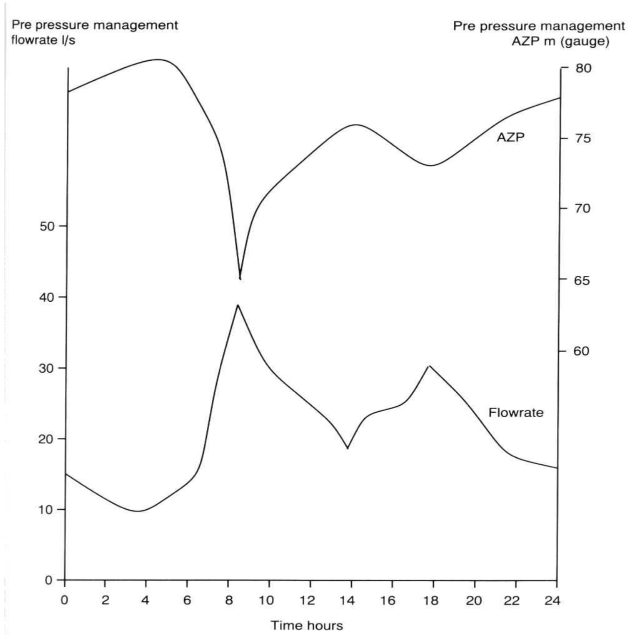
Utilities are always expected to provide adequate and safe drinking water with sufficient pressure at all delivery points. Pressures at consumers yard connections have to be as close to the minimum level as possible, though this is supposed to be determined by local authorities. The minimum pressure at a customer’s connection is in the order of 15 meters while the maximum is as high as 40 meters; pressure range in excess of 60 to 70 meters will damage house installations such as boilers, float valves, taps, gaskets inside the fittings, etc.

4.4.2.2 Relationship between Pressure and Water Demand

Pressure variation in a distribution network is caused, amongst others, by changes of demand of the users. Frequent starts and stops of pumps, closure and opening of control valves that induce water hammer are also some of the causes to be mentioned for pipe breakage and water loss. The Figure here below shows schematic presentation of the relationship of flow rate in a day versus pressure changes. Note that high pressures than the targeted level and the daily pattern of the pressure changes (ups and downs) in a given day.

The pressure diagram has an almost reversed pattern: low during daytime with increase of demand and high during night hours when the demand is low. Note how the “peaks” of demand correspond with “valleys” of pressure curve in the daily diagram.

As can be seen from the monitoring of the selected area, there is an excess pressure build-up in a network when demand drops especially during the night. Obviously, there is the need to cut down this unduly excessive pressure in order to avoid the bursting of pipes or reduce the amount of leakage.



Source Eddie Moir 2009

Figure 5: Flow Rates and Variations of pressure in a network

The pressure diagram has an almost reversed pattern: low during daytime with increase of demand and high during night hours when the demand is low. Note how the “peaks” of demand correspond with “valleys” of pressure curve in the daily diagram.

As can be seen from the above figure , there is an excess pressure build-up in a network when demand drops especially during the night. Obviously, there is the need to cut down this unduly excessive pressure in order to avoid the bursting of pipes or reduce the amount of leakage.

Variations of pressure may cause frequent pipe bursts or damages. Past studies on the effect of high pressure on losses, particularly leakage from pipes, have indicated that leakage is almost proportional to the service pressure.

The following methods can be envisaged to achieve the cutting down of the excessive pressure:

* Adjust the **speed of pumps** to maintain reasonably constant pressures in the distribution network for areas supplied directly by pumps.
* Install a **pressure-reducing valve** (PRV) or
* Divide the system into **pressure zones.**

4.4.2.3 Pressure Control in the Network

The pressure in the Control (nodal) Point could almost be made constant by opening and closing the PRV as dictated by the changes in demand. The PRV allows the regulation of pressure for only one Control Point. Similar installation has to be made elsewhere at nodes where unnecessarily high pressures are identified. The figures shown here below illustrate level of leakage at high and low pressure levels.

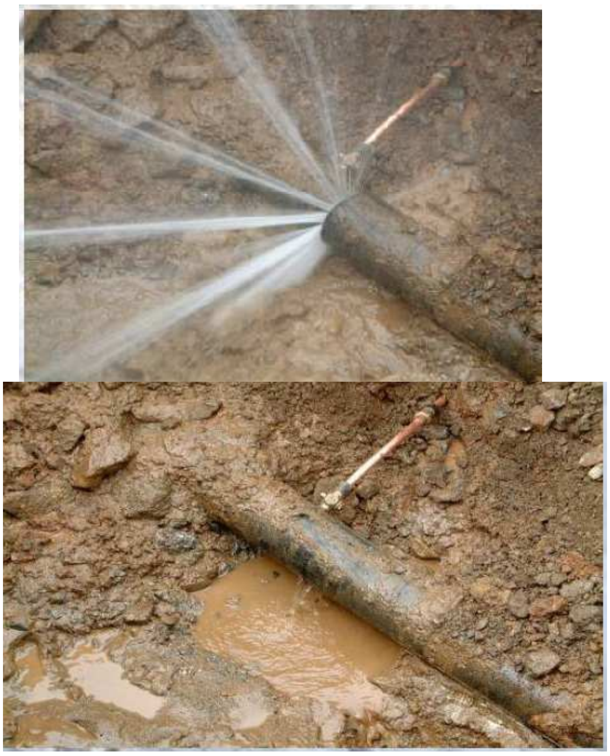


Figure 6: Illustrating Level of leakage at high (left) and low (right) pressure levels

The following benefits can be achieved from a well-organised pressure control system:

* Reduce frequency of bursts and damage to pipes
* Reduce leakage and thereby save water resources, energy, chemicals, etc.
* Provide reliable service to customers with optimal pressure and thereby achieve high public regard
* Subject pipes, fittings and other appurtenance to lower/safe working pressures

A Pressure Reducing Valve (PRV) is a device to keep pressure in the Control Point at the desired level. The most sophisticated one has both electronic and hydraulic components. Apart from being costly, it will not be easy to maintain this two-component device. The simplest device is the flow-modulated PRV. This devise raises the operating pressure (to target level) as the flow increases and lowers the pressure as the flow decreases. The operation and maintenance of such a device is simple as it does not have an electronic component.

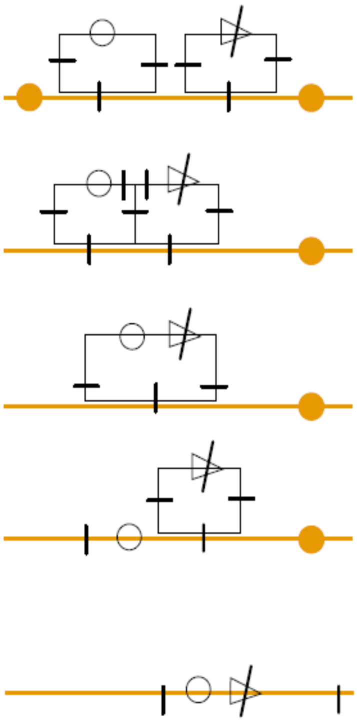
A PRV should usually be installed in a chamber so that maintenance, repair or modification can readily be carried out, power may be required to the site if telemetry or powered control systems are being considered. This should be considered during the selection of the PRV.

The cost of installing flow meters at the same time as a PRV is a little more than the actual meter cost. The advantage is that the benefits of the pressure reduction can be measured and monitored. Some PRV control systems also require a meter. A disadvantage is that it is an extra asset to maintain. Weather to install a meter with a PRV is probably decided by the size of the Pressure Managed Areas (PMA).

There are several options for PRV installation design. The criteria which should be used in the selection are:-

- The cost of the PRV and its accessories
- Will the design interface match with the operation and accuracy of the meter and PRV?
- Will the operation of the meter and PRV interfere with each other?
- Ease of access for servicing and repair;
- Ease of isolation for servicing and repair
- Is a strainer required to keep the meter and PRVs working effectively in the local water quality conditions?
- Have the installation requirements of the meter and PRV been met?
- Can the meter be calibrated in-situ?
- Can the layout of pipe-work be easily understood from the layout of covers?

Figure shown here below shows possible arrangement for the selection and installation of meter and PRV in a distribution network.



Separate meter and PRV bypasses. High cost. allows meter and bypass to be separately isolated. Useful if no room for combined bypass on one site.

Combined bypasses. Allows meter and bypass to be separately isolated.

Low cost, with meter straight on to PRV. Flow straighteners are likely to be needed. Metered flows may not be accurate.

Meter in-line, where meter is low maintenance.

Low cost installation with meter straight on to PRV. Flow straighteners probably required. Low maintenance PRV and meter required. Metered flows may not be accurate.

Figure 7: Selection of potential meter and PRV layout in a network

Pressure control may have to ease if complaints of inadequacy of service pressures arise from some customers. The local utility staff may decide to raise the pressure by, for instance, opening the PRV to the full.

Such decision has to be combined with the initiation to monitor flows, as the consequence of raising pressures inevitably results in the rise of minimum night flow and average demand, and obliges the utility staff to look for leaks in the area.

The pressure in a control point could be maintained almost constant by opening and closing a PRV. The device controls pressure at only one control point and it is possible that pressures elsewhere could be unnecessarily high thus requiring installation of several PRVs. This has cost implication and the operation increases the burden on O & M crews. Moreover, the manually operated devices may fail and the communication link may break down for the automatic ones. Figure here below shows Typical PRV installation.

Figure 8: **Illustrates typical installation of PRV**

Alternatively, solutions like establishing pressure zones in a network, based on similar range of optimal pressure levels for certain areas, have proved to be effective and dependable means of controlling pressures in a distribution system.

In locations where sharp changes in topography occur (hilly or mountainous regions), it is common practice to divide the distribution system into two or more service areas or pressure zones. This avoids the difficulty of extremely high pressure in low-lying areas in order to maintain reasonable pressure in higher elevations. In practice valves that are closed off during normal operations interconnect such pressure zones.

4.4.2.4 Corrosion

Water supply pipeline is in continuous contact with soil surrounding it and the water moving through it. Water or the surrounding soil may cause problems that will affect the performance and life of the distribution pipes in the system. Corrosion is a problem that is created in such an environment and it is defined as an electrochemical reaction that deteriorates a metal or an alloy. The majority of the main breaks occur at locations where the pipe wall has been weakened due to corrosion of metal pipes (see Figure here below).

Figure 9: Corrosive attacks of pipes

4.5 Causes of Corrosion

The following are to be the causes of corrosion that can be considered in a water distribution system:

* Aggressive water flowing through the pipes
* Chemical and electrical conditions of the soil in which the pipe is buried.
* Connecting components of dissimilar metals without, such as galvanised steel pipe to a cast iron water pipe without an insulation union.

4.5.1 Prevention of Corrosion

In a given situation corrosion may have one cause or many; hence control measures must be planned to meet the specific conditions. Since it would be impossible to give specific measures that cover all local problems, the following control measure, which are common and practical, are listed as guide to establish corrosion control measures and solve specific problems.

(a) Designing against Corrosion: Good design entails the selection of proper materials, the allowance of extra thickness of metal where it is known that corrosion may occur, the proper protection of metals by protective coatings and linings, and the provision of adequate water treatment devices.

(b) Selection of Materials: A basic step in the prevention of corrosion is the selection of the most resistant material for a given environment. In good soils it is safe to use ductile iron pipe. For corrosive water conditions, cement-lined ductile iron pipe should be used instead of plain cast iron. In highly corrosive soil, use of either cement-lined and coated steel pipe, or coal tar enamelled pipe is preferable. Corrosion is not normally a cause of failure or leakage of ductile cast iron pipes because of their thickness and corrosive-resistant characteristics. PVC pipes have gained popularity in that they are more corrosive resistant than ductile cast-iron pipes. Steel pipes, as water mains require special treatment, both for inside and outside coatings.

In deciding upon the type of pipe to be used, apart from other factors to be considered, the type of water quality to be conveyed and its possible corrosive effect upon the pipe material with, perhaps, a serious reduction in length of life must be taken into account.

c) Protective Coating and Linings: Protective coatings and linings serve as barriers between the metal to be protected and the corrosive environment. In many cases, it may be more economical to use a protective coating than to use a more resistant material. Depending on circumstances, protection may be needed either internally or externally. Protective coatings and linings may either be metallic or non-metallic. Non-metallic protection commonly includes paint, enamel coatings and cement linings.

When installing pipes, extreme care must be taken not to scrape off paint or enamel coatings as corrosion will be exceptionally severe where the coating has been damaged (figure here below).

A general rule cannot be made as to the selection of protection methods because each has its application to special circumstances:

1) *Paints* or coating is by far the most generally accepted method of corrosion control. Commonly used ones are bituminous paints, which are prepared by blending refined coal tar and asphalt. They are used in protecting the underground elements of systems from soil and bacterial corrosion.
2) *Metallic coatings* with zinc are the most widely used in water works. The use of galvanised pipe is very common in a distribution network as well as for interior piping and service connections. Galvanising is used mostly for small pipes. It gives reasonably good protection against atmospheric corrosion but is poor with highly aggressive and corrosive waters and its protective effect is uncertain as to time.
3) *Cement lining and coatings* are applied for ductile cast iron and steel pipes and fittings. Care must be taken in their handling and installation so as not to crack the lining.

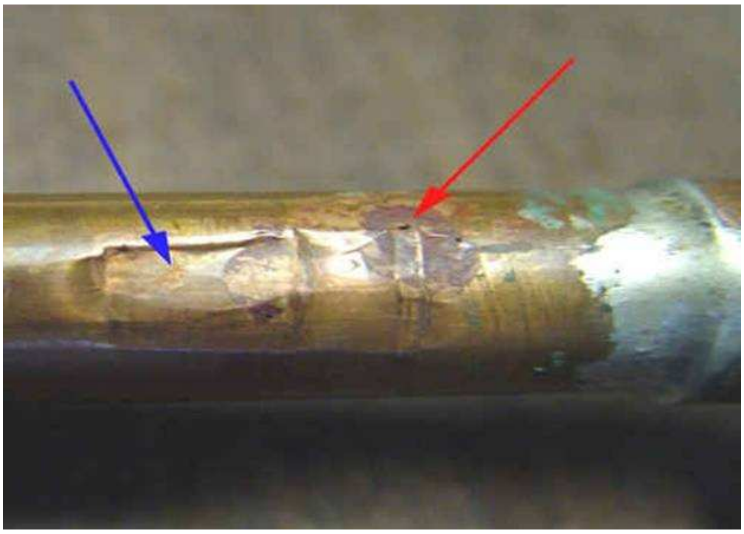


Figure 10: Pipeline corrosion resulting from damage to coatings

4.5.2 Effects of Soil Condition

Some soils, such as clays and other highly organic soils can be extremely corrosive, though corrosive conditions can exist in other soils. Soil conditions are responsible for the exterior corrosion of metal structures under or in contact with the ground and some of the causes for current to flow from one electrode to the other within soils thus causing corrosion are:

* Non-uniform texture of the soil,
* Differential aeration or difference in the availability of oxygen
* Two or more different types of soil, such as sand and clay,
* Presence of foreign matter, such as cinders in the soil, and
* Difference in the moisture content of the soil

In general, salt bearing soils, highly alkaline soils, clay, brackish marshes, and poorly drained soils are conducive to corrosion.

4.5.3 Effect of Quality of Water

Water is rarely found in a pure state; it may carry a variety of substances, such as minerals, salts, acids, organic matter, oil and grease. Such impurities either cause or accelerate corrosion whereas chemically pure water will not tend to be more corrosive. On the other hand, impure water may gradually deposit mineral or organic matter that builds up a protective coating to retard corrosion of metals,

Some waters are naturally corrosive because of the presence of oxygen and free carbon dioxide while others, after coagulation, may be quite soft and acidic and are also aggressive, that is corrosive. Often treatment of the water reduces its corrosiveness.

4.6 Pipe-Laying Standards

4.6.1 General

Pipe mains are designed to withstand anticipated internal and external forces. However, structural failure can occur if the actual forces exceed the structural strength of the pipe material. Poor design, deterioration of pipe material and unanticipated load condition will result in pipe breakage.

Even if pipes have been designed or manufactured properly, unanticipated forces that exceed the pipe’s strength can occur from excessive internal pressure, external load and temperature variation.

(a) Internal Loads: The pressure of water causes tension in pipe walls. It can be computed by the formula

S = r*p/t

In which S is the stress in the metal pipe in Kg/cm^2, r is the radius of the pipe in centimeters and p is the pressure in kg/cm^2 and t is the pipe thickness in centimeters.

Excessive internal pressures are commonly caused by water hammer, which result when a pump is shut off and or a valve is closed quickly. An allowance has to be made for water hammer over the specified working pressure. A valve should be closed by turning the wheel slowly without causing sudden pressure in the line. Table here below shows the allowance for pressure due to water hammer for ductile cast iron pipes for distribution networks.

Table 21: Water-hammer allowance for DCI pipe

Size (mm)	Pressure (bar)
75-250	8.5
300-350	8
400-450	7
500	6

Source- AWWA 1986

Nowadays DCI pipes with class K9 can take excessive pressures as high as 32 bars. If water hammer over the ones shown in the table is to be expected for a given size of pipe, protection should be obtained by using surge tanks or other means.

Where pipes change direction, centrifugal force exerted by the moving water and unbalanced pressure will tend to pull the pipeline apart at the joints. Accordingly, at joints such as bends, tees and Ys concrete thrust blocks should be constructed to overcome the unbalanced internal pressure.

(a) *External Loads:* The external load on pipes buried underground is made up of the overlaying material or backfill and weight of traffic plus impact. The trench conditions, laying methods and workmanship also influence it. Large mains (250mm and above) are likely to experience crushing failure due to excessive external pressure. Small diameter mains (150 - 200mm) are often sensitive to beam failures (failure of pipes due to bending) if their bedding support is poor, if there is movement due to expansive surrounding soil, and if soil shifting is caused due to adjacent construction.

(b) *Temperature variations:* Temperature changes will cause stresses in pipe, and they may be of importance in exposed pipes. Major breaks in water systems are experienced in places or countries where seasonal variations in temperature are significant. In such places, a major portion of the annual main breaks occurs during cold seasons when frost penetration due to significant drop in temperature causes increased tensile stress of the mains. In general, pipes laid without cover and exposed to freezing temperature could burst due to excessive tensile stress caused by expansion of freezing water in the pipes. Flexible bell-and-spigot joints absorb normal stresses induced by temperature variation. However, structures in contact with water mains may restrict easy movement of the flexible joints, thus creating excessive tensile stresses.

4.6.2 Standard Practices in Excavation and Back-filling

Great care is not necessary as such in laying pressure water pipes accurately to grade, but they should be covered sufficiently to protect them against traffic loads. Water mains may have to be lowered when installed in order to protect them from damage resulting from grading and paving of streets.

Trench widths should be wide enough to allow sufficient space for good workmanship. Table 12 gives recommended trench widths for various sizes of ductile cast iron and PVC pipes.

Table 22: Minimum trench widths for various sizes of GS, CI & PVC pipes

Ductile Cast Iron Pipes		**PVC Pipes**	
Pipe diameter (mm)	**Trench width (mm)**	**Pipe diameter (mm)**	**Trench width mm)**
50	450	100	450
100	450	150	500
150	550	200	550
200	600	250 & above	300 + D
250	650		
300	700		
350	750		
400	800		

Source- AWWA 1986

Trenches should not be very deep to avoid caving and bracing. However, a minimum cover of 750mm should be kept wherever there is a normal excavation in open areas. Whereas, pipe trenches under pavements should be deeper depending on the traffic load. In rock excavation the rock should be removed and bedding of sand or other soft soil should be placed as a cushion between the rock and the pipe.

Back-fill material should be free from stones and other solid materials. Back-fill from the bottom of the trench to the centreline of the pipe should be made by hand with sand, gravel or other satisfactory material (depending on the type of pipe) laid in layers of 100mm.

From the pipe centreline to 300mm above the pipe, back-fill should be done by hand or very carefully if machine is used. Back-filling of trenches under pavements subject to traffic load should be made with sand or other soft soil to 300mm above the pipe centre followed by selected fill material well compacted. For typical pipe trenches in traffic and non-traffic areas for PVC and ductile cast iron (DCI) pipes, refer to Figure here below.

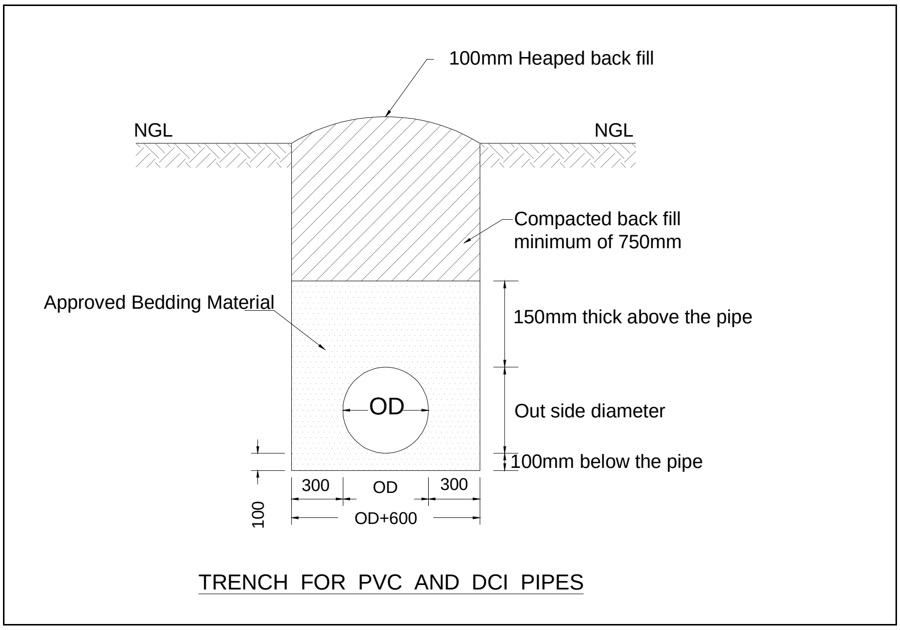


Figure 11: Typical Pipe Trench for PVC and DCI pipes

4.7 Effect of Age of Pipe

There has been a growing concern that many older urban water distribution system are deteriorating and in need of massive rehabilitation. Many studies reveal that costly rehabilitation programs will be required to replace mains older than some predetermined number of years in age or “useful life”. There are no scientifically based criteria for defining the useful life for water mains.

Though age is considered as an indicator for predicting the break rate of ductile cast iron, some studies have shown that it is not the major determinant factor for water main break rates. Thus the concept of “useful life” may not be generalised for predicting break rates. The “useful life” of ductile cast iron pipes is commonly taken to be 50 years while in reality they can serve for as long as 100 years. Figure 4.9 shows typical leakage from old pipe burst.

Figure 12: **Leakage from an Old Pipe Burst**

4.8 Connection of Old and New Water Supply Systems

During implementation of new water supply systems, sometimes the old network is ignored from further consideration during design stage to be integrated. Finally, at the time of commissioning stage due to water supply shortages, a decision might have been reached to connect the new with the old system. The two systems normally do have a different fixed grade line or hydraulic grade line owing to new locations and capacity of reservoirs and new pumping head. This would result in big pressure difference between the old and the new and subsequent excessive leakage and even sometimes cause for continuous pipe breakage. Therefore, in order to avoid such problem, the following measures need to be taken.

- Right from the outset, i.e., at the time of study and design stage, pipes which have completed their service have to be identified and not to be considered for further integration within the new system. However, pipes with reasonable condition or which have not yet completed their design phase would be made to be integrated
- The new distribution network lay out plan plus the result of the model hydraulic network analysis shall be used to determine the residual pressures for making future connections and constructing future extension lines
- The new pipe lay out plan plus the model network analysis result had to be handed over to the TWSSEs by the concerned consultant or contractor.
- The TWSSEs had to plan how shifting from the old to the new water supply network had to be executed within scheduled time.

4.9 Leakage and/or Water Loss Survey

4.9.1 The Need for the Survey

Water loss occurs in all distribution systems, only the volume of loss varies, depending on the characteristics of the pipe network and other local factors, the water company's operational practice, and the level of technology and expertise applied to controlling it. It is important to differentiate between total water loss and leakage. Total water loss is the difference between the amount of water produced and the amount which is billed or consumed. Leakage is one of the components of water loss, and comprises the physical losses from the pipes, joints and fittings and also from service reservoirs. These losses can be severe, and may go undetected for months or even years. The larger losses are from burst pipes, or from the sudden rupture of a joint, while smaller losses are from leaking joints, fittings, service pipes, and connections. The volume will depend largely on the characteristics of the pipe network and the leak detection and repair policy practiced by the company, such as:

- The pressure in the network
- Whether the soil type allows water to be visible at the surface
- The 'awareness' time (how quickly the loss is noticed)
- The repair time (how quickly the loss is corrected)

The need for the leak and water loss survey arises from the necessity to minimise leakage thereby reduce production costs and defer the incurring of capital costs. The exploitation of new and expensive supply sources can be deferred by avoiding wasteful use of the more economic sources already available.

A leak survey program can be justified by a cost-benefit analysis. Such analysis enables water utilities to assign priorities and allocate funds for repair. The key to develop a leakage strategy for any network is first to ask some questions about the network and how it is operated, and then select the right tools to find the solution. The questions and tools are;

- How much water is being lost? (tool: water balance calculation);
- Where is it being lost? (tool: pilot studies);
- Why is it being lost? (tool: review of the network and operation practice);
- How can we reduce the losses and improve the performance (tool: development of a strategy and appropriate action plan);
- How can we maintain the strategy? (tool: training, monitoring, operation and maintenance)

Each element of the strategy and the tool to address the question is listed below.

Element	Tool
HOW MUCH is being lost?	**WATER AUDIT** Measure components Check production /consumption Recalculate water balance Review records/operating procedures/skills
WHERE is it happening?	**PILOT STUDIES** Quantify total losses How much is leakage? — distribution network — transmission mains — reservoirs How much is non-leakage losses? Refine the water balance calculation
WHY is there water loss?	**REVIEW NETWORK** *Investigate:* Historical reasons Poor practice/poor QA (Quality Assurance) Poor materials/infrastructure Local influences Cultural/financial/social/political factors
HOW TO IMPROVE performance?	**ACTION PLANS/STRATEGY DEVELOPMENT** Update records systems/GIS Introduce zoning/DMAs Monitor water losses and leakage Prioritize areas Address non-physical losses Detect and locate leaks Initiate repair/rehabilitation policy
HOW TO MAINTAIN the strategy?	**TRAINING/AWARENESS** Improve awareness Increase motivation Transfer skills Introduce best practice/appropriate technology Give hands-on experience/continual reinforcement Monitor and follow-up action plans /implementation Involve community Consider demand management policy Initiate water conservation programme

Chapter 9 of the manual describes detail assessment strategy of leakages/water audit in detail.

4.10 The Concept of Unaccounted for Water (UFW)

4.10.1 General

UFW is determined by obtaining the difference between water produced and sold. If all deliveries are metered, the difference between the total amount delivered and the sum of the service meter readings and any unregistered publicly used water will be the UFW.

Calculating Unaccounted-for Water

Unaccounted-for water can be expressed in millions of liters per day (mld) but is usually discussed as a percentage of water production:

$$\text{Unaccounted-for water (\%)} = \frac{(\text{Production - metered use}) \times 100\%}{(\text{Production})}$$

Not all the unaccounted-for water is physically lost. Either the utilities master meter or some of the customers' meters may be inaccurate. In cases of inaccurate customers' meters, the water is "lost" as far as accounting and billing is concerned, any meter inaccuracies make it difficult to assess the amount of water actually lost through leaks. Therefore it is important for a utility to reduce metering errors.

Customer meters usually tend to under register. Sometimes customer meters do not work at all. Meters that under register or which do not function properly may account for significant water and revenue losses. An ongoing customer meter testing and replacement program is essential to alleviate this problem.

The acceptable level of unaccounted-for water differs from community to community. A 15-percent loss has generally been considered acceptable for large water utilities. It is probably profitable to control any loss above 10 percent. Most authorities recommend implementing a water loss control program where losses exceed 20 percent or more.

4.10.2 The Importance of Registered Services in UFW Assessment

Water utilities need some means of accurately measuring the water that is delivered to the consumer through the distribution network. If the meters are of the recording type, valuable information regarding hourly rates of consumption will be available.

Metering of delivered water consists of placing a recording meter in the line leading from the water main to the area served. The area could be a district or zone. Consumers are then billed for the water they use based on reading of water meters installed at their yards. The alternative to these methods is charging the consumers on the basis of flat rates, which has no relation to the actual consumption or to the amount wasted.

Billing by metering is advantageous. Pumping and treatment cost money and wasting of water means a greater cost to the utility, which in turn will be distributed among the customers. If deliveries are unmetered, the careful consumers are made to bear the burdens imposed on them by the careless and wasteful ones. It is almost impossible to construct a good system of water charges without the use of water meters and hence the necessity for the use of it to collect water charges based on actual consumption.

4.10.3 Assessment of Collected Data

Water production from supply sources has to be registered every month or once in two months, depending on the billing frequency. The registered productions are compared with the overall consumption as obtained from meter readings taken for bill preparation. The overall UFW is calculated by obtaining the difference between water production and overall consumption, taking into consideration any unregistered publicly used water.

4.10.4 Unavoidable Level of Leakage

Water loss survey and control programs save enormous amount of water, sometimes making it possible to defer implementation of expansion programs for years. For instance 450 litres per day per kilometre of water mains is taken as unavoidable leakage. Any large amount of unaccounted-for water will justify a leak survey.

Much of the allowable leakage is due to settling of the line under external pressure as well as due to internal pressures in excess of working or test pressures that permit some amount of water to escape through joints

4.11 Methods of leakage detection

4.11.1 General

Water leak detection is a systematic method of locating visible and non-visible leaks in a distribution system through visual inspection and using listening equipment to identify leak sounds and pinpoint the location of non-visible, underground leaks.

The losses of water are inevitable in the process of supplying thousands of customers spread over large areas. Starting from treated water reservoirs at treatment plants, through the complex network to the farthest customer, water is lost through leakage or taken without authorisation (see Figure here below).

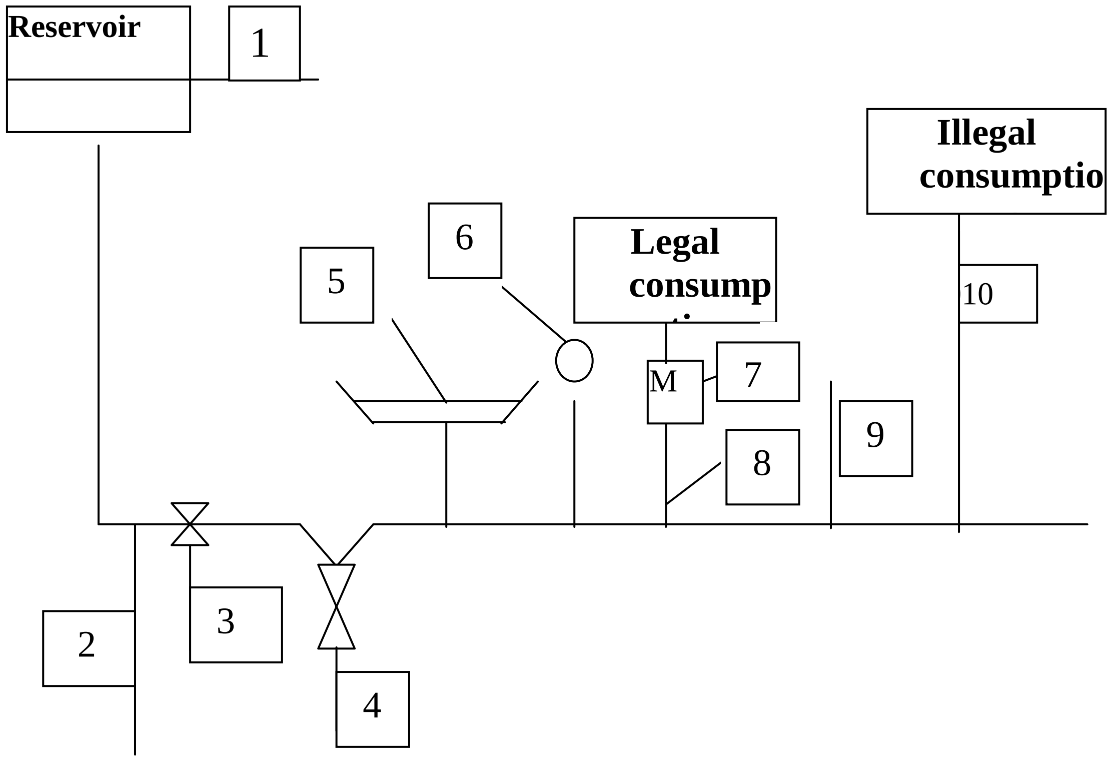


Figure 13: Illustration of Losses in Water Distribution System

1. Over-spilling & leakage
2. Leakage from pipes
3. Leakage from valves
4. Drains left open
5. Losses in taps and fountains
6. Leakage from hydrants
7. Water meter under-readings
8. Leakage on connection pipes
9. Unregistered consumption
10. Illegal consumption and theft

Pipe bursts of large mains are often visible and are not considered as major causes of high water losses as these incidents are quickly spotted and repaired or isolated. Most of the water is lost through numerous small holes, which are very difficult to locate, as the pipeline is laid underground. Water could easily flow out into the aquifer or a nearby creek for years before the leak is detected and repaired. Sometimes, inspection of storm sewers in dry weather period may disclose a flow that can be traced as coming from a broken water main.

To the layman, the task of locating the losses in a complex distribution system may look difficult. But losses have to be controlled and there are methods and equipment specially developed for this purpose.

In general underground or invisible leaks can be detected by different methods and some of the methods for detecting are described briefly in the following sections.

4.11.2 Continuous Monitoring of Night Flow

Minimum night flow in a supply system can fairly be estimated by observing night-time water production and the changes in storage. For complex networks, the calculation can be made in a central control room where automatic control system for the monitoring of production and reservoir levels is installed.

In a simple network with a supply from a high level reservoir, an estimate of the night flow can be obtained by shutting off the supply temporarily for a certain time during the period of minimum consumption. The drop in the level of the high level reservoir is then measured at regular time intervals to determine the change in storage and thereby estimate the outflow. The calculated outflow is then compared with the normal night flow in the demand pattern or the "genuine" night consumption. Night consumption of certain large water consumers such as abattoirs has to be taken into account.

4.11.3 Location of Large Leaks by Pressure Measurement

A large leak in a small network can be located by pressure measurement during hours of minimum supply. Normally where there is leak the pressure in the system will be lower or reduced. Successive sections of the distribution network are isolated from the supply by shutting off valves starting at the extreme end of the network and towards the reservoir (see Fig. 6.2).

For each valve closure of the section of the network, pressures are recorded downstream of the reservoir. When the section from which water is leaking has been isolated from the reservoir supply, the pressure at downstream of the reservoir valve will quickly rise to a higher level.

1. Close V5 take pressure reading at pressure gauge
2. Close V4 take pressure reading at pressure gauge
3. Close V3 take pressure reading at pressure gauge since there is leak after V3 the reading of the pressure gauge will increase indicating there is leakage between V4 and V3.

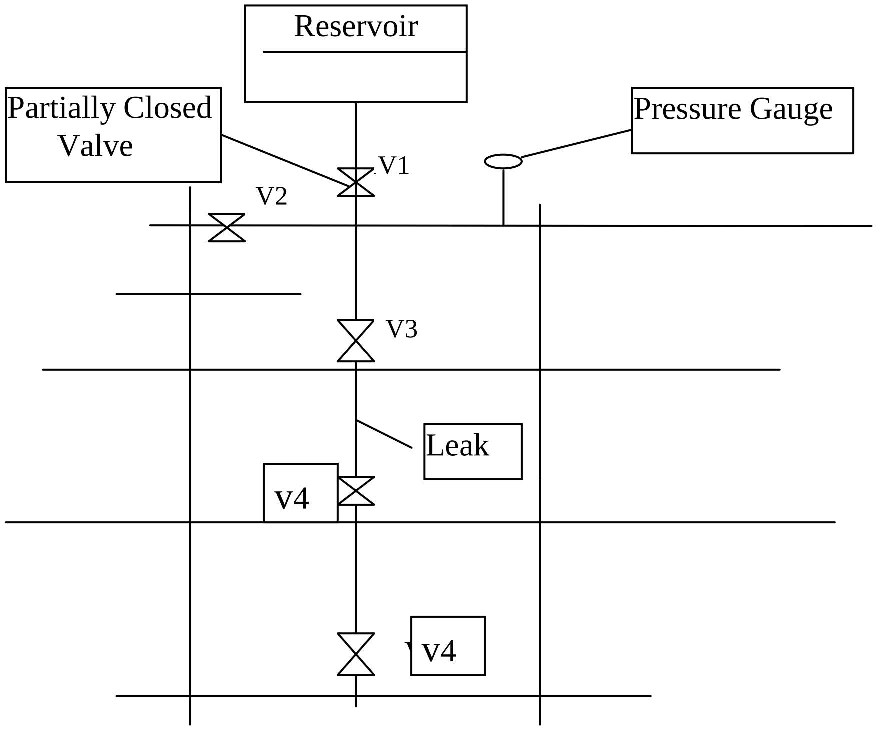


Figure 14: Locating leaks by pressure measurement during night flow

4.11.4 Leak Detection by Analysis of Data

Flow within the network system or making use of accurate flow meters and water meters must monitor a well-defined area (zone or district). The information is regularly sent to the company for analysis. There are two main methods for analysing the losses:

Total Integrated Flow (TIF): All inflows to and outflows from a subsystem, or district must be monitored. The difference between inflows and outflows is the demand, which is the sum of genuine consumption of water and losses.

Genuine consumption varies in time depending on human activities, while losses are more or less constant throughout the day except in some cases where pressures can be high during the night and leakage also rises accordingly.

The data analysis to estimate the loss thus depends on comparison of the measured or computed demand with pre-determined consumption of the control area or zone.

Minimum Night Flow (MNF): High night flows are taken as an indication of high leakage. However, some customers, such as chemical and food factories, which operate for 24 hours, consume a lot of water during the night. One should, therefore, identify such customers and subtract their night demand from the total night flow. The analysis is most efficient when applied in relatively small and controllable areas, though organisation of a full sub-system of districts in large and complex systems might be difficult and expensive.

All flows to and flows from a district must be monitored. A district should not preferably include facilities like pumping stations, reservoirs or water towers, which may distort the flow pattern or make the management of pressure difficult.

Analysis of the minimum night flows (MNF) is a very effective method of finding the losses, provided registered flow data are available. Therefore, in order to use this method, one must have flow data for several days, measured relatively with short interval of time (typically 15 – 30 min.) By examining the data one could conclude whether the losses in the district supplied through the flow meter(s) or water meter(s) are high or low.

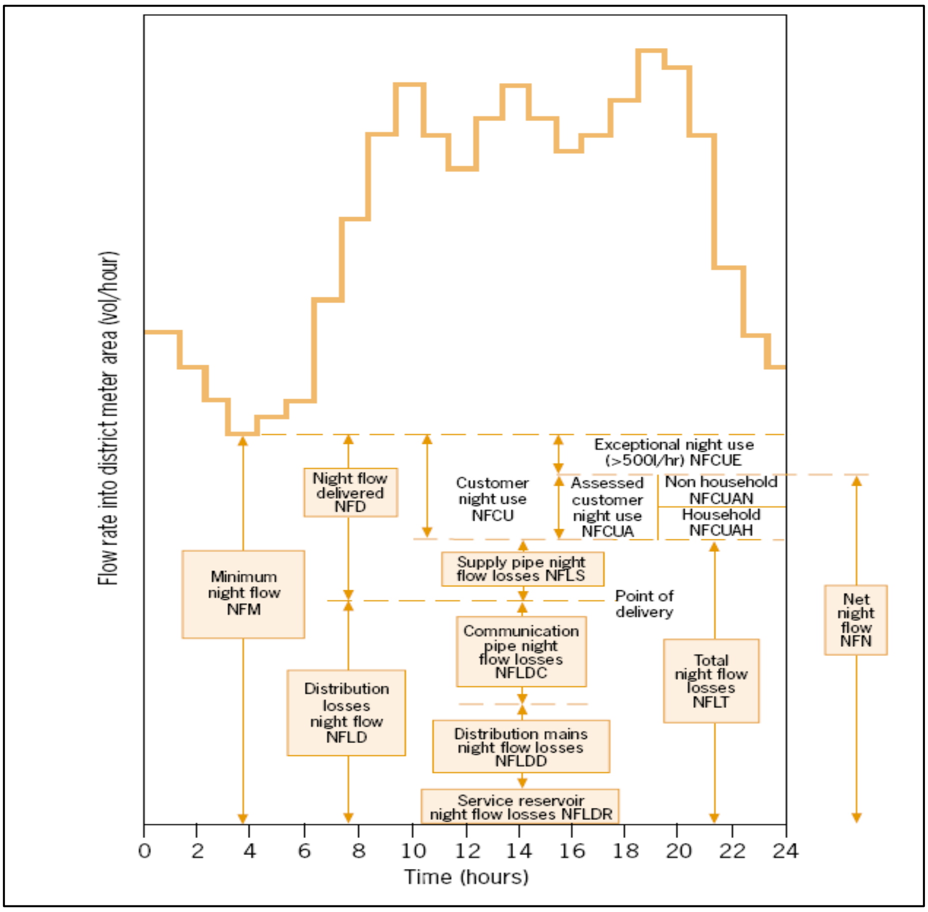
The characteristics of low leakage areas are:

MNF is very small, of the order of 10 to 20% of the average daily flow

Changes in MNF with time (the so called "night line") is steady for several months or years

Daily diagrams of (MNF), established by plotting flow verses time, have regular shapes and follow a similar pattern for similar users.

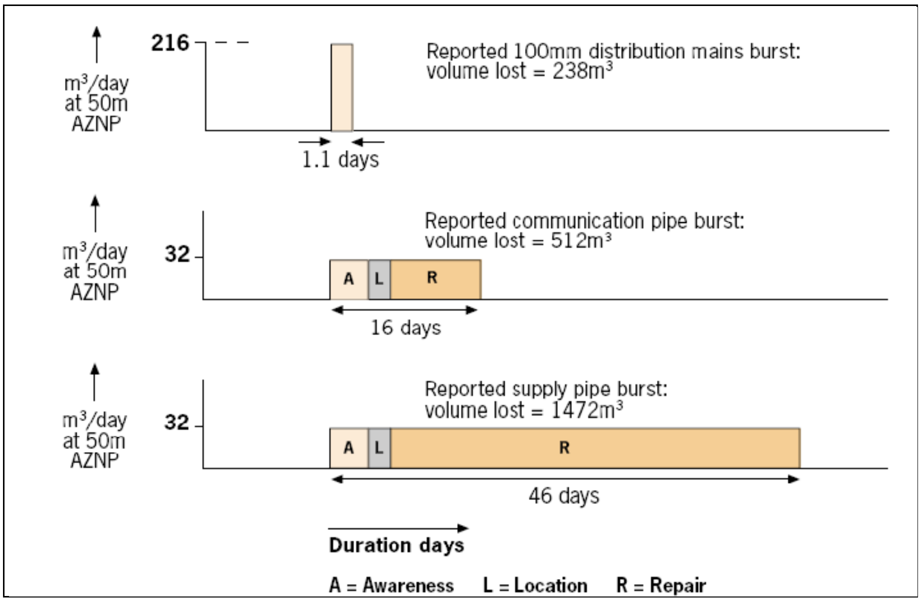
If the result of the analysis follows the above characteristics, the leakage or loss could be taken as small. This evidence, however, cannot be taken as conclusive before it is confirmed by other results – computing the balance of flows and registered consumption (TIF method) for instance (see Fig here below).



Source Farley M. 2001

Figure 15: Components of minimum night flows

A sharp increase of the MNF is often a sign of bad burst, which can be spotted on the daily diagram/graph, and action can be taken for immediate repair (see Figure below).



Source Farley M. 2001

Figure 16: Flow record corresponding for a sudden pipe burst and quickly repaired

The other type of leaks is the so-called progressive or creeping leaks in which the rise in the MNF is noticeable. But as the rise is gradual, the immediate effects could be small and no one could notice the leak. However, the value of the MNF increases little higher every day and soon it will be noticed that something has to be done to repair the leakage. After leakage was repaired, the MNF will return to its previous level.

In general a constant and careful monitoring of flows in all districts has to be done in order to effectively and efficiently reduce leakage in a water supply distribution network. If such efforts are loose, leakage control programs could be very costly in the end and the endless war to reduce leakage may not be won.

Collection of such data will not be cheap especially if data loggers are used. But manual readings could give good information at much lower price than the inexpensive data loggers and they are certainly better than none at all. The use of computers is advantageous to achieve better results.

4.11.5 On-site Investigation

Utility crews usually discover leaks in the normal course of operation and maintenance. For instance, leaks could be discovered while closing or opening of valves during routine operations. Meter readers have the opportunity to identify visible leaks in a meter box when reading meters.

On-site investigation for leakage of major water supply components include: Transmission lines, distribution and service lines, isolating valves, air-relief drain valves, reservoirs, customer water meters, hydrants, Joints supported by thrust blocks, and river crossings.

4.11.6 Determination of Leakage Amount in a System

Three methods are indicated here for measuring the rate of loss and the total volume lost through leak holes.

4.11.6.1 Bucket and Stopwatch Method

Leaking water is collected in a container of known volume. Time taken to fill the container is measured using a stopwatch. The rate of loss per unit time is computed in l/s or m3/hr. If a 20 litre bucket is filled in 10 seconds, the rate of loss is 2 l/s. Large leaks can be estimated by collecting the leak through gutters and draining it into a container of known volume.

4.11.6.2 Hose and Meter Method

Where applicable, a hose can be connected to the leak with a clamp saddle connection and the leak can be measured by simply reading the water meter to determine volumetric flow rate.

4.11.6.3 Calculation method

This method is simple and often useful for large leaks where the flow is quite much to measure the above mention methods. The size of the leak holes will be measured and that the line pressure is determined. A pressure gauge is used to determine the line pressure and the size of the leak whole is measured, though error may be introduced due to irregularity of the shape of the whole. The empirical formula to determine flow rate of a leak from such holes is

$$Q = (12,879.38) * A * \sqrt{P}$$

where Q is flow in m3/hr, A is cross-sectional area of the leak hole in m2, and P is measured line pressure in meters. If leak hole is circular, A would be Π * D2/4 where D is measured diameter of hole.

An orifice coefficient of 0.8 is applied to the above formula to determine small leaks from such items as broken taps and cracked service pipes. Table 6.1 shows volume of water loss though different hole sizes for ½ inch pipe at 5m, 15m and 32m pressure.

Discharge in litres/day		
5m	15m	32m
7 013	23 376	49 090
2 932	9 970	20 945
2 496	8 308	17 454
421	1 402	2 945
234	779	1 636

Experiments were carried out by Liverpool Corporation to determine the rate of loss through various sized holes in 0.5 inch diameter lead pipe under a pressure of 31.6m head.

The results are shown in this diagram

Source Farley M. 2001

4.11.7 Leak Inventory and Reporting Methods

Inventory and reporting of leaks comprises leak survey outcomes and post-repair information. Location of the leak in the system, type of leak encountered, cause of leak, method of detection applied, staff involved, estimate of flow rate, etc. are parts of the information to be included in the leak survey report.

In the post-repair report, information such as opening of trenches, incidental interruption time, replacement of parts, staff involved, cost of repair, planning of the repair task, recovered value of the water loss, etc. should be reported after leakage repair activity is completed.

An important and often neglected post-repair step is determining whether the project was a cost effective water conservation measure. To determine cost effectiveness the utility must evaluate the completed task of leak detection and repair.

As an example, determination of cost effectiveness for Metro Durban Utility in South Africa is presented hereunder:

Total water recovered from all repaired leaks = 13.04 l/s
Average estimated life of leakage = 2 years
Total leakage recovered = 63072m3 for every l/s in 2 years
Cost of production of water = $ 0.222/m^3
Value of water recovered = 13.04 l/s * 63,072m^3 * 0.222$/$m^3$
= $ 183,335.00

Leak detection survey cost

Equipment = $ 2,404.65
Training = $ 400.00
Survey cost = $ 25,994.84
Total leak detection survey cost = $ 28,749.49

Benefit: Cost Ratio (B/C) = value of water recovered / total cost of leak detection survey
= $ 183,335 / $ 28,749.49
= 6.4

Average Survey Cost per km of main surveyed

Total cost of leak detection survey / Total no. of km surveyed
= $ 28,749.00 / 124.7 km = $ 230.60 /km

This is helpful information for planning future leak detection efforts.

4.11.8 Pipe Locators and Leak Detection Equipment

4.11.8.1 Pipe Locators

Pipe locators are used to accurately track underground metallic pipes over long distances. A pipe locator is equipped with an easy to read meter which permits quick location and depth reading of pipe lined up to 4.5 meters.

4.11.8.2 Audible Leak Detectors

Audible leak detectors are equipment used to detect sounds of leakage. As pressurised water is forced out through the leak outlet, the sound waves thus created are sensed by simple mechanical device or amplified by electronic transmitters. These detectors are equipped with sensitive leak sensor ground microphones and a lightweight amplifier fitted with filters to avoid an accounted noise in the surrounding. The detector can be used to listen to leaks in PVC pipes in the range of 200 - 600 Hz frequencies and in cast iron pipes, in the range of 400 -1200 Hz frequency. Figure 6.5 shows a leak noise *correlator which is a portable micro-processor-based device that pinpoints leaks automatically*.

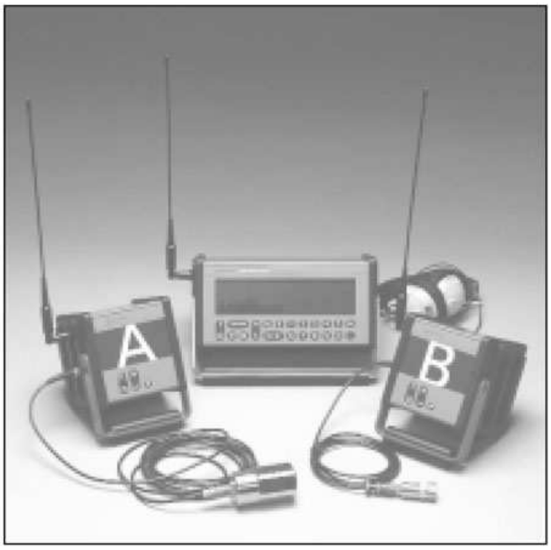


Figure 17: A Leak noise Correlator

4.11.8.3 Initial Listening Survey

The objective of the initial listening survey is to listen for leak sounds on all contact points such as meters, valves, hydrants, bottom drains, and air release valves in the distribution system. The listening stick or contact microphone is used for listening of the contact points. An attempt has to be made to identify whether other interfering sounds from water use, meter sounds and the like exist. This initial search of contact points for each of the district or sub-district has to be conduct quickly. Figure 6.6 shows examples of typical listening device.

Figure 18: A Typical listening devices - ground microphones

As sound travels quite a distance on metallic surfaces, leak sounds along the length of the main could also be heard as one tries to listen at contact points on the same main. Therefore, a little extra effort may be required during listening surveys and one may be required to listen over the entire main itself with a ground microphone.

One has to perform the following practical exercise in order to determine whether one needs to listen directly over mains in addition to contact points:

- Fix a contact point on the main and use a listening stick or ground microphone to hear a leak sound over the main.
- Let a co-worker open a tap in a private yard along the main.
- Determine how far away along the main you can hear the leak sound from the private tap.
- Compare the distance between the contact point and the point of leak sound on the private tap with that of the leak point on the main.
- If the distance between the contact point and the tap is greater than the sound travels along the main, then listening over the main has to be made using microphones at appropriate intervals (between 3 and 15 meters)

As sound travels less on non-metallic mains, a similar effort has to be made while listening to PVC pipes. A number of factors influence how far a sound will travel along non-metallic lines, including system pressure and pipe diameter. The sensitivity of listening equipment also limits the length along which sound can be heard.

4.11.8.4 Problems Encountered with the Listening Procedures

A number of sounds can interfere while listening with leak detection equipment. Some of them are:

- Sounds from showers, toilets, washing machines, pumps and meters interfere. Even the sound of people talking in the nearby may be picked up by the listening equipment.
- Listening equipment could pick radio broadcasting and lawn watering, sounds caused by aircraft, wind and rain, street traffic; interference from power lines or transformers may distort leak sounds.
- Sounds usually come to the listening equipment from a number of adjacent leaks thus making it difficult to isolate and identify.
- Faulty equipment, loose electrical connection, inadequate training and insufficient pressure (less than 10 meters) can also obscure leak noises.

Listening during the night is, therefore, preferred as most of the interference reduce or are minimal.

4.11.8.5 Factors affecting leak sounds:

- Pressure: for sonic leak detection it is necessary to have line pressure of at least 10m.
- Pipe material: metallic pipes are good sound conductors than non-metallic pipes; closer test interval is required when reading for leaks on non-metallic pipes.
- Soil type: practical observation and experience have shown that sand is a good conductor of sound than clay.
- Surface type: experience has shown that asphalt or concrete paved surfaces are good resonation of sound and give uniform sounding than surfaces lined with grass and earth (turf or sand).

4.11.8.6 Pinpointing Leaks

The objectives of pinpointing leaks are:

1. To determine the leak sound is from leakage, water use, or some other noise, and
2. If it is a leak sound, to determine the exact location of the leak.

This requires a systematic elimination of other interference adjacent to the suspected leak point. Pinpointing leaks can be a difficult task requiring the highest degree of operators' skill. Although the leak will be found at the point of maximum sound intensity (see Figure 6.8), there are many factors that increase the complexity of pinpointing. The other important factor is the pressure of the line, which normally gives a high noise level and better sound characteristics during high pressure. A very hard surface over the main transmits sound more effectively than muddy soil. Uniform sonic values are produced over such surfaces and thus pinpointing is done easily.

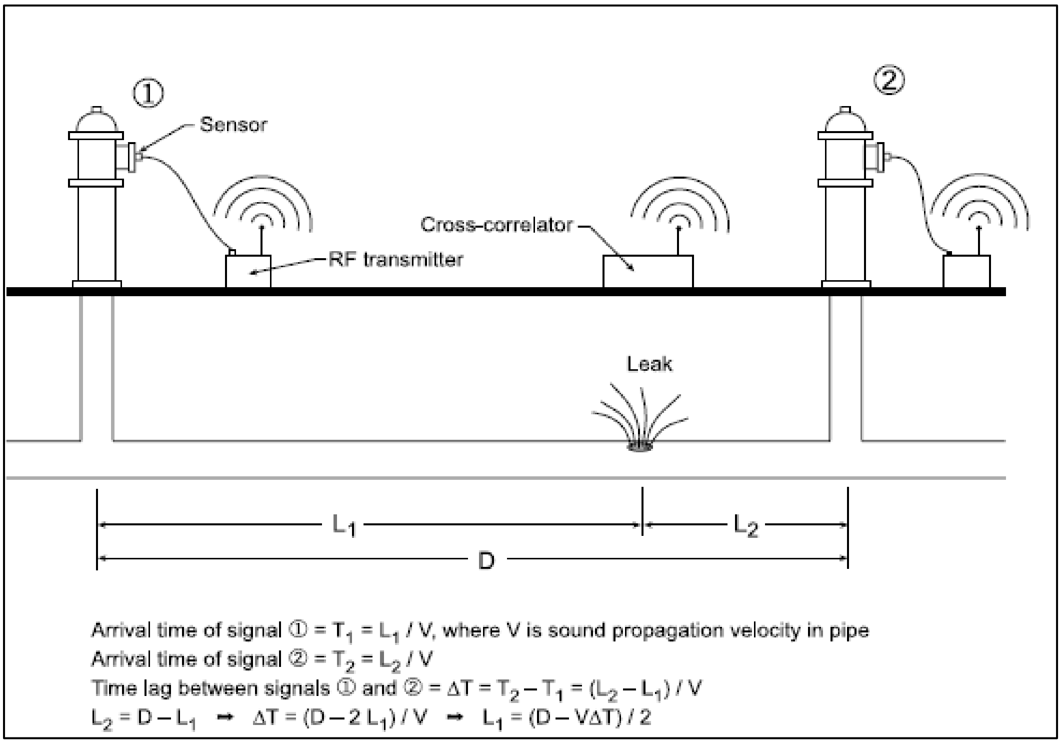


Figure 19: Typical example of pinpointing leaks using a ground microphone

Leak sounds are naturally amplified at all bends, tees, reducers or any other constrictions along the main and the operator must know these locations for precautions to avoid error in pinpointing.

4.12 Remedial Measures to Reduce Leakage in a System

The following are considered to be remedial major measures to be taken to reduce leakage in a water supply system:

- Quality of workmanship in the installation of pipes, fittings, valves and other appurtenance including conducting pressure testing
- Care in selection of pipe material and accessories
- Standardisation of equipment and availability of spare parts
- Organisational structure and placement of skilled personnel for key positions and for the operation and maintenance staff
- Offering of training based on continuous need assessment for management, supervisory team and operators

- Inspection water supply components such as transmission mains, distribution and service lines, reservoirs, pumping stations, valves, hydrants, bulk meters, customers meters
- Keeping accurate as-built information of the system on drawings
- Installation of accurate master meters and customer water meters to allow correct measurement of production and consumption.

4.13 What Practical Actions Should Be Taken To Fight Corrosion?

As discussed above, corrosion is a phenomenon that is encountered when water meets with water carrying materials/holding structures.

At least if it is not possible to eliminate corrosion but in order to minimize it and thereby increase the life of water containing structures or materials the following practical measures are recommended:

1. Conduct appropriate water treatment in order to eliminate aggressive carbon dioxide (usually cause of corrosion both for ferrous and concrete) in case surface water
2. Apply disinfection in the distribution network and transmission line to avoid growth of iron and sulfur bacteria
3. Carry out scheduled maintenance in the pumping station –paint the pipes and fittings with anti- rust paint. This is the most simple, cheap and practical method to fight corrosion in ferrous materials at TWSSEs level
4. Carry out scheduled flushing of transmission and distribution network especially dead ends.
5. Avoid manual bending of pipes instead of using fabricated fittings
6. As much as possible avoid welding of pipes but if welding should be done due to unavoidable reasons, paint anti –rust on the welded spot/area
7. Use appropriate connection fittings or adaptors for connecting two different types of pipe materials
8. Select appropriate materials starting from design phase. For instance zinc coated pipes are normally corrosion resistant for aggressive soils
9. Use of appropriate stainless steel materials which are normally corrosive resistant
10. Control high velocity since high velocity will rub the internal surface of pipe materials and thereby damage the natural protective coatings formed inside the pipe. This can be done during design and carrying out extension works.
11. Paint bituminous paint of the external surface of the concrete structures with the exception of reservoirs
12. Use of good concrete grade during construction of water retaining structures
13. Use of appropriate and approved coatings for reservoirs both for inside and outside

4.14 Organisation and Management

For an effective management of a water supply service in general and water loss control in particular, water supply utilities must have appropriate organisational arrangement with sufficient delegation of authority for the management team to implement projects and remedial measures for service improvement based on comprehensive studies and analysis.

The leak detection and control units need to be established having survey and repair crews.

Cost recovery mechanism has to be designed to ensure financial sustainability through tariffs to enable the water utilities to cover their operating expenses and to secure funds for system improvement and expansion. Capable management and technical staff have to be placed to achieve high level performance. Utility personnel at all level have to be given practical and theoretical training based on a continuous training need assessment to improve skill.

Often underestimated is the creation of a management information system of certain modules to manage the utilities efficiently. The information system may be fully computerised and sophisticated or may rather be simple based on manual records in logbooks. However competent a utility company could be with the current state of affairs, organising an efficient Data Management System (DMS) will be essential for the improvement of the services through judicious application of modern technology.

Natural resources such as lakes, rivers, springs and subsurface waters are limited. The price of energy, chemicals and other items are constantly rising. Therefore, water losses have to be monitored regularly by establishing better organisations with skilled personnel and through consolidated and dependable data.

The obvious consequence in the use of DMS will be, amongst others,

- Economical uses of resources by efficient operation and cutting down the losses as much as possible.
- Quality of management decisions for planning and justifying leakage control program.
- Closer follow-up for alarms and unusual circumstances in water distribution
- Better co-operation and understanding with the public

4.15 Leakage Repair

4.15.1 General

Once the area of the leak is spotted quick measure has to be taken to repair it in order to control the water loss. Prior to starting the actual repair work, the activity has to be planned with respect to manpower, equipment and parts required for the repair. The area of work has to be free of traffic conflicts by isolating it from vehicular path by means of barricades and traffic signs. The maintenance personnel should ensure their safety and should wear reflectors especially if the repair work is to be carried out at night.

4.15.2 Data Records

As systematically and uniform data registration is needed for several reasons:

- To help locate faults and make repairs
- To ensure that all connections are known and to enable extensions and improvements to the system to be correctly designed
- To enable the system to be correctly operated efficiently

The information which is needed include:

- The position of all pipes and their sizes, fittings, valves, connections and water meters, street mains
- The materials and condition of pipes
- The purpose of valves and special fittings.
- Pipe drawings must be drawn with established symbols

These data are normally recorded in as built drawings of pipe lay out plans or maps.

4.15.3 Maintenance Procedures

If a major leak is reported, it should be investigated at once to determine the seriousness of the problem and to see whether the repair is the responsibility of the utility or of the owner of the service line. If the leak is serious in an area where it quickly could affect extensive property damage, then it should be repaired immediately.

The procedures involve immediate isolation of the leaking line, contacting of other utilities to determine where their underground lines are located, mobilising of crew with parts and equipment, actual performing of the repair and reporting and documenting of the repair activity.

4.15.3.1 Isolation of the Leak

The first thing to deal with leak repair is to get the water loss under control as quickly as possible by complete or partial shutdown of the line. After the leak is found, it is promptly marked with stakes or otherwise with white markers or chalks on surfaces. Shutdowns should be planned so that the area affected is kept as small as possible and the out-of-service period is minimized. Customers should be notified about the interruption and the period of time it would take to repair the break.

Isolation processes are difficult and time consuming without accurate maps showing the supply network and other appurtenance in the system. An up-to-date system map with accurate valve locations and main sizes is valuable at this time. Therefore, as-built maps and drawings of network must be available during repair work. This helps the repair crew to locate the isolating valves so that shutdown of the line where leak is spotted could be made without wasting time. It also helps to avoid damage of an underground line while working on another.

4.15.3.2 Crew and Equipment Mobilization

A well trained supervisor should normally lead the repair tasks and a sufficient number of qualified plumbers and fitters should be available to expedite the operation. The survey crew that has located or pinpointed the leak and the repair crew should work together to uncover the leak.

The actual leak hole may not be spotted quickly as it could be on the bottom of the pipe or a few distances away or no sign of dampness or water may be visible. Time and money can be wasted by digging in the wrong spot. Teamwork, therefore, is required to exactly locate the leak hole and sharing of knowledge and experience can make locating easier.

Excavating equipment will have to be made ready to start the repair. In addition to excavating equipment, the following are some of the items that should be on hand.

* A pump (or a bailing bucket) for dewatering the excavated area
* Appropriate size of pipe, sleeve, couplings, clamps and other essential fittings
* Pipe cutters and/or saws
* A torch if the repair will be done at night
* Traffic signs such as barricades, reflectors, cones, etc.
* Pavement cutter if the spotted underground leak is beneath a surface paved with asphalt or concrete.

Accidental injuries are likely to happen especially in unplanned situation and therefore safety procedures should not be ignored while rushing to handle the emergency.

4.15.3.3 Repair Activity

If the break is severe, the damaged section may have to be cut away with a saw or pipe cutter and a new section installed. It may also be that the leak can be fixed with a flexible clamp or coupling of the correct size and material as the pipe to be repaired.

Several preliminary procedures should be observed to help ensure a good repair. The diameter of the pipe should be checked from appropriate as-built drawings to have the appropriate size of repair clamps and joints. After the pipe is uncovered, the area on the pipe where the repair will be done should be scrapped to remove as much dirt and corrosion as possible.

In applying the clamp, care should be taken that no foreign material sticks to the gasket or becomes lodged between the gasket and pipe as nuts are tightened. Appropriate pipe wrenches should be available to achieve proper tightening and the bolts should be kept free of foreign material.

After repair is completed, the line should be pressure tested for leaks before back-filling the excavation. After testing, the line should be flushed to remove any dirt that may have entered while it was under repair. In principle, the entire line has to be chlorinated to reduce the danger of contamination from soil, surrounding dirt material and back siphon.

Back filling has to be made with proper compaction; the area has to be reinstated and excess excavated material should be hauled away. The area should be checked to make sure that no equipment or traffic hazards remain and closed valves to isolate lines should be opened to resume water delivery service to customers.

4.15.3.4 Activity Reporting

The importance of reporting requirements should not be underestimated after the repair has been completed. It is helpful to determine the type and cause of break. Information should be recorded on leak repair report similar to the ones shown in Annexes E and F. It is helpful to record the information on the water main failure and repair report similar to the one shown in Annex E and F. Well organised reporting system contributes to helpful information from the standpoint of undertaking future similar repairs in a timely and efficient manner.

4.15.4 List of Tools for Leak Repair Crew

The following equipment has to be provided for Leak detection crew:

* Sonic listening equipment with a high frequency probe. And

* A low frequency ground microphone for pinpointing leaks

Safety equipment to be provided for crew members include:

* Safety vests
* Traffic cones
* Barricades

Tools to be provided to measure flow rates should include:

* Stopwatch
* Bucket
* Pressure gauge
* Measuring rule

Working tools to be provided include:

* Meter box lid lifters
* Valve cover lifters
* Valve keys
* Small bailing buckets or small manual dewatering pumps
* Chalk or spray paint
* Pipe locator
* Wrenches for tightening meter spud nuts

4.16 Pipe Cleaning Procedure

4.16.1 Flushing Techniques

Following leak repair, mains should be flushed (but not always done) in order to remove any foreign material that may contribute to contamination or reduce water quality. Flushing could be done through a hydrant or bottom drain (blow-off). It should be done at a velocity of about 1m/s to obtain proper flushing action. For known pipe diameter, therefore, one can determine how much water must be used to adequately flush various pipe sizes.

Flushing is necessary in order to:

* Protect consumers from using contaminated water
* Prevent the growth of nuisance organisms and thus avoid the contamination of the distribution system
* Alleviate customer complaints

4.16.2 Pipe Cleaning Procedures

Mechanical cleaning (not practised in this country) may be necessary in order to remove deposits of encrustation in older cast iron or galvanised steel pipes or where iron bacteria and slime growth are a severe problem. Initial cleaning usually involves flushing, but when this is in adequate, it may become necessary to use either air purging or cleaning devices such as swabs or pigs.

Air Purging: In this cleaning process, air mixes with water is used to clean small mains up to 100mm in diameter. Before starting the cleaning, all service lines must be shut off. Air from compressor is then forced into the upstream end of a main after bottom drains on the main are opened at the downstream end. The air-water mixture (spurts) will remove all deposits including the toughest scale.

Swabbing or Pigging: Swabs are special kind of foam plugs, somewhat larger than the inside diameter of the pipe to be cleaned. Pigs are bullet-shaped foam plugs. They are similar to swabs, but are harder, less flexible, and more durable which allows them to remove harder encrustation. Both are forced through the water main by water pressure.

The advantages of such cleaning are:

* Removal of encrustation and other objectionable material from the main
* Increase in the flow rate through the main
* Reduce operating pressure losses
* Reduction in pumping time and energy costs

4.16.3 On-site Disinfection for Pipe Cleaning

Chlorine is the chemical used as a disinfectant for pipeline. Calcium hypochlorite and sodium hypochlorite solutions are the form in which it is usually used. The chlorine solution is usually injected at end of the main through a solution-fed chlorinator and booster pump while at the same time water is discharged from the opposite end of the main. Precaution must be taken to prevent dosed water from flowing into the potable water supply. All high points on the main being treated should be vented.

Rate of application should result in a uniform concentration of at least 25 mg/l at the end of the section being treated and the average retention period is 24 hours. If unfavourable or unsanitary conditions exist, the period may have to be extended to 48 hours or more. If shorter retention periods must be used, the chlorine concentration should be increased to 50 or 100 mg/l.

The chlorinated line should be flushed until the residual chlorine is gone out or approaches the normal concentration. In principle, after the chlorinated water is flushed out and the pipe is filled with water from the rest of the system, bacteriological test has to be performed to ensure that the water in the main is free of bacteria before placing the main in service.

5 ENVIRONMENTAL PROTECTION, SAFEGUARD AND WATER QUALITY ANALYSIS

5.1 Water Quality

One of the major responsibilities of water supply utilities is to supply potable water to the user community so that the service contributes its role to enhance the productivity and economic growth of user communities. Water is the most solvent materials and carries water born diseases; hence its quality must be surveyed continuously to assure that the water is potable related to National and international quality standards. For a water to be safe/potable;

- It must be free of any water born bacteriological hazards,
- Its physical quality must be to the required standard,
- Its chemical content shall not be in excess of what is required,

5.2 Water Quality Test

Water quality test comprises of three major activities. These are;

- Physical tests,
- Chemical tests and ,
- Bacteriological tests

Table 23: water quality test schedules

Item No.	Types of water quality tests	Quantities of samples	Schedules for test	Special cases
1	Physical test	Sufficient quantity for test	• Twice a year, one during summer and the other during winter • When study for new water supply system is required	• If the source is from a dam • If the source is exposed to contamination due to flood
2	Chemical Tests	Sufficient quantity for test	• Twice a year, • When study for new water supply system is required • If there is industrial waste contamination hazard around the supply area	• If the source is from a dam , if there is fear of contamination by industries nearby
3	Bacteriological test	• One sample for population less than 5000 • One sample for 5000 heads if population is between 5000-100,000 • One sample for 10,000 and 20 additional samples if population is above 100,000	monthly	• This test is very important to assure safe supply of water to the user community

5.3 Locations for Taking Water Samples

Here above, the quantity of water samples for each tests is described. Water samples for each tests are required to be taken at different sections of the system to identify the major causes and locations of contamination. Hence, the utility is required to take samples for each tests from sources, reservoirs, public water points and user taps according to their distribution in the system. Places of hazard suspects shall be given special attention in assuring quality.

5.4 Environmental Factors affecting Water Quality

5.4.1 General

Abnormal Changes in environment affects the quality and quantity of sources of water for systems. Hence safeguarding the environment is vital in order to assure sustainable supply of water which can satisfy current and future water demand of the community.

5.4.2 Surface water

Some of the factors affecting water quality within the Reservoirs and Lakes are;

1. Waste water, agricultural runoff, grazing of livestock, drainage from mining areas, runoff from urban areas, domestic and industrial discharges may all lead to deterioration in physical, chemical, or biological/bacteriological water quality within a reservoir.
2. Farming practices
3. Fish die off.
4. Natural factors:

- Climate: temperature, intensity and direction of wind movements as well as the type, pattern, intensity and duration of precipitation,
- Watershed and drainage areas: geology, topography, type and extent of vegetation, and use by native animals;
- Wild fires;
- Reservoir Areas: geology, land form including depth, area and bottom topography and plant growth at the time the reservoir is filled.

5.4.3 Ground Water

Some of the factors affecting water quality ground water are;

1. Landfills,
2. Mining activities,
3. Abandoned sites,
4. Abandoned wells,

5. Agricultural practices,
6. Underground storage tanks and pipeline,
7. Increased salinity and salt water encroachment,
8. Septic tank and soakage pit system,
9. Petroleum exploration,
10. Radioactive wastes.

5.5 Sanitary Survey of Water Sources

The sanitary survey should include the location of all potential and existing health hazards and the determination of their present and future importance. The information furnished by a sanitary survey is essential to evaluating the bacteriological and chemical water quality data. It is desirable to

i) Identify potential hazards, and

ii) Determine factors which affect water quality.

Following are some of the probable essential factors, which should be investigated in a sanitary survey.

5.5.1 Sanitary Survey for Surface Water

1. Proximity to watershed and character of sources of contamination including industrial
2. Wastes, oil field brines, acid waters from mines, sanitary landfills, and agricultural drain waters.
3. Population and wastewater collection, treatment and disposal on the watershed.
4. Closeness of sources of fecal pollution to intake of water supply.
5. Wind direction and velocity data; drift of pollution; algal growth potential in case of lake or reservoir supplies.
6. Character and quality of raw water.
7. Protective measures in connection with the use of watershed to control fishing, boating, swimming, wading, ice cutting, and permitting animals on shoreline areas.
8. Efficiency and constancy of policing activities on the watershed and around the lake.

5.5.2 Sanitary Survey for Ground Water

1. Nature, distance and direction of local sources of pollution.
2. Possibility of surface-drainage water entering the supply and of wells becoming flooded.
3. Drawdown when pumps are in operation, recovery rate when pumps are off.
4. Methods used for protecting the supply against contamination from wastewater collection and treatment facilities and industrial waste disposal sites.
5. Presence of an unsafe supply nearby and the possibility of cross connections causing a danger to the public health.
6. Disinfection: equipment, supervision, test kits, or other types of laboratory control.

5.6 Assessment Report on Sanitary Survey and Remedial Measures

The utility is required to conduct sanitary survey for both surface and ground water sources based on the check lists listed here above once in a month. Detail report on the assessment is required to be prepared.

If environmental hazards which affect the quality and quantity of water sources are found, the utility under the leader ship of the Board shall take remedial measure in collaboration with local and national stakeholders. Enforcement of national and regional environmental laws may be required in case the responsible body caused the hazard does not give prompt response to amend the treat.

Currently, the government of Ethiopia is at large doing soil and water conservation works. This event assists utilities to recover the quality and quantity of their water sources. Hence, it is advisable that, the utilities shall take leading role in this campaign even by allocating considerable budget for this mitigation measure.

5.7 Special Sanitary inspection

The tasks mentioned here above are the primary barriers to assure water quality and quantity. But this needs to be confirmed conducting water quality as per the previously indicated schedule and amount of samples for each test.

In addition to the above regular tasks, there are cconditions which force for special inspection of environment. Listed as;

i. When there is report on spreads of water born diseases by the government
ii. When contamination of water occurs due to flood
iii. When there is symptom of bacteriological contamination of water by tests of the water, and
iv. When other causes of contamination is observed

The major causes of bacteriological contamination of the water supply system may be the following but not limited to;

1. Contact with toilets in the town,
2. Contact with septic tanks in the town,
3. Bursting of sewerage lines in the town
4. Contact with the remains of animals in the town
   Similar to regular sanitary survey tasks, appropriate remedial measure is also required for the findings of these special surveys.

6 CHLORINATION/DISINFECTION

6.1 Introduction

The disinfection of potable water is almost universally accomplished by the use of gaseous chlorine or chlorine compounds, because of the limitations of other procedures, for example ozone, ultraviolet light, chlorine dioxide etc.

Chlorine is easy to apply, measure and control. It persists reasonably well and it is relatively inexpensive

It is available in gaseous (chlorine gas) liquid (sodium hypochlorite) and solid (calcium hypochlorite) form. Of the three forms, powder or solid chlorine is presently the most common one used in the country since gas chlorination has many disadvantages in operation and maintenance.

Hypo chlorites can be classified, as either dry or liquid, in accord with commercial availability. Calcium hypochlorite is the prominent dry bleach widely used for potable and swimming pool water treatment. Sodium hypochlorite is the only liquid hypochlorite disinfectant in current use.

As indicated here above disinfection of water can be done using different materials including ultraviolet light. However, this manual is about disinfection using chlorine, which can also be called as chlorination using bleaching powder found solid compounds form, which is suitable for affordable disinfection of water in developing countries.

6.2 Factors relating to the disinfection efficiency of chlorine

The following factors have to be taken into account when treating water with chlorine.

The stage at which chlorine is applied. Chlorine is often applied at more than one stage in the treatment of water. ‘Pre-chlorination’ comprises the application of chlorine to a water (often a raw water) before it is processed through treatment works, e.g. before clarification and filtration. ‘Intermediate-stage chlorination’ is chlorine added between stages of treatment. ‘Final chlorination’ means the final disinfection of a water before it is put into supply. The purposes of pre-chlorination and intermediate-stage chlorination are often partly biological so as to reduce bacterial content, prevent bacterial multiplication and restrain algal growth; and partly chemical, so as to assist in the precipitation of iron and manganese and achieve other oxidation benefits. Final chlorination is always for the purpose of disinfecting the water and to maintain a residual in the distribution system so that it is safe for drinking.

Effect of turbidity. The effect of turbidity in a water is to make it difficult for the penetration of chlorine and therefore the destruction of bacteria taking shelter in particles of suspended matter. It is always necessary therefore, that final disinfection by chlorine is applied as a final stage of treatment in water which contains low turbidity. For effective disinfection the WHO (1993) suggests a guide level value for turbidity of less than 1 NTU.

Consumption of chlorine by metallic compounds. A substantial amount of chlorine may be used to convert iron and manganese in solution in the water into products which are insoluble in water. Reduction of these parameters by upstream processes is therefore essential. Typically iron and manganese should be less than 0.1 mg/l as Fe and 0.05 mg/l Mn, respectively. If at the point of chlorine application their levels are too low to justify removal, the dose must take their demand into account.

Reaction of chlorine with ammonia compounds and organic matter. The ammonia compounds may exist in organic matter or, alternatively, ammonia may exist separately from organic matter; in either case they will form combined chlorine which is not as effective a bactericide as free chlorine. Chlorine may be used in the oxidation of some organic matter, but at the risk of forming disinfection byproducts. Ammonia should not exceed 0.01 mg/l as N. When this value is exceeded or when organic matter is present, an allowance should be made both in the chlorine dose and contact time to satisfy the chlorine demand prior to disinfection. Therefore the substances that are causing a chlorine demand must be removed prior to disinfection by upstream treatment or an allowance for them must be made in the chlorine dose, otherwise disinfection could be compromised.

Low temperature causes delay in disinfection. A very substantial decrease in killing power takes place with lowering of temperature. The difference in kill rate of bacteria between the temperatures of 20 and 2 °C is noticeable both with free and combined chlorine. This must be borne in mind when fixing the contact period.

Increasing pH reduces effectiveness of chlorine. In free chlorine and in combined chlorine the
more effective disinfectants in each case, i.e. hypochlorous acid and dichloramine respectively, are formed in greater quantities at low pH values than at high values. Thus disinfection is more effective at low pH values; the guide level value suggested by WHO (1993) is less than 8.

The number of coliforms presented for disinfection. This has an influence on the disinfection efficiency. To be confident of achieving 100% compliance with the requirement of zero coliforms after the disinfection stage, the water subjected to disinfection ideally should not contain more than 100 coliforms/100 ml. Most ground waters satisfy this criterion. In surface waters, coagulation followed by solid–liquid separation processes, achieves up to 99.9% bacteria removal (Section 7.13). Consequently pre-disinfection in addition to conventional treatment is only required for heavily polluted surface waters.

Time of contact is important. The disinfecting effect of chlorine is not instantaneous. Time must be allowed for the chlorine to kill organisms. This important factor is dealt with in the next section.

6.3 Objective of chlorination

The primary objectives of the chlorination process are disinfection, taste and odour control in the system, preventing the growth of algae and other micro organisms that might interfere with coagulation and flocculation, keeping filter media free of slime growths and mud balls and preventing possible built up of anaerobic bacteria in the filter media, destroying hydrogen sulphide and controlling sulphurous taste and odour in the finished water, removing iron and manganese, bleaching of organic colour.

It can also be used for flushing pipeline before it is brought into operation after carrying out repairs etc. However in such case chlorinator is adjusted to apply chlorine or hypochlorite solution at the rate of 50 p.p.m. Heavily chlorinated water should be allowed to stand in the pipeline for at least 30 min. and preferably for 12 hours before being replaced with potable water.

6.4 Methods of application of chlorine

Disinfection is carried out by applying chlorine or chlorine compounds. The methods of application are as follows:

1. Preparing weak solution by bleaching powder
2. Preparing weak solution by electrolysing brine solution.
3. By adding chlorine either in the form of gas or solution prepared from dissolving chlorine gas in small feed of water.

6.5 Disinfection by bleaching powder

6.5.1 General

Bleaching powder or calcium hypochlorite is a chlorinated lime, which contains about 25 to 34% of available chlorine by weight. Chlorine being a gas is unstable and as such it is mixed with lime to retain its strength for a longer period, as far as possible. The bleaching powder is hygroscopic in nature. It loses its chlorine strength rapidly due to storage and hence should not be stored for more than three months. The method of chlorination by bleaching powder is known as hypo-chlorination.

The general reaction of ionisation of bleaching powder when mixed with water is as follows:

$Ca(OCl)^2 \rightarrow Ca^{++} + 2OC1^-$

$H_2O \rightarrow H^+ + 2(OH)-$

$H^{+} + OC1^{-} \rightarrow HOCl$
$Ca^{++} + 2(OH)^{-} = Ca(OH)_2$

The calcium hydroxide settles as precipitate.

The combined action of hypochlorous acid and hypochlorite ion brings about the disinfection of water.

6.5.2 Preparation of solution

a. The concentrated solution of bleaching powder is prepared in one or two tanks of capacity suitable for 24 hours requirement.
b. The tank inside should be of glazed tiles or stoneware and should be covered.
c. The powder is first put on a perforated slab placed longitudinally inside the tank at a higher level, with respect to bed level of tank.
d. Water is sprinkled on the powder through a perforated pipe above this perforated slab. The solution of bleaching powder & water now enters the tank.
e. The solution is rotated for thorough mixing of powder with water by a hand driven/motor- reduction gear operated slow speed stirrer.
f. The precipitates of calcium hydroxide settles at the bottom of the tank. The super-natant water, which contains OCl-, Cl-, is now ready for use as disinfectant.

6.5.3 Dosing of solution

a) The solution is discharged to a small measuring tank at a lower level through PVC pipe or any other material resistant to chlorine. The level of water in this tank is maintained constant through a float valve. A micrometer orifice valve discharges the solution at any pre-set rate, by adjustment on the scale fitted on it. The solution is dosed to the clear water channel by gravity at the time of entry to clear water reservoir. The waste precipitates at the bottom of tanks are taken out occasionally by scour valve

b) The dose has to be monitored properly, depending on the desired residual chlorine required in clear water reservoir

6.5.4 Precautions

i. The operating personnel should use hand gloves, aprons and other protective apparel, while handling and mixing.
ii. The valves, stirrer, tanks, plumbing arrangements require renovation at every 6 months or so.

Table 24: Operation and maintenance requirements for chlorination

S.N	Task Description	Frequency	Tools/material	Manpower requirement
1	Prepare chlorine solution and feed as required, and record the amount of chemical consumed	Daily	Chlorine and dosing equipments, weigh, containers	Local operator/technician
2	Conduct regular test on disinfected water for effectiveness of disinfection	Weekly	comparator	Local operator/technician
3	Conduct periodic tests of residuals in the distribution system	Monthly	comparator	Local operator/technician
4	Inspect equipment in the chemical store	Annually	Pen and paper	Local operator/technician
5	Clean dosing gravity feeder	Bi- annually	Cleaning materials	Local operator/technician
6	Inspect and overhaul dosing equipment	Annually	New containers	Local operator/technician
7	Inspect laboratory and equipment	Annually	Pen and paper	Local operator/technician
8	Check chlorine leaks in store using chlorine detectors, if gaseous chlorine is used	Weekly	Pen and paper	Local operator/technician
9	Replace all chlorine supply lines	Annually	New parts	Local operator/technician

The disinfection task can be once in three days or once in a week depending the quality of water based on the tests.

6.6 Calculation for Amount of Chlorine Powder

Chlorine for disinfection is available in various forms combined with other materials, majorly either in form of gas or powder. The commonly used is the powder form. The formula we use to determine the amount of chlorine powder is;

$$Cl2 = \frac{\text{Ct x V}}{\text{Co}}$$

Where: **Cl_2** is the amount of chlorine powder in gram

Ct is the required chlorine water solution in mg/liters(which needs to be calculated ,and

Co is the percentage of chlorine available in the powder in % commonly between 35 to 65%

V is the volume of water to be treated in m3, commonly the volume of water in the tank to be treated.

The application of the above formula depends on the following major criteria. They are;

a. The required solution of chlorine in water for newly started system, for disinfection of the system is required to be between 10 to 50 mg/l , and
b. For continuous disinfection of existing system, the concentration of chlorine by weight volume ratio is required to be between 0.5 to 5 mg/l
c. The required value of free residual chorine is between 0.05 to 0.1mg/l
d. The required combined residual chlorine is between 1 to 2mg/l
e. If disinfection is to be done at the reservoir for some amount in the tank, the mixing is required to be done closing all the outlets and it shall be allowed to the distribution system after 30 minutes the chlorine is mixed. Proper mixing can be achieved by adding the chlorine when the tank is half full as the water is flowing in or by properly mixing the solution if added after the tank is full.

Determination on the above values depends on the vulnerability of the system for contamination.

7 PROVIDE APPROPIATE PERSONNEL AND CAPACITY BUILDING PROGRAMME

7.1 Deployment of Appropriate Personnel for O&M

As it is discussed under the "Scenario of O&M in Ethiopia", UTILITIES are the only public entities given less attention by local government, majorly in strengthening their organizational structure and staffing. As we can learn from this document, proper implementations of O&M for town water supply services require skilled and experienced personnel in different disciplines. The degree of experience and qualification depends on the complexity of the water supply system and the size of population of the town. Separate guideline is also prepared for setting the organizational structures of the utilities of different levels.

The major forces for implementation of O&M are availability of appropriate personnel under organized management body. As is described under the following sections, continuous capacity building is the major strategy for O&M. However, unless the required personnel with minimum required skill and experience is available, however much training is conducted; the objective of O&M cannot be achieved.

7.2 Training

Continuous formal and on the job training is one of the minimum criteria to assure and achieve effective and efficient O&M for urban water supply services. Training assists to refresh skill, get familiar with new technological developments and enable newly employed staffs to operate and maintain the system properly. But detail justification on the requirement of the training is described under the following section.

7.3 Justifications for Training Need

The Utility shall identify and exhibit that the training is required so as to attain one or more benefits of the following:

- To update knowledge on operation and maintenance management issues
- To remedy deficiencies in skills or knowledge required to perform assigned tasks with competence.
- To inform new employees of the utility's rules and regulations and code of conduct.
- To instruct maintenance personnel of modifications in the operation of the maintenance management program.
- To inform senior management of the capabilities of the maintenance section to provide information via the maintenance management system
- To provide employees with new knowledge to qualify them for promotions.

Hence regular training needs assessment, planning, and conducting shall be major duty and responsibility of all UTILITIES in the country. Conducting planned capacity building training by UTILITY is major measure for its organizational standard.

8 RESERVE FOR SPARES

The National policy, strategy and regional laws enforce as UTILITIES need to have reserve equipments like submersible pumps for some of their Borehole sources, pipes, fittings and for other electro mechanical equipments.

This will assure sustainability instead of creating problems on their users and loosing income for the utility.

The list and amount of reserve need to be decided based on study related to the nature of their water supply system and the most frequent maintenance events occurred.

Materials, tools and equipments which are frequently used in operation and maintenance, and spares which cannot easily be found in the country, which take longer duration for purchase and import during breakage/failure shall be given priority to have spare.

9 WATER AND ENERGY AUDIT

9.1 Introduction

Periodical performance assessment of the specific area of the service of the UTILITY related to its general objective is very vital to revise plan based on recent findings. Even though, there are many areas of auditing to improve performances, the two major once related to Operation and Maintenance are Water and Energy Audits.

The general objective of these special tasks is to assess the degree of proper utilization of produced water minimizing wastage and find ways of minimizing energy required to run pumps by assessing factors which contribute to increased consumption in addition to finding ways of minimizing.

9.2 Water Audit

Water Audit of a water supply scheme can be defined as the assessment of the capacity of total water produced by the Water Supply Authority and the actual quantity of water distributed throughout the area of service of the Authority, thus leading to an estimation of the losses. Otherwise known as non-revenue water, unaccounted-for water (UFW), is the expression used for the difference between the quantity of water produced and the quantity of water which is billed or accounted.

9.2.1 Objective of Water Audit

The objective of water audit is to assess the following.

i. Water produced,
ii. Water used,
iii. Losses both physical and non-physical,
iv. To identify and priorities areas which need immediate attention for control.

9.2.2 Planning and Preparation

Planning and preparation shall include the data collection element and the preparation of sketch plans for the distribution centers and other locations for the installation of the flow meters. Also included within this shall be the confirmation of flow rates for the bulk meter locations which has been carried out by the use of portable ultrasonic flow meters or inspection of flow meters.

9.2.2.1 Verification and Updating of Maps

Mapping and inventory of pipes and fittings in the water supply system: If the updated maps are available and bulk meters are in position network survey can be taken up as a first step. Otherwise maps have to be prepared and bulk meters fixed. The agency should set up routine procedures for preparing and updating maps and inventory of pipes, valves and consumer connections. The maps shall be exchanged with other public utilities and also contain information on other utility services like electricity, communications.

9.2.2.2 Installation of Bulk Meter with Delineating Suitable Boundaries

The major activity during the overall water audit will be bulk meter installation at those points on the distribution network where water enters the system. It is expected that bulk meters will be required at the following locations:

a) All major system supply points.
b) All tubewells which supply the system directly.
c) Major transfer mains which are expressly required for audit.

At distribution centres, the most appropriate meter position is on the outlet pipe from the service reservoir. Installation of a meter at this point will allow measurement of flows into the system not only if supplies are coming from the service reservoir but also if they are being pumped directly from the clear water reservoir.

The size of the meter can be determined by:

1. Number of properties served.
2. Per capita consumption (litres/person/day).
3. Population density.
4. Hours of supply.

Meter sizes must be sized according to current supply hours. Future changes to system operation may require the substitution of some bulk meters with those of a smaller size, due to reductions in flow over longer supply hours. the arrangement of Bulk and flow meters need to as indicated in the figure here below with gate valves.

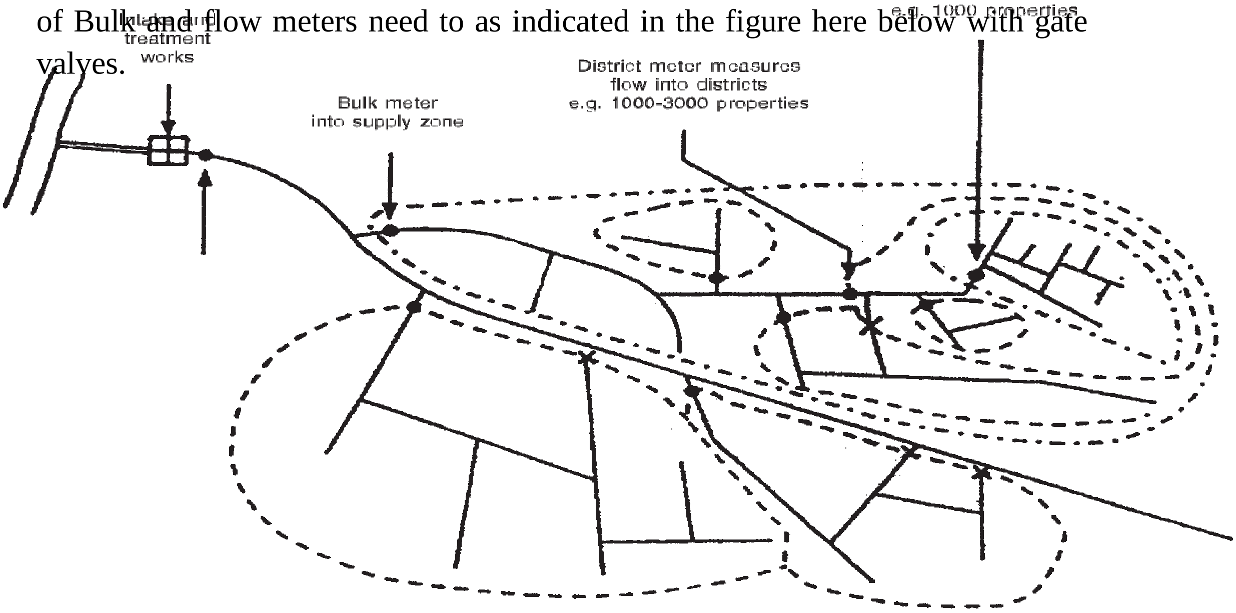


Figure 20: District Metering Area

The above sketch is self explanatory. Main bulk water meter, district and sub district water meters within main and sub boundaries are required to be delineated. for interconnection between the boundaries gate valves are required to prevent interflow during auditing.

in addition to doing the above tasks for the whole system majorly for distribution network, the following system elements are required to be audited separately as described under the following sections.

9.2.3 Monitoring of the Production System

The assessment of the leakage rates through the various features of the water supply system should be undertaken. The first step is assessment for the major upstream components groups as production parts which will include:

i. Raw water transmission system.
ii. Reservoirs.
iii. Treatment Plant.
iv. Clear-water transmission system.
v. Inter zonal transmission system.
vi. Wells.

9.2.3.1 Transmission System

The methodology adopted to make an assessment of the level of losses in the transmission system is to install insertion probes/bulk meter at both ends of each section of main being monitored, thus monitoring both the inflow and outflow of the section. This monitoring should be done for a minimum period of 7 days. The difference of inflow and outflow will indicate the losses in the transmission main. The advantage of this method is that the trunk main need not be taken out of service.

9.2.3.2 Reservoirs

To reduce or avoid any leakage or consequent contamination in reservoirs, the reservoirs should be periodically tested for water tightness, drained, cleaned, washed down and visually inspected. The losses in water storage structures can be monitored for a particular period noticing the change in the level gauges when the structure is out of use i.e. there is no inflow and outflow of water during this monitoring period.

The most reliable method for measurement of leakage from a service reservoir is to fill it to full level and isolate it from supply and to measure change in level over suitable time period. Suitable equipment to measure reservoir levels could be chosen like:

- Sight gauges
- Water level sensors (as per manufacturers instruction)
- Float gauges
- Submersible pressure & level transducers (as per manufacturers instruction).

9.2.3.3 Treatment Plant

The losses in treatment plant can be monitored by measuring the inflow into the plant and outflow from the plant with the help of mechanical/electronic flow recorders. The difference of inflow and outflow for the monitoring period will indicate the water losses in the plant. In case the loss is more than the design limit, further investigation should be carried out for remedial measures.

9.2.3.4 Wells

In conjunction with the programme of bulk meter installation is the operation to monitor the approximate yield from the wells This exercise can be carried out by the installation of semi-permanent meters to the tube wells on a bypass arrangement similar to that for the bulk meters. This can be effected utilising the smaller diameter bulk meters. Insertion probes or the portable ultrasonic flow meters will be used for measurement of flows on the common feeder mains.

9.2.4 Monitoring of the Distribution System

Distribution system comprises of service reservoirs, distribution mains & distribution lines including appurtenances, consumer service lines, connections viz. metered, unmetered (flat rate), public stand posts, hydrants, illegal connections. The area of the city is divided into Waste Metering Areas (WMA)/ Sample area zones. Since at one time it is not possible to carry out water audit in all WMAs, it is done for a part of the city at one time followed by other parts of the city in future. This has to be a continuous process managed by a water audit wing or a Leak Detection cell.

Water audit of the distribution system consists of:

i. Monitoring of flow of water from the distribution point into the distribution system (WMA).
ii. Consumer sampling.
iii. Estimating metered use by consumers.
iv. Estimating losses in the appurtenances and distribution pipe line network including consumer service lines

9.2.4.1 Monitoring Flow in to the Distribution System

A bulk meter of the appropriate type and size is installed at the outlet pipe of the service reservoir or at the point where the feeding line to the area branches off from the trunk main. If water from the WMA flows out into another zone a valve or meter is to be installed at this outlet point..

9.2.4.2 Customer Meter Sampling

Water audit is a continuous process. However, consumers’ meter sampling can be done on early basis by

- Review of all existing bulk and major consumers for revenue. A co-relation between the production/power consumed in the factory vis-a-vis water consumption can be studied.
- Sampling of 10% of all bulk and major consumers.

- Sampling of 10% of small or domestic consumers.
- Series meter testing of large meters suitably according to standard, calibrated meter
- Testing of 1% large and 1% domestic meters.
- Estimating consumption at a representative 5% sample of Public Stand Posts (PSP) and unmetered connections by carrying out site measurements.
  All non-functioning and broken meters in the sample areas will be replaced and all meters may be read over a week. This information will be brought together with information derived from the workshop and series testing in order to estimate the average water delivered and correction factors for consumer meters These factors can then be extrapolated to the rest of the customer meter database.

9.2.4.3 Customer Metered Use

The average consumption per working meter is calculated by dividing the total consumption of all working meters in the WMA by the number of working meters. This average consumption is then multiplied by the meter correction factor derived from the customer meter sampling exercise in which the serial metering test and bench test of meters is done. Average slow or fast percentage of test recording of meters is known as correction factor. This average metered consumption multiplied by the correction factor is known as water used by consumer. Unmetered connections & illegal connections will also be treated to have same consumption as metered property.
Estimating customer metered use can also be carried out using the customer data obtained from the customer billing records. Consumption analysis will be carried out by:

- Consumer type.
- Revenue zone/sample area/WMA.
- Direct supply zone/sample area/WMA.
- Overall for the city/Water Supply Scheme.

During the analysis the correction factors derived in the sampling exercise will be applied for metered consumption. Default values will be applied to connections with estimated bill. Public Stand Posts (PSP), unmetered and illegal use will also be treated as metered consumption. Analysis of the billing data will enable the production of:

- A report on overall water delivered.
- An estimate of water delivered to wards/sample areas/WMA.
- UFW i.e., Physical losses and non-physical losses.
- Errors in assessment of water production. (in case of wells).

9.2.4.4 Losses in Customer Service Lines and Appurtenances

Losses can be calculated by deducting from the total quantity, the following :

- Metered consumption.
- Unmetered consumption (assuming metered use).

- Illegal connection consumption (assuming metered use).
- PSP use.
- Free supply, fire-hydrants, use in public toilets, parks etc.

9.2.5 Analysis

The information of the results of monitoring the distribution system together with the results of the bulk metering exercise will be consolidated and brought together to produce the water balance report and the overall water audit report. These results may be interpreted in financial terms.

Further exercise will be done to classify the water consumed/wasted/lost in financial terms with relation to the current and future level of water charges. This exercise will be carried out as a result of the field tests and the review of existing records forming part of the overall water audit.

This water audit will provide sufficiently, accurate area wise losses to prioritise the area into 3 categories viz.

- Areas that need immediate leak detection and repair.
- Areas that need levels of losses (UFW) to be closely monitored.
- Areas that appear to need no further work at the current time.

It is recommended that cursory investigation should be carried out in the areas that appear to have the least levels of losses (UFW), locating any major leaks, followed by the leak repairs would reduce the losses (UFW) levels further. After water audit of few cities it has been established that the components of UFW may generally be as follows:

- Leakage (physical losses) 75 to 80%
- Meter under-registration 10 to 15%
- Illegal/unmetered connections 3.5 to 6%
- Public use 1.5 to 3.5%

Water audit provides fairly accurate figures of both physical and non-physical losses in the different waste metering areas of city. Accordingly the areas with higher percentage of losses can be identified for carrying out the leakage control exercise for reduction of water losses. As explained earlier, the reduction in losses will result in saving in the form of:

- Operational cost
- Capital cost

Apart from this, the saving in losses will result in consumer satisfaction, improved water quality and additional revenue to the Water Authority and postponed of augmentation schemes.

9.2.6 Control of UFW

Conducting the above process is not final stage of getting the loss to the required level. the preceding level is only an indicator for setting priorities of further detail study analysis and planned action to reduce loss.

According to the priorities set as the result above process with areas for and detail assessment identified, planned and systematical assessment of UFW in terms of physical loss, meter error, illegal connection and other losses shall be identified.

9.3 Energy Audit and Conservation of Energy

9.3.1 Introduction

Energy is very scarce commodity particularly in developing and underdeveloped countries. Cost of energy is spirally increasing day-by-day. Generally pumping installations consume huge amount of energy wherein proportion of energy cost can be as high as 40 to 70% of overall cost of operation and maintenance of water works. Need for conservation of energy, therefore cannot be over emphasized. All possible steps need to be identified and adopted to conserve energy and reduce energy cost so that water tariff can be kept as low as possible and gap between high cost of production of water and price affordable by consumers can be reduced. Conservation of energy is also important and necessary in national interest as the nation is energy deficit due to which problems of low voltage, load shedding and premature failures of equipments are encountered.

Some adverse scenarios which require conservation of energy are;

1. Energy consumption is higher than optimum value due to reduction in efficiency of pumps.
2. Operating point of the pump is away from best efficiency point (b.e.p.).
3. Energy is wasted due to increase in head loss in pumping system e.g. clogging of strainer, encrustation in column pipes, and encrustation in pumping main.
4. Selection of uneconomical diameter of sluice valve, butterfly valve, reflux valve, column pipe, drop pipe etc. in pumping installations.
5. Energy wastage due to operation of electrical equipments at low voltage and/or low power factor.

Such inefficient operation and wastage of energy need to be avoided to cut down energy cost. It is therefore, necessary to identify all such shortcomings and causes which can be achieved by conducting methodical energy audit.

Strategy as follows, therefore need to be adopted in management of energy.

1. Conduct thorough and in-depth energy audit covering analysis and evaluation of all equipment, operations and system components which have bearings on energy consumption, and identifying scope for reduction in energy cost.
2. Implement measures for conservation of energy.

Energy audit as implied is auditing of billed energy consumption and how the energy is consumed by various units, and sub-units in the installation and whether there is any wastage customer forum and communication due to poor efficiency, higher hydraulic or power losses etc. and identification of actions for remedy and correction.

In respect of energy conservation, various organizations are working in the field of energy conservation and have done useful work in evolving measures for energy conservation. The reported measures are discussed in this chapter. The measures if adopted can reduce energy cost up to 10% depending on the nature of installation and scope for measures for energy conservation.

9.3.2 Frequency Audit

Scope of energy audit, suggested methodology is discussed below. Frequency of energy audit recommended is as follows:

Large Installations	Every year
Medium Installations	Every two years
Small Installations	Every three years

9.3.3 Actions and Steps in Energy Audit

Energy audit includes following actions, steps and processes:

i. Conducting in depth energy audit by systematic process of accounting and reconciliation between the following:
- Actual energy consumption.
- Calculated energy consumption taking into account rated efficiency and power losses in all energy utilizing equipment and power transmission system i.e. conductor, cable, panels etc.

ii. Conducting performance test of pumps and electrical equipment if the difference between actual energy consumption and calculated energy consumption is significant and taking follow up action on conclusions drawn from the tests.

iii. Taking up discharge test at rated head if test at Sr. No. (ii) is not being taken

iv. Identifying the equipment, operational aspects and characteristic of power supply causing inefficient functioning, wastage of energy, increase in hydraulic or power losses etc. and evaluating increase in energy cost or wastage of energy.

v. Identifying solutions and actions necessary to correct the shortcomings and lacunas in (iv) and evaluating cost of the solution.

vi. Carrying out economical analysis of costs involved in (iv) and (v) above and drawing conclusions whether rectification is economical or otherwise.

vii. Checking whether operating point is near best efficiency point and whether any improvement is possible.

viii. Verification of penalties if any, levied by power supply authorities e.g. penalty for poor power factor, penalty for exceeding contract demand.

ix. Broad review of following points for future guidance or long term measure:
- C-value or f-value of transmission main.
- Diameter of transmission main provided.
- Specified duty point for pump and operating range.
- Suitability of pump for the duty conditions and situation in general and specifically from efficiency aspects.
- Suitability of ratings and sizes of motor, cable, transformer and other electrical appliances for the load.

9.3.4 Performance Test of Pumps

9.3.4.1 Parameters to be Determined

• Head
• Discharge
• Power input to motor
• Speed of pump

9.3.4.2 specific Points

- Only one pump-motor set shall be tested at a time.
- All gauges and test instruments shall be calibrated.
- Rated head shall be generated by throttling valve on pump delivery.
- Efficiency of motor shall be as per the manufacturer's curve or type test certificate.
- Water level in the sump/intake shall be maintained practically constant and should be measured frequently (once in every 3-5 minutes).
- Test should be conducted for sufficient duration (about 30-60 minutes) for better accuracy.

9.3.4.3 Test Gauges and Instruments

Following test gauges and instruments are required for performance test.

A. Determination of head
✓ Pressure and vacuum gauges.
✓ Float gauge with calibrated scale to measure elevation difference between water levels and pressure gauge or elevation difference between two gauges.
B. Determination of discharge
✓ Flow meter
✓ In absence of flow meter, volumetric measurement preferably at both source and discharging point wherever feasible or otherwise at one of the two points which is reliable shall be carried out.
C. Input Power
✓ 2 numbers of single phase wattmeter
✓ Current Transformer (CT)
✓ Potential Transformers (PT)
✓ Test lids
✓ Frequency-meter
D. Speed

✓ Contact tachometer
or
✓ Non-contact optical tachometer

9.3.4.4 Test Codes

- Test shall be generally conducted as per IS 9137 - Code for acceptance test for pumps
✓ Class 'C'. Where high accuracy is desired, test shall be conducted as per IS 10981
✓ Code for acceptance test for pumps - Class 'B'.
- Correction for rated speed corrected to average frequency during the test shall be carried out as per affinity law specified in IS 9137, IS 10981 and IS 5120 (Technical requirements for rotodynamic special purpose pumps).

9.3.5 Measures for Conservation of Energy

Measures for conservation of energy in water pumping installation can be broadly classified as follows:

A. Routine Measure

The measures can be routinely adopted in day to day operation and maintenance.

B. Periodical Measures

Due to wear and encrustation during prolonged operation, volumetric efficiency and hydraulic efficiency of pumps reduce. By adopting these measures, efficiency can be nearly restored. These measures can be taken up during overhaul of pump or planned special repairs.

C. Selection Aspects

If during selection phase, the equipment i.e. pumps, piping, valves etc. are selected for optimum efficiency and diameter, considerable reduction in energy cost can be achieved.

D. Measures for System Improvement

By improving system so as to reduce hydraulic losses or utilized available head hydraulic potentials, energy conservation can be achieved.

9.3.5.1 Routine Measure

A. Improving Power Factor to 0.98

Generally as per rule of power supply authority, average power factor (PF) of 0.9 or so is to be maintained in electrical installations. If average PF is less than 0.9 or specified limit over the billing period, generally penalty at rate of 0.5% of bill per each 1% (may vary) shortfall in PF is charged. It is, therefore, obligatory to maintain PF to level of 0.9 or specified limit. Improving PF above the limit is beneficial for conservation of energy. The power factor, can be improved to level of 0.97 or 0.98 without adverse effect on motors. Further discussion shows that considerable saving in power cost can be achieved if PF is improved.

For 1000 kW load and 3.3 kV system, if the LF is improved from 0.9 to 0.98;

a. the load current decreases from 194.4A to 178.5A,
b. copper losses (assuming 3% copper losses) decreases from 30 kW to 25.3 kW

The kVA recorded at PF 0.9 and 0.98 are,

$kVA_{0.90}$ = 1000/0.90 = 1111 kVA

$kVA_{0.98}$ = 1000/0.98 = 1020 kVA

B. Operation of Working and Standby Transformer

As regards operation of working and standby transformers, either of two practices as below
is followed :

i) One transformer on full load and second transformer on no-load but, charged.
ii) Both transformers on part load.
Detail analysis is required to be done by an electrician.

C. Voltage Improvement by Voltage Stabilizer or at Transformer by OLTC

If motor is operated at low voltage, the current drawn increases, resulting in increased copper losses and consequent energy losses. It is, therefore, beneficial to correct operating voltage to rated voltage of motors. Voltage can be corrected by selecting appropriate tap on tap changing switch of transformer. More preferable measure is to provide on-load tap changer (OLTC) on transformer or automatic voltage stabiliser due to which voltage can be maintained at rated level.

D. Reducing Static Head(Suction Side)

A study shows that energy can be saved if operating head on any pump is reduced. This can be achieved by reducing static head on pumps at suction end or discharging end or both. One methodology to reduce static head on pumps installed on sump (not on well on river/canal/lake source) is by maintaining WL at or marginally below Full Suction Level(FSL), say, between FSL to (FSL - 0.5 m) by operational control.

E. Keeping the Strainer or Foot Valve Clean and Silt Free

Floating matters, debris, vegetation, plastics, gunny bags etc. in raw water clog the strainer
or foot valve creating high head loss due to which the pump operates at much higher head
and consequently discharge of the pump reduces. Such operation results in :

1. Operation at lower efficiency as operating point is changed. Thus, operation is energy wise inefficient.
2. Discharge of the pump reduces. If the strainer/foot valve is considerably clogged, discharge can reduce to the extent of 50% or so.
3. Due to very high head loss in strainer/foot valve which is on suction side of the pump, NPSHA may fall to low level causing drop in pressure to below vapour pressure. This may result in cavitation of pump and consequent damages due to pitting, vibration etc.

The strainers or foot valve should therefore, be cleaned regularly. Frequency of cleaning should be more during rainy season depending on load of floating matters.

F. Preventing Throttling of pump

At times, if motor gets overloaded, field officer resorts to throttling of pump to prevent overloading of motor. Due to throttling, operating point is shifted from point high discharge and low head to low discharge high head. Which though prevented overloading of the motor, discharge is reduced resulting in operation for more number of pumping hours to fulfill demand and therefore, increase in energy consumption. The operation is also generally at low efficiency and consequently results in increased energy cost. Such throttled operation therefore should be avoided.

G. Replacement of Existing Mercury Vapor lamps by Sodium Vapor Lamps

Sodium vapour lamps are considerably energy efficient as compared to mercury vapour lamps. Lumens per watt of SV lamp is nearly twice that of MV lamps. Hence mercury vapour lamps should be replaced by sodium vapour lamps of lower wattage as and when MV lamps become unserviceable to reduce energy bill.

9.3.5.2 Periodical Measures

A. Restoring Wearing Ring Clearance

Due to wear of wearing rings , the clearance between wearing ring increases causing considerable reduction in discharge and efficiency. Reduction in discharge up to 15 - 20% is observed in some cases. If wearing rings are replaced, the discharge improves to almost original value.

If wearing rings are replaced, the clearances can be brought to original value and discharge can be improved almost to rated value and wastage of energy which may be as high as 15% can be avoided. It is advisable to replace wearing rings of pump to specified clearance once in 3 - 4 years or when discharge of the pumps reduces by 5% or more.

B. Reducing Disc friction Losses

Disk friction losses in pump accounts for about 5% of power consumed by the pump. The water particles in space between impeller shrouds and walls of casing/bowl acquire rotary motion due to rotation of impeller which functions as disk. The particles move outwards and new particles approach disk at centre. Thus re-circulation is established and energy is spent. A study shows that if surfaces of the impeller and casing are rough, the disk friction losses increase. If casing is painted and impeller is polished, disk friction losses can be reduced by 20% to 40% of normal loss. Thus as disk friction loss is about 5% of power required by the pump, overall saving in power consumption will be 1% to 2%. For large pump the saving can be very high.

C. Scraping Down Encrustation inside Column Pipe

Due to operation over prolonged period, encrustation or scaling inside the column pipe develops causing reduction in inside diameter and making surface rough. Both phenomenon cause increase in friction losses. If scrapping of encrustation is carried out whenever column pipes are dismantled energy losses can be avoided.

9.3.6 Selection Aspects

9.3.6.1 Optimum Pump Efficiency

Optimum efficiency of pump can be ensured by appropriate selection such that specific speed is optimum. Specific speed, N_S is given by,

$$N_s = \frac{3.65 N \sqrt{Q}}{h^{0.75}}$$

Where N = rotative speed, rpm
Q = discharge, m3/s
h = head per stage, m

Thus by varying N and number of stages and therefore h, the optimum specific speed can be chosen and optimum efficiency can be ensure.
Thus by varying N and number of stages and therefore h, the optimum specific speed can be chosen and optimum efficiency can be ensured. In most supplies, a graph showing variation of efficiency with variation in specific speed and discharge is available. Ns should be around for optimum efficiency. It should not be too less than 100 as efficiency is very low and in water supply installation, N_S should not be more than 295 as power required at shut off is more than that at b.e.p. requiring higher motor rating. Otherwise such pumps are to be started and stopped against open delivery valve which is not possible if parallel operation of pumps is involved.

9.3.6.2 optimization of Sluice Valve/Butter Fly Valve and Non-Return Valve on Delivery Pipe

'K' values of sluice valve and non-return valve are 0.35 and 2.50 respectively which amount to combined 'K' valve of 2.85. Due to very high 'K' value, head loss through these valves is significant and therefore, it is necessary to have optimum size of valves. Typical comparison of design velocities, head loss and energy loss in sluice valve and NRV can be done in terms of finance.

9.3.6.3 Column Pipe Diameter in Vertical Turbine Pump

Selection of economical diameter of column pipe is of utmost important; particularly for raw water V.T. pumps where length of column pipes is considerable and at times as high as 30 m. Head loss in column pipe upto 2-3 m is not uncommon if diameter is not selected suitably

9.3.6.4 Delivery Pipe for Submersible Pump

As delivery pipe for submersible pump is comparatively long and therefore, head loss in delivery pipe is considerable, it is of importance to select proper diameter. Optimum design velocity is around 1.1 - 1.5 m/s. However, pipe diameter should not be less than 50 mm.

9.3.7 Measures for System Improvement

9.3.7.1 Replacement of inefficient Pumps

At times it is observed that the pump efficiency reduces by about 10% - 15% and can not be improved though wearing rings are replaced and overhaul carried out to the pump set because of abnormal deterioration in pump. In such a case, it is necessary to replace the old and inefficient pump to save the tremendous wastage of energy. increase in energy cost per annum can easily be determined. the cost for new pump related to the annul operation cost can also be compared.

9.3.7.2 Preventing Open Channel Flow in Raising Main

In case of rising main if HGL is cutting the pipeline at hump and thus causing open channel flow in downstream section, feasibility of lowering the pipeline at hump and thus reducing head on the pump need to be examined and if feasible, should be implemented.

9.3.7.3 Providing Wash Water Pumps instead of Tapping from Clear Water Raising Main or Filling Wash Water Tank from Reservoir

In some installations, wash water tank is fed from tapping on clear water rising main or, from reservoir at higher elevation. This practice is adopted to save capital cost of wash water pump without realising that such operation results in tremendous wastage of energy. As head on clear water pump is usually much higher than that required for wash water pump, considerable head and energy are wasted.

9.3.7.4 Using Right angled fittings instead of Y-Connections on joints along the pumping lines.

Y-Branches on suction and delivery pipes have lower friction factors than right angle junctions hence plays significant role to reduce energy due to friction/

10 SAFETY MEASURES

10.1 General

Personnel engaged in the operation and maintenance of water supply is dealing with important and dangerous equipment and devices. Important in a sense is that the water supply is life matter to the community and dangerous in that the electrical or mechanical parts can cause death or harm if not operated and maintained safely with knowledge.

Hence, safety measures shall always be considered or safety training should be provided to operators and maintenance personnel.

Operation and maintenance procedures for electromechanical equipment shall be overruled by the specific manufacturer's manual provided with the specific equipment, and only in the absence of the manufacturers manuals that procedures of this manual can be applied.

To start with the safety measures, the UTILITY shall be equipped with:

- A complete first aid kit with alcohol, medicines, bandages, splints, etc.
- A complete set of compulsory tools shall be procured by the UTILITY and be used appropriately.
- One fire Extinguisher at the generator house
- Never dismantle any component without proper knowledge to inspect
- Never dismantle any piece or part before knowing that an appropriate and working part is available at the UTILITY.

For all maintenance services, the operator should ensure that he has adequate illumination, sufficient work space and secure footing. He should not wear loose clothing and jewellery near moving parts. He should wear gloves, a safety hat, safety boats and safety goggles as required.

10.2 Safety Precautions when using tools

A high percentage of accidents in operation and maintenance are caused by improper use of tools. In this regard, there are several safety measures to be taken, listed as:

- Select the proper tool for the specific job
- Inspect tools and repair or replace damaged or worn once.
- Do not leave tools in places where they may fall and hurt others.
- Do not use tools on moving machinery or equipment
- Allow sufficient clearance and ensure solid footing when preparing to use tools.
- Learn and apply the proper method for using the tool
- Wear eye protection when using impact tools, chipping, wire brushing etc.

10.3 Safety precautions when handling electrical equipment:

- It is good practice to wear rubber gloves when starting electric motors
- Operators should be required to stand on rubber mats or wear rubber shoes when handling switch gear.
- During any electrical repair, the power line feeding the equipment to be repaired should be isolated
- High voltage circuits and panels should be repaired only by competent electricians
- Do not touch equipment, cables or any metal that touches, or is in danger of touching, high voltage lines.
- Only approved and inspected extension cords should be used.
- Electric hand tools should always be grounded.
- No electric equipment is to be handled while in contact with water.

10.4 Safety Aspects of chlorination

10.4.1 General

Chlorine is potentially dangerous. It is, therefore, important that person engaged in a chlorine plant or in any activity involving handling of chlorine should understand the hazards of chlorine and should know preventive measures needed.

10.4.2 Health Hazard

Wet chlorine being corrosive, it forms corrosive acid with body moisture. Inhalation can cause respiratory injury ranging from irritation to death depending upon its concentration and duration of inhalation.

1. Acute Exposure

The first symptom of exposure to chlorine is irritation to the mucous membranes of eyes, nose and throat. This increases to smarting and burning pain. Irritation spreads to chest. A reflex cough develops which may be intense and often associated with pain behind the breast-bone. The cough may lead to vomiting. Cellular damage may occur with excretion of fluid in the alveoli. This may prove fatal if adequate treatment is not given immediately. Vomit frequently contains blood due to lesions of the mucous membrane caused by the gas. Other common symptoms include headache, retrosternal burning, nausea, painful breathing, sweating, eyes, nose, throat irritation, coughing, vomiting, increase in respiration and pulse rate. Massive inhalation of chlorine produces pulmonary oedema, fall of blood pressure and in a few minutes, cardiac arrest.

2. Chronic Exposures

Persons rapidly lose their ability to detect the odour of chlorine in small concentrations. On account of this, the concentrations beyond threshold limit value may exceed without notice. Prolonged exposure to concentrations of 5 ppm results in disease of bronchitis and predisposition to tuberculosis and concentration of 0.8-1.0 PPM can cause moderate but permanent reduction in pulmonary function. Person exposed for long period of time to low concentrations of chlorine may suffer from acne, tooth enamel damage may also occur.

10.4.3 First aid-Trained personnel and equipment

In the plant trained first aider having the knowledge in the use of aid equipment and rendering artificial respiration should be available. First aid box with necessary contents should be available. Properly designed showers and eye fountains should be provided in convenient locations and they should be properly maintained. If oxygen is available the same should be administered by authorized person. Such training is imparted by civil defense.

1. General

Remove the affected person immediately to an uncontaminated area. Remove contaminated clothing and wash contaminated parts of the body with soap and plenty of water. Lay down the affected person in cardiac position and keep him warm. Call a physician for medical assistance at the earliest.

Caution: Never attempt to neutralize chlorine with other chemicals.

2. Skin Contact

Remove the contaminated clothes; wash the affected skin with large quantity of water. **Caution**: No ointment should be applied unless prescribed by the physician.

3. Eye Contact

If eyes get affected with liquid chlorine or high concentration of chlorine gas, they must be flushed immediately with running water for atleast 15 minutes keeping the eyelids open by hand.

Caution: No ointment should be used unless prescribed by an eye specialist.

4. **Inhalation**

If the victim is conscious, take him to a quiet place and lay him down on his back, with head and back elevated (cardiac position). Loosen his clothes and keep him warm using blankets. Give him tea, coffee, milk, peppermint etc. for making good effect on breathing system. If the victim is unconscious, but breathing, lay him down in the position mentioned above and give oxygen at low pressure until the arrival of doctor. If breathing has stopped, quickly stretch him out on the ground or a blanket if available, loosen his collar and belt and start artificial respiration without delay. Neilson arm lift back pressure method is useful. Automatic artificial respiration is preferable if available. Continue the respiration until the arrival of the doctor. Amboo bag can also be used for this purpose.

10.5 Emergency measures

In case of leakage or spillage:

1. Take a shallow breath and keep eyes opened to a minimum.
2. Evacuate the area.
3. Investigate the leak with proper gas mask and other appropriate Personal protection.
4. The investigator must be watched by a rescuer to rescue him in emergency.
5. If liquid leak occurs, turn the containers so as to leak only gas.
6. In case of major leakage, all persons including neighbours should be warned.
7. As the escaping gas is carried in the direction of the wind all persons should be moved in a direction opposite to that of the wind. Nose should be covered with wet handkerchief.
8. Under no circumstances should water or other liquid be directed towards leaking containers, because water makes the leak worse due to corrosive effect.
9. The spillage should be controlled for evaporation by spraying chilled water having temperature below 9.4oC. With this water crystalline hydrates are formed which will temporarily avoid evaporation. Then try to neutralize the spillage by caustic soda or soda ash or hydrated lime solution carefully. If fluroprotein foam is available, use for preventing the evaporation of liquid chlorine.
10. Use emergency kit for controlling the leak
11. On controlling the leakage, use the container in the system or neutralize the contents in alkali solution such as caustic soda, soda ash or hydrated lime.

Caution: Keep the supply of caustic soda or soda ash or hydrated lime available. Do not push the leaking container in the alkali tank. Connect the container to the tank by barometric leg.

12. If container commences leak during transport, it should be carried on to its destination or manufacturer or to remote place where it will be less harmful. Keeping the vehicle moving will prevent accumulation of high concentrations.
13. Only specially trained and equipped workers should deal with emergency arising due to major leakage.
14. If major leak takes place, alert the public nearby by sounding the siren.
15. Any minor leakage must be attended immediately or it will become worse.
16. If the leakage is in the process system, stop the valve on the container at once

10.6 Personnel Protection Equipment

1. Breathing Apparatus

Various types of respirators and their suitability are as follows:

a) Self-contained breathing apparatus

This apparatus is equipped with a cylinder containing compressed oxygen or air which can be strapped on to the body of the user or with a canister which produces oxygen chemically when the reaction is triggered. This type of equipment is suitable for high concentration of chlorine in an oxygen deficient atmosphere.

b) Air-line respirator: Air-line length 90 mtrs. (max.)

It is suitable for high concentrations of chlorine provided conditions permit safe escape if air supply fails,. This device is suitable in any atmosphere, regardless of the degree of contamination or oxygen deficiency, provided that clean, breathable air can be reached.

c) Industrial Canister Type Mask : Duration: 30 min. for 1% Cl2

It is suitable for moderate concentration of chlorine provided sufficient oxygen is present. The mask should be used for a relatively short exposure period only.If the actual chlorine concentration exceeds 1% by volume or oxygen is less than 16% by volume, it is not useful. The wearer in such cases must leave

the place on detection of chlorine or experiencing dizziness or breathing difficulty.

2. Protective Clothing

Rubber, or PVC clothing is useful in massive exposure which otherwise creates mild skin burns due to formation of acid on the body.

3. Maintenance of Protective Equipment

a. Clean with alkali after every use.

b. Keep in polythene bag at easily accessible place.

c. Check them periodically about their suitability. Many times the seal ring of face mask gets hardened.

11 FINANCIAL MANAGEMENT

It is essential to establish a sound financial management system to make the water supply system financially viable. This can be achieved by controlling expenditure and increasing the income. Control of O&M expenditure can be achieved by preparing an annual budget of income and expenditure of O&M, based on realistic estimates. The estimation of outlays on O&M varies from city to city and it is mainly a function of establishment and power charges for pumping schemes and often lesser or no power charges for gravity supplies. The breakup of O&M cost varies from place to place. From the basis of available data the average breakup of O&M cost is likely to be as follows: Power Charges about 30 to 50%, Salaries as high as 36%, Chemicals such as Alum and Chlorine about 3 to 4%, Repairs and replacements about 10 to 15%, debt servicing about 20%, depreciation about 2%. The financial system of the UTILITY shall be designed in such a way that, the records of each elements of O&M costs be compared to each other related to the total income and quantity of water sold and produced.

It will be possible to increase the revenue by reviewing water rates in case income is less and revise these in time to cover the losses. The organisation shall realise that full cost recovery of O&M cost by user charges is a must. The tariff structure is to be evolved to recover the O&M cost and have a surplus for debt servicing and depreciation. Though everyone shall contribute to the cost, it is still necessary that a survey on the paying capacity of consumers may be required to ensure that tariffs are affordable. It is always prudent to levy the minimum payable charges by the economically weaker section and suggest higher rates to others who can afford. A review of free supplies through public stand-posts may be required. Perhaps the possibility of organised selling of water through public taps can also be studied. It will be necessary to establish a system of raising bills and recoveries to maintain the cash flow and also aim at a larger ratio of collection to billing. Cost recovery can also be achieved by reducing losses by applying better pipe laying and plumbing techniques, undertaking timely preventive maintenance, detecting and reducing losses and controlling illegal connections.

Revenue management system is an important aspect of any Water supply System as it governs the financial aspect. Besides fixing a tariff structure, billing and collection of revenue play an important part.

12 PLANNING, RECORD KEEPING, MONITORING, EVALUATION AND MIS

12.1 Planning

A program or a plan has to be prepared for operation and maintenance of every major unit to be specifically written for that particular unit. The overall operation and maintenance plan of an organization is made up of collecting operation and maintenance programmes of various individual units. This plan has to contain procedures for routine tasks, checks and inspections at intervals viz. daily, weekly, quarterly, semi-annually or annually.

The individual plans must be prepared for all units and all pieces of equipment. Each unit must have a plan to fix responsibility, timing of action, ways and means of achieving the completion of action and contain what objectives are meant to be achieved by this action. Generally actions recommended by the manufacturer or by the engineer who has installed the equipment or who has supervised the installation can be included. Often the contractor's recommended operation and maintenance procedures at the time of design or construction will be a good starting point for writing a sound programme. This plan has to be followed by the operation and maintenance staff and also will be the basis for supervision and inspection and also can be used for evaluation of the status of operation and maintenance.

If the labour costs for operation and maintenance are high compared to replacement cost, the latter course of action will be preferable. The managers shall realize that most of the operation and maintenance can be carried out without more staff. The existing operation and maintenance staff with little training can do the operation and maintenance work without any extra expense. Similarly, record keeping and analysing does not require any additional cost. However costs have to be provided in the budgets for spares, tools and plants, training to operation and maintenance staff and any specialized services for important equipment.

Briefly the plan shall contain what actions are required, when these actions are to be taken, who has to take these actions, how these actions are to be achieved and why these actions are required. The nature of maintenance can be described in a separate maintenance manual and related by numbers in the plan for reference, so that the maintenance staffs know as to how to carry out the numbered actions. Checklists can be prepared for use by the supervision or inspecting officers to ensure that the actions indicated in the operation and maintenance plan are carried out promptly and properly.

The plan of the UTILITY shall mainly have goals to minimize operation cost, increase income, and satisfy the demand of the community in terms of all requirements.

12.2 Record Keeping

Degree of improvement on the performance of the UTILITY can only be known if and only if each and every event in Operation and Maintenance are recorded. The current century is the era of information. Information is the major source and base for future improvement and decision by management bodies. Hence, the UTILITY under close monitoring by the BOARD shall record all events using formats prepared for this purpose.

Record keeping is very important task of the UTILITY, which helps to:

- Get information for superior level of management
- Recognize which percentage of the system capacity is reached,
- Get design parameters for future projects and extensions,
- Determine performance parameters,
- Calculate specific consumption,
- Assess system efficiency,
- Detect cheating,
- Estimate operation costs,
- Determine unaccounted for water (technical and administrative water losses),

Records are also helpful in preparation of reports, saving time with high degree of accuracy. The reports are also major tool to monitor the outcomes and take correct decisions accordingly.

In this manual there are a total of about **23** formats for recording and reporting. During the course of action, the UTILIY can also add additional and supportive formats to record and report unforeseen events.

Major daily records among others are;

1. Daily water production using meters at the outlet of each sources
2. Daily water production using the meters at the outlet of each reservoirs
3. Machineries working hours including chemical and energy dosages etc.

Detail of all the recording formats are as listed under Chapter 15 of this manual.

12.3 Monitoring, performance Evaluation and reporting

12.3.1 Monitoring

The main objective of monitoring and evaluation is to compare plan against accomplishment to determine if there are deficiencies and take corrective action if needed so as to manage **time**, **cost** and **quality of service** provided by the maintenance system.

The purpose of reporting is to inform management and other responsible parties as to the progress of maintenance activities and any needed changes in operating procedures or resource requirements.

The UILITY management and the BOARD shall regularly monitor the performance of the utility related to the plan using selected performance indicators which can be base to measure its performance and compare its standard to other similar utilities.

12.3.2 Performance Evaluation

Effective evaluation of the status of operation and maintenance depends primarily on the ability to measure current performance. This can be achieved using indicators and targets for the performance of different functions.

The concept of monitoring the performance of operation and maintenance is to use the results to improve the situation. Evaluation is made through performance indicators defined as variables whose purpose is to measure change in a process or function. Indicators are collected at regular intervals through regular reports, to track the way in which a system is performing or an activity is unfolding. Indicators may be used to assess the change resulting from a particular activity. In one way, performances indicators are used to monitor the progress of the process; another way, indicators are used to evaluate the outcome of the system. Evaluation requires the situation to be assessed both at the beginning and at the end of a certain activity.

Indicators may be quantitative or qualitative in nature.

The evaluation process begins at the scheme level as reports on input; output and performance are generated and reported to utility for verification and assistance. The performance indicators under implementation by the Ministry of Water and Energy shall be measured using the records under O&M event as a basis.

Detail of performance indicators are listed on annex part of form-6.

12.3.3 Reporting

Reporting is an indispensable part of all management functions and provides the key input to performance evaluation.

Technical personnel of the Urban Water Supply Service /UWSS/ shall understand the value of the records and keep the forms filled and in their routine operation activity and make the reporting process realized. Such record reports allow management to measure performance and compare actual performance with standards and targets. The results may indicate that corrective action is required to obtain conformity with the plan.

Table 25: Type and Source of Reports

No.	Type of Report	Source
1.	Daily/occasionally Technical Operation Daily Technical Maintenance Report	Scheme operator daily fills out the prepared forms and keeps in a water proof binder submits by the end of the month
2.	Monthly/occasionally Operation and performance Report Maintenance Report	Utility
3.	Annually Performance Report Maintenance Report	Utility

The utility is required to know the importance of reporting and make sure that all forms generated in the operation and maintenance activities are complete and filed as per table indicated below for the use of the different management level, when the need arises.

The filing system of these technical reports shall be made as shown in table below:

Table 26: **Technical Files folder system at the UTILITY**

No.	Name of technical file folders	Task category	Contents	Recipient
1	T-1 utility	Operation	Working hrs, Water produced, distributed, consumed, etc	Utility
2	T-1.1 Utility	Operation	Electric/ Fuel consumption, etc	Utility
3	T-2 Utility	Maintenance	Maintenance undertaken, etc	Utility

12.4 MIS-COMPUTERIZED MANAGEMENT OF INFORMATION

With the advancement of the Information Technology in this millennium, there is a need to adopt a methodology to align the information strategy with the business strategy of the organization to derive maximum benefits of computerization. A computerized system is a more sophisticated method of providing useful information in different formats to different levels within the organization for discharging duties in a more efficient way. Computers are good at rapid and accurate calculation, manipulation, storage, and retrieval but less good at unexpected or qualitative work or where genuine judgment is required. It has been suggested that computers can be used to best advantage for processing information, which has the following characteristics.

(a) Number of interacting variables.
(b) Speed is an important factor.
(c) Accuracy of the output.
(d) Operations are repetitive.
(e) Involves large amounts of data.

the operation and services of the utilities work with information of above nature, hence preparation of computer programs which enable to integrate information is required. The task can start by preparation of EXCEL supported once integrated VISUAL BASIC. Hence, Utilities and management Boards shall plan and implement MIS starting with simple once.

13 OUTSOURCING

The sector policy and strategy also encourages active participation of private sector in the operation and maintenance services and expansion of water supply service of the town.

Hence the UTILITY need to study and decide on the type of maintenance and operation works which can be handled by the utility's own force and those which can be done by external service providers.

The decision shall mainly depend on the cost benefit analysis for the utility. The UTILITY shall always plan to improve its performance to cope up with the current technological and information standards. To achieve this, the UTILITY shall practice outsourcing of required services beyond their capacity by preparing appropriate Terms of References and specifications.

14 PUBLIC AWARENESS AND CUSTOMER RELATION

14.1 Objective of Public Awareness Programme

The objective of a water supply UTILITY is to provide adequate supply of safe, good quality potable water at a reasonable cost and serve its consumers in a prompt and courteous manner. The consumers must be made to understand that potable water is not a free commodity and that it is a value-added commodity with cost implications. The quality of people's lives often depends on what the water utilities do and how they do it. The objective of any programme for public awareness is to achieve better customer relations, greater water conservation, and enhanced organizational credibility. This chapter discusses the need for public awareness with regard to water supply system maintained by local body. It also deals with the various aspects that are to be considered to improve the local public awareness by involving individually, with the voluntary organization groups or by organizing different forum groups.

The water supply strategy of the country enforces the establishment of Customer Forums. Hence each Utility shall facilitate the establishment of the forum and carry out the tasks with the scope stipulated here under in the following section.

14.2 Scope of Public Awareness Programme

Scope of a public awareness programme is:

a. To enable the public to understand the operational dynamics of the water supply system.
b. To promote civic consciousness.
c. To understand and appreciate the water distribution strategies.
d. To inculcate consumer responsibility.
e. To establish good reputation for quality/service.
f. To inform and to obtain approval of public for various improvement measures thus creating a feeling of close participation.
g. To educate them on the basic rights of consumers and efforts undertaken by water utility/local body to ensure their basic rights.

14.2.1 Process of Building up Public Awareness

It is necessary to identify the audience such as community leaders, school children, or the average customer. It is advisable to prepare the publicity material to suit the target audience. Its public communication policy shall involve the elected Civic Body, Consumer Action Groups etc. The UTILITY shall try new and imaginative ways of involving local communities in its plans and programmes thus according the public, its due pride of place.

14.2.2 Selection of Communication Methods

A variety of media and communication methods exist, each with its own advantages and disadvantages. The use of several media at the same time can reinforce the messages. Person to person contact from community members who are already convinced of the message's truth is usually the most effective means of communication. The following are some of the consumer friendly measures that could be effectively used for Public Awareness Programme for attaining complete transparency in operations.

a. Fact sheets/brochures/pamphlets/handbills/Bill boards.
b. Telephones/Telex/FAX/computer based Interactive Voice Response System (IVRS) dialing service.
c. Visual Aids-Radio/T.V./Films/Video.
d. Modern Electronic/Computer aids-E-mail.
e. Hosting a web site.
f. Slide/speech presentations.
g. Small group meetings, Conferences, Seminars, Congresses.
h. Community newsletters and oral communications, direct letter correspondences.
i. News releases, advertising.
j. Press meets and tours.
k. Participation in Exhibition, Trade Fair.
l. Open house meetings by involving Voluntary organization, Residents Association and concerned interested group.
m. In-house House journal to provide information to employees and stakeholders and tomotivate to write articles/stories/lyrics/related subject.

14.2.3 Formation of Public Relation Unit

The following services may be offered under public relations Information & Facilitation:

a. Registration and redressal of public complaints with feedback from complainant with help of reply cards, maintenance of suggestion books for customers to record their suggestions/remarks on the function of public relations counter.
b. Guidance to the public for new water connections and assistance for filling up of application form.
c. Guidance to the public for new assessment for water tax, name changes, annual value changes, classification changes and other tax and charges matters.
d. Guidance to the public to meet the concerned officer to make their representations and redressal of their grievances.
e. Information regarding disruption of water supply due to urgent repair works.

f. Supply of self-explanatory application form for the use of consumers that would help the consumer to tick and submit application with required enclosure to obtain various services such as new water connections, new assessments, name changes, annual value changes, classification changes, reconciliation of wrong demand, payment of water charges in installment, etc.
g. Supply of pamphlet on procedure on complaint registration and redressal.
h. Obtaining feedback from the consumers in redressal of their complaints/grievances.
i. Supply of Citizen's Charter to consumer to know the service standards of the organization and also assurances for adherence to such service standards.
j. Supply of pamphlet on rain water harvesting methods, procedures, and approximate estimate.
k. Creation of a single window system for redressal of grievances.
l. A separate telephone line should be available round the clock to record complaints for addressing them. It will be better if one could have three digit telephone numbers for easy remembrance.

14.2.4 Suggested Guidelines For Answering Calls

a. The staff at the telephone shall answer the call promptly say by third or fourth ring.
b. The agency's staff at the telephone shall identify himself/herself and let the caller know whom the caller is talking to.
c. The staff at the telephone shall not conduct side conversation and minimize distractions so that the caller can be given full attention avoiding repetition of names, addresses etc.
d. The staff at the telephone shall minimize transfers of the calls to other concerned officers.

14.2.5 Answering Consumer Enquiries

The staff at the telephone of the Public Relations Counter shall:

- Be familiar with the information of the services and policies of the utility.
- Learn to listen rather than interrupt the caller.
- Avoid technical jargon/unnecessary high sounding terms while talking to the caller.
- Summarise the caller's problem and repeat it to the caller for confirmation.
- Make every effort to promise specific action on the caller's complaint.

15 RECORD KEEPING AND REPORTING FORMATS

Form-1-Engine working hours and fuel/energy consumption Recording
Form-2-Daily Water Production report
Form-3-Daily water distribution report
Form-4-Monthly water production/distribution report
Form-5-Monthly summary of water consumption
Form-6-Monthly fuel/electric energy and chemicals consumption report
Form-7-Monthly technical report on O & M
Form-8-Water quality monitoring report
Form-9-Monthly performance report of the utility
Form-10 -Annual Performance Report of Utility
Form-11-Monthly financial report
Form-12-Financial report of Operation and Maintenance
Form-13-Work Request
Form-14- Work Order
Form-15-Monthly Work Order Report
Form-16-Work Request Logbook
Form-17 -Work Order Logbook
Form-18 -Maintenance logbook
Form-19-Quarterly Maintenance Report
Form-20-Annual Maintenance Report
Form-21-Request for Repair
Form -22 - Daily O& M Procedures for Submersible Pumps Run By Generator Set
Form -23- Daily O & M Procedure for Submersible Pumps Run by EEPCO Power

16 FORM-1-ENGINE WORKING HOURS AND FUEL/ENERGY CONSUMPTION RECORDING

ENGINE WORKING HOURS
AND FUEL/ENERGY CONSUMPTION
RECORDING
Location and Name/Identification/ of Engine______________________________

Month: ________________ Year: __________________ Name of Operator: ________________________

Model/made of engine____________________________ Year of installation________________________

Day	During Daylight Time			During Night Time			Day's Total Hours	Weekly fuel (1) or energy(kWh) Consumption
	Start	Stop	Hours	Start	Stop	Hours		
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
Total monthly working hours/monthly fuel consumption/Electricity								

17 FORM-2-DAILY WATER PRODUCTION REPORT

DAILY WATER PRODUCTION REPORT

Month: _______________ Year: ________________ Name of operator: ________________________

Day	Meter No.	Source No.	Production (m^3/day)	Day	Meter No.	Source No.	Production (m^3/day)
1				16			
2				17			
3				18			
4				19			
5				20			
6				21			
7				22			
8				23			
9				24			
10				25			
11				26			
12				27			
13				28			
14				29			
15				30			
Total water production (Q_p) (m^3/month)							

Checked by ______________________ Signature _____________ Date ____________

18 FORM-3-DAILY WATER DISTRIBUTION REPORT

DAILY WATER PRODUCTION REPORT

Month: _______________ Year: ________________ Name of operator: ________________________

Day	Meter No.	Reservoir No.	Distribution (m^3/day)	Day	Meter No.	Reservoir No.	Distribution (m^3/day)
1				16			
2				17			
3				18			
4				19			
5				20			
6				21			
7				22			
8				23			
9				24			
10				25			
11				26			
12				27			
13				28			
14				29			
15				30			
Total water Distribution (Q_d) (m^3/month)							

Checked by ______________________ Signature _____________ Date ____________

19 FORM-4-MONTHLY WATER PRODUCTION/DISTRIBUTION REPORT

MONTHLY WATER PRODUCTION/ DISTRIBUTION REPORT Month: _______________ Year: ________________ Name of accountant: ________________________					
Meter No.	Source No.	Production (m^3/month)	Meter No.	Reservoir No.	Distribution (m^3/month)
Total water production (Q_p) (m^3/month)			Total water distribution (Q_d) (m^3/month)		
Monthly water loss in the transmission main = $(Q_p - Q_d) / Q_p$ = Monthly water loss in the distribution = $(Q_d - Q_c) / Q_p$ = Monthly total water loss = $(Q_p - Q_c) / Q_p$ =					

Q_c – Total water consumption of the month obtained from Bill

Checked by ______________________ Signature _____________ Date ____________

20 FORM-5-MONTHLY SUMMARY OF WATER CONSUMPTION

MONTHLY SUMMARY OF WATER CONSUMPTION

Month: ________________ Year: __________________ Name of reader: ________________________

Number	Meter No.	Customer Name	Water Consumption (m^3/month)	Remark
Total (m^3/month) = Q_C				

Checked by technician ______________________ Signature _____________ Date ____________

21 FORM-6-MONTHLY FUEL/ELECTRIC ENERGY AND CHEMICALS CONSUMPTION REPORT

MONTHLY FUEL, ELECTRIC ENERGY AND CHEMCAL CONSUMPTION REPORT

Month:______________ Year:________________ Name of accountant: _________________________

Monthly fuel and electric energy consumption Total Cost of fuel ________________ Birr

Total Cost of electric power ________________Birr

Generators	Fuel consumption/month		EEPCO Meters	Electric power consumption	
No.	Liter	Birr	No.	kWh/month	Birr
Total			Total		

Monthly consumption of chemicals

Chlorine
Cost of chlorine _______ Birr/kg

Dosage Point	Kg/month	Birr	Dosage Point	Kg/month	Birr	Dosage Point	Kg/month	Birr
Total			Total			Total		

Checked by Technician ______________Signature _____________ Date ____________

22 FORM-7: MONTHLY TECHNICAL REPORT ON O&M

Month : ______________________________ , Year : __________________________

Name of Reporter : ____________________________

1) Monthly O&M Activities

S.N	List of O&M Activities	Remarks
1	Monthly Water Production (m3)	
2	Monthly distributed water (m3)	
3	Monthly consumed chemical (m3)	
4	Monthly fuel consumption (lt)	
5	Monthly Pump/Generator working time (hr)	
6	Monthly Electric Consumption (kwh)	
7	Current pump capacity (lt/sec)	
8	Number of new connections made during this month	
9	Number of customers complained on water quality	
10	Number of requests for connection during the month	
11	Monthly water supply interruption	
12	Number of customers with water meter installed	

2) Indicators for O&M

S.N	Indicators for O&M Activities	Remarks
1	Water loss	
2	Pump efficiency	
3	New connections	
4	Complain on water quality	
5	Sustainability of water supply	

Head Technical Department

Name : ______________________________________-

Signature :__________________________Date_______________________

23 FORM-8-WATER QUALITY MONITORING REPORTING FORMAT

Date sample collected: __________________	**Utility Name** __________________________
Sample Collected by:__________ ____	**Water Quality analyses conducted at** ______________________________________
Reported by: __________________	**Remarks***

SN	**Water Sampling point**	**Physical**		**Chemical**		**Bacteriological**	
		Objectionable	None 0bjectionable	Objectionable	None Objectionable	Objectionable	None Objectionable
1	Intake/ Borehole site						
2	Effluent at treatment Station						
3	Service reservoir						
4	Distribution network						
5	Customer tap						

***Remarks are evaluated against National or International water quality standards**

Discussion and Recommendation____

____

Lab Technician ______________Signature _____________ Date ____________

Checked by O&M head ______________Signature _____________ Date ____________

24 FORM-9-MONTHLY PERFORMANCE REPORT OF THE UTILITY

MONTHLY PERFORMANCE REPORT OF UTILIY Name of utiliy, _________________Woreda_____________ Month/year__________	
Type of Indicator	**Rate**
1. Personnel Indicators **1.1 Attendance** Total hours of operation personnel on duty in the month (a) Total hours of operation personnel Assigned in the month (b) **a/b**	__________ __________ __________
1.2 Over Time Total number of hours worked on overtime in the month (c) Total number of hours worked in the month (a) **c/a**	__________ __________ __________
1.3 Training Number of days spent on training in the month of all staffs (e) Total number of days on duty of all the staffs (f) **e/f**	__________ __________ __________
2. Equipment and parts Indicator **2.1 Efficiency of equipment** Equipment operating capacity (g) Equipment design capacity (h) **g/h**	__________ __________ __________
2.2 Efficiency of units Units or component production capacity (gg) Units or components design capacity (hh) **gg/hh**	__________ __________ __________
3. Unaccounted-for water Total monthly production m^3 (i) Total monthly consumption m^3 (j) **{(i-j)/(i)}x100**	__________ __________ __________
4. Level of Service Indicator **4.1 Reliability or Piped water supply continuity** Average number of hours of supply per day divided by 24	__________
4.2 Water Quality No. of customers complained on water quality/Total number of customers	
4.3 Demand Response Number of new connection made during the month (k) Number of requests for connection during the month (l) **k/l**	__________ __________ __________
5.System efficiency indicator **5.1 Total O&M Cost per volume of Sold Water** **5.2 Energy cost per Volume Sold Water**	
6. Financial Indicator **6.1 Revenue collection Efficiency** Total revenue collected (m) Total billed (n) **(m/n)x100**	__________ __________ __________
6.2 Billing efficiency Total billed (z)	__________

Total number of connections required to pay (p) **(z/p)x100**	___________ ___________
6.3 Cost-recovery and cost distribution ratio Total Operation cost in the month (q) Total maintenance cost in the month (r) Total tariff revenue plus subsidies and miscellaneous income (s) Total O&M cost (q + r) **6.4 Cost recovery ratio (s)/(q + r)** Power/fuel cost divided by O&M cost Labor cost divided by O&M cost Chemicals cost divided by O&M cost	________________ _____________ _____________ _____________ _____________ _____________ _____ ________________ _____ ________________ _____________ _____________ _____________ __________

Prepared by ___________________Position_______________signature_____________date__________
Checked by _________________signature_____________ date___________

25 FORM-10 -ANNUAL PERFORMANCE REPORT OF UTILITY

ANNUAL PERFORMANCE REPORT OF Utility Town ______________________________year__________	
Type of Indicator	**Rate**
1. Personnel Indicators **1.1 Attendance** Total hours of operation personnel on duty in the year (a) Total hours of operation personnel Assigned in the year (b) **a/b**	______ ______ ______
1.2 Over Time Total number of hours worked on overtime in the year (c) Total number of hours worked in the year (a) **c/a**	______ ______ ______
1.3 Training Number of days spent on training in the year of all staffs (e) Total number of days on duty of all the staffs in the year (f) **e/f**	______ ______ ______
2. Equipment and parts Indicator **2.1 Efficiency of pumps** Total No. of days pump malfunctioning due to break down divided by 365	______
s. Unaccounted-for water Total yearly production m^3 (i) Total yearly consumption m^3 (j) **(i-j)/(i)**	______ ______ ______
4. Level of Service Indicator **4.1 Demand Response** Number of new connection made during the year (k) Number of requests for connection during the year (l) **k/l**	______ ______ ______
s.3 Reliability or Piped water supply continuity Number of days of supply interruption in the year divided by 365	
5. Financial Indicator **5.1 Revenue collection Efficiency** Total revenue collected in the year (m) Total billed in the year(n) **(m/n)x100**	______ ______ ______
5.2 Billing efficiency Total billed in the year (z) Total number of connections required to pay (p) **(z/p)x100**	______ ______ ______
5.3 Cost-recovery and cost distribution ratio Total Operation cost in the year (q) Total maintenance cost in the year ® Total tariff revenue plus subsidies and miscellaneous income in the year(s) Total O&M cost (q + r) **Cost recovery ratio (s)/(q + r)** Power/fuel cost of the year divided by O&M cost of the year Labor cost of the year divided by O&M cost of the year Chemicals cost of the year divided by O&M cost of the year	______ ______ ______ ______ ______

Prepared by __________________Position_____________signature____________date_________

26 FORM-11-MONTHLY FINANCIAL REPORT

Monthly financial report			
	Preventive maintenance	Repair	Total
No. of work orders completed			
Total labour cost Total material cost Total other cost			
Total cost			
Average cost per work order			
COMMENTS			
Prepared by………………………..………Date……………Signature………………			

27 FORM-12-FINANCIAL REPORT OF OPERATION AND MAINTENANCE

Financial report of Operation and Maintenance

Town:.________________________________. Reporting period________________________________

	Preventive Maintenance	Corrective	Operation Cost	
No. of work orders completed			Fuel Cost	
			Electricity Cost	
Total labour cost			Chemicals Cost	
Total material cost			Personnel fee	
Total spare part cost				
Total other cost			Miscellaneous	
Total cost	(1)	(2)	(3)	
Total O & M cost (1)+(2)+(3) = (4)				
Total Revenue Collected (5)				

COMMENTS
(5) / (4) >1 Okay if < 1 Problem Examine Performance and plan for achievement
____
____

Prepared by……………………..…………Date……………Signature………………

28 FORM-13-WORK REQUEST

WORK REQUEST
Town ________________________________

Requester:...Date and time:..
Equipment/Part/Component needing attention:...
Exact location:...ID. No.:.......................................
Malfunction observed:...
Date, time, person observing:...
Expected cause of problem:...
....
Action already undertaken:...
Anticipated work to be done:... Special instructions:..
Approval by ~~WC~~………………………………………………………………..

29 FORM- 14- WORK ORDER

WORK ORDER
Work order no.: ....
Type: Repair or Preventive maintenance
Date: .... Originator: ....Priority: ....
Person to conduct work: ....
Manufacturer's manual available...........................
WR No. if RP……………..

Water scheme name and location: ....
Equipment name: ....
Exact location: ....ID No.: ....

Nature of work to be done:

Target completion date and time: ....

Work performed:

Problems/resolution:

Completion (Date and time): ....
Person performed: ....
Approval by ~~WC~~..

Labour use				Material use		Vehicle/equipm. use			
Pers.	Hrs	Rate	Cost	Requis. no.	Cost	Item	km	cost	Other cost
									Total Cost
Total				Total		Total			

30 FORM-15-MONTHLY WORK ORDER REPORT

MONTHLY WORK ORDER REPORT

	Preventive Maintenance.	Repair	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 No.	Date	Reason of delay	Expected completion

Reported by--------------------------
date……………………Signature………………………..

31 FORM-16-WORK REQUEST LOGBOOK

WORK REQUEST LOGBOOK

Work request no.	Date written	Requester	Work Location	Work description	Priority	Completion date	Total cost	File location

32 FORM- 17 -WORK ORDER LOGBOOK

WORK ORDER LOGBOOK

Work order no.	Date written	Responsibl e person	Work Location	Work description	Priority	Completion date	Total cost	File location

33 FORM-18 -MAINTENANCE LOGBOOK

S.N	Date issued	Work performed	Preventive/ corrective	Man-hours needed	Date completed	Cost

34 FORM-19-QUARTERLY MAINTENANCE REPORT

QUARTERLY MAINTENANCE REPORT

Quarter: I. II. III. IV. Year: ....
Town: .... Head: ....

Work orders in the quarter

	Preventive Maintenance	Repair	Total
No. of work orders done this quarter			
No. of work orders originated this quarter, but not completed			

Cost Analysis

	Preventive Maintenance	Corrective maintenance	Total
Total labour cost Total material cost Total other cost			
Total cost			
Average cost per work order			

35 FORM-20-ANNUAL MAINTENANCE REPORT

ANNUAL MAINTENANCE REPORT

Year: ....
Town: .... Head: ....

Work orders in the year

	Preventive Maintenance	Corrective maintenance	Total
No. of work orders done this year			
No. of work orders originate. this year			

Cost Analysis

	Preventive Maintenance	Corrective maintenance	Total
Total labour cost Total material and parts cost Total other cost			
Total cost			
Average cost per work order			

36 FORM-21-REQUEST FOR REPAIR

REQUEST FOR REPAIR
A. Description of equipment: (ID. No. ....) Manufacturer: .... Type: .... Serial number: .... Capacity: .... kW, horsepower, m^3/ h, l/s Other characteristics: .... **B. History of equipment:** Construction date: .... Installation date: .... 1. Major previous repairs (date): .... Kind: .... 2. Major previous repairs (date): .... Kind: .... 3. Major previous repairs (date): .... Kind: .... Total working hours: .... h Defect detected (date): .... Person observing defect: .... **C. Description of defect, malfunction, problem etc. observed** Expected cause of problem: .... Attempt of repair already undertaken: .... By utility mechanic/electrician name): .... Head of utility (Signature): .... Date: ....

37 FORM- 22- DAILY O& M PROCEDURES FOR SUBMERSIBLE PUMPS RUN BY GENERATOR SET

1. Before Starting of the Pump

1.1 Check engine oil, fuel, and water top up if required
1.2 Check V-belt
1.3 Check leakages of fuel, oil and water

2. After starting of the Generator Set

2.1 Let the engine warm up for about 3 minutes
2.2 Put on the main switch
2.3 Check the voltage of all three phases between neutral and phases
2.4 Start the pump
2.5 Watch the 3 ampere meters
2.6 Monitor the pressure gauge, make sure pressure is not below normal pressure
2.8 Close the pressure gauge tap so that the needle stays at 0 bar
2.9 Check the exhaust gas color (it has to be clear)

3. Before stopping the generator

3.1 Stop the pump
3.2 Switch off the main switch
3.3 Let the engine run without load for about 1 minute then stop it

4. After stopping the Gen. Set.

4.1 Fill the daily reports
4.2 Fill the fuel tank
4.3 Clean the generator Set
4.4 Clean the adjacent area

38 FORM – 23- DAILY O & M PROCEDURE FOR SUBMERSIBLE PUMPS RUN BY EEPCO POWER

1. Before starting of the pump

1.1 Put on the main switch
1.2 Check the voltage of all three phases between neutral and phases
1.3 Start the pump

2. After starting the pump

2.1 Watch the 3 ampere meters
2.2 Monitor the pressure gauge, make sure pressure is not below normal pressure
2.3 Close the pressure gauge tap so that the needle stays at O bar

3. End of Operations

3.1 Stop the pump
3.2 Switch off the main switch
3.3 Fill the daily reports
3.4 Clean the area