

# CHAPTER 1

## INTRODUCTION

### 1.1 SECTOR ORGANIZATION

Water supply and sanitation is treated as a State subject as per the federal Constitution of India and, therefore, the States are vested with the constitutional right on the planning, implementation and cost recovery of water supply and sanitation projects. At the local level, the responsibility is entrusted by legislation to the local bodies like Municipal Corporation, Municipality, Municipal Council, Notified Area Committee/Authority for towns or on a State/Regional basis to specialized agencies. The economic and social programme of the country is formulated through five-year plans.

The Public Health Engineering Department (PHED) is the principal agency at the State level for planning and implementation of water supply and sanitation programmes. In a number of States, statutory Water Supply & Sanitation Boards (WSSBs) have taken over the functions of the PHEDs. The basic objectives for creation of WSSBs have been to bring in the concept of commercialization in the water supply and sanitation sector management and more accountability. Such Boards have been set up in Assam, Bihar, Gujarat, Karnataka, Kerala, Maharashtra, Orissa, Punjab, Uttar Pradesh and Tamil Nadu. The metropolitan cities of Bangalore, Hyderabad and Chennai have separate statutory Boards. The water supply and sanitation services in the cities of Mumbai, Kolkata, Delhi, Ahmedabad, Pune and few other towns are under the Municipal Corporations.

The Ministry of Urban Development & Poverty Alleviation, Government of India formulates policy guidelines in respect of Urban Water Supply & Sanitation Sector and provides technical assistance to the States & Urban Local Bodies (ULBs) wherever needed. The expenditure on water supply and sanitation is met out of block loans and grants disbursed as Plan assistance to the States, and out of loans from financial institutions like Life Insurance Corporation (LIC) and Housing and Urban Development Corporation (HUDCO). The Central Government acts as an intermediary in mobilizing external assistance in the water supply and sanitation sector and routes the assistance via the State plans. It also provides direct grant assistance to some extent for water supply and sanitation programmes in urban areas.

A modest beginning has been made to provide central assistance for provision of safe drinking water supply facilities in towns having population less than 20,000 (as per 1991 census) in the country. Accordingly, a Centrally Sponsored Accelerated Urban Water Supply Programme (AUWSP) has been launched in the country during 1993-94. Under this programme, 50% of the cost is provided by Government of India as grant, 45% by the respective Provincial Government as grant and the balance 5% is mobilized through beneficiary contribution.

The role of the Statutory Bodies (SBs) is by and large confined in some States to mostly construction activities only, while in States like Kerala, Karnataka & Maharashtra the State level body looks after operation, maintenance and cost recovery also. After commissioning of schemes, the SBs usually hand over the projects to the ULBs for Operation & Maintenance, or perform this function also on their behalf. Thus, the pattern varies across different States.

The responsibility of operation, maintenance and revenue collection is generally vested with the elected urban local body. However, in some cases, the specialized agencies such as the State Public Health Engineering Departments, Water Boards etc. are in charge of these functions and formulate the water tariff and implement the same with the approval of the Governments. For instance, in Rajasthan right from planning up to O&M of Water Supply & Sewerage Schemes is being carried out by the State PHED. The local bodies generally receive some grant assistance for capital works on water supply and sanitation from the State Government.

The State Water Supply & Sewerage Boards do not have much autonomy in setting tariffs and generating revenues for O&M. Since the State Governments have the power to issue directives to the Boards, it is apparent that tariff revisions still require prior consent of the respective State Government and in essence rests with the State Governments.

## **1.2 OPERATION & MAINTENANCE SCENARIO**

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 rupees, they are unable to provide the services effectively to the community for which they have been constructed, as they remain defunct or under utilized 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.

Therefore, there is a need for clear-cut sector policies and legal framework and a clear demarcation of responsibilities and mandates within the water supply sub-sector.

From the Indian experience, it has been observed that in the case of pumping schemes, by and large, about 20 to 40% of the total annual Operation & Maintenance cost goes towards

the personnel (Operation & Maintenance Staff), 30 to 50% of the cost is incurred on power charges and the balance is utilized for consumables, repairs and replacement of parts and machinery and miscellaneous charges. In most of the cities in India, the tariffs are so low that they do not even cover the annual Operation & Maintenance cost.

Measures such as control of Unaccounted for Water (UFW) and metering of the water connections, as detailed below may help reduce the wastage of water and increase the revenue to the local body to the maximum extent.

### **1.2.1 UNACCOUNTED FOR WATER (UFW)**

Several pilot studies conducted in the country have shown water losses in the distribution systems to be of the order of 20 to 50% of the total flow in the systems. It has been noticed that maximum leakage (more than 80%) occurs in the distribution system and house service connections. In addition, losses do occur at the source, transmission system, treatment plant and service reservoirs, which may add up to another 10 to 20% of the total output. In India, where water supply is, by and large, intermittent (supply hours ranging from 3 to 10 hours), the external pollution may get sucked into the system through points of leak, during non-supply hours when the system is not under pressure, causing health hazards. Therefore, a systematic approach towards wastage, leakage and preventive maintenance should form an integral part of Operation & Maintenance on a regular basis to save considerable quantity of water, prevent possible contamination, improve pressures in the distribution system and increase revenues to make the systems self-sufficient. If such measures are taken up by the water supply agencies in the country, there may not be any immediate need to take up augmentation schemes. Another important aspect is non-availability of indigenous good quality and precise electronic leak detection equipment for usage in the leak detection exercise.

### **1.2.2 METERING OF WATER SUPPLY SYSTEMS**

There are no two opinions that metering of water supply is desirable to minimize wastage and to maintain economic pricing of water. Though most of the major towns have been provided with domestic and bulk water meters, over the years it has been observed that 20 to 50% of the installed meters remain defunct due to their poor quality. Sometimes tampering of the meters by the owners has also been noticed. Moreover, the infrastructure and repair facilities for water meters are not adequate in most of the Urban Local Bodies and Water Supply Boards, which delay their repairs and early reinstallation. In the absence of working meters, billing for water consumed is often estimated, either on average basis or on flat rate, as the case may be. Though a few companies have been manufacturing water meters for domestic use, it is necessary to get domestic and bulk water meters of the desired quality and precision manufactured within the country through technology transfer from developed countries for Indian market. As per the prevailing practice, the consumers own the domestic meters. As such, they have direct access to the meters. However, it is perhaps worthwhile to explore the possibility of owning such meters by the respective water supply agencies and local bodies themselves to ensure that the consumers do not have direct access to the meters so as to avoid possible tampering of the meters.

### **1.3 NEED FOR MODIFICATION IN POLICY FRAMEWORK FOR EFFECTIVE OPERATION AND MAINTENANCE**

In the light of the 74th Amendment to the Constitution, the role and responsibilities of Urban Local Bodies have increased significantly to provide the basic facilities of water supply and sanitation to the community on a sustainable basis. The said amendment has enabled the Urban Local Bodies to become financially and technically sound to provide these basic civic amenities to the community. Though certain degree of cross-subsidy is inevitable in respect of the economically weaker sections of the society, it is very necessary to run the water supply systems on commercial principles due to the fact that water is an economic good and as such it should no longer be considered as a free commodity. Therefore, imposition of realistic tariffs for various beneficiaries and its effective realization is the key to the success of water supply sector performance including that of operation and maintenance. Of late, it has also been observed that even the poor are willing to contribute some percentage of the user charges for such facilities, provided reliable service is ensured by the water supply authorities and Urban Local Bodies.

Apart from providing minimum required quantity of drinking water to the people, the operation and maintenance authorities should always bear in mind that its quality is maintained at all times to safeguard the health of the community. City level consumer forums may be set up to keep a vigil on the water sources to prevent possible contamination and make periodical reporting to the operation and maintenance agencies for appropriate action well in advance. At the same time, awareness programmes on water conservation, wastage prevention, water quality, personal hygiene etc. may have to be designed and implemented with the help of NGOs, Residential Welfare Associations and neighborhood committees.

Consumer satisfaction should be the topmost priority of the operation and maintenance agencies. Complaint/suggestion cells may be set up by the operation and maintenance agencies to enable the consumers to lodge complaints on aspects such as leakage and wastage of water, low pressure at consumer's end, contamination/poor quality of water, pilferage of system components, malfunctioning of water meters, problems related to meter reading, payment of bills, etc. and suggestions, if any, for better performance of the system. At the same time, all such complaints received by the operation and maintenance agencies should be attended to within a reasonable time frame, so as to win the confidence of the consumers.

#### **1.3.1 PUBLIC PRIVATE PARTICIPATION**

Though privatization of water supply and sanitation sector could not make significant progress as of now, there is substantial potential available in the country for privatization and hence there is an urgent need for the same. Perhaps, it could be introduced in phases, either on Build, Operate and Own (BOO) or Build, Operate, Own and Transfer (BOOT) basis. Primarily, it is possible in two ways i.e. privatization of the existing water supply systems and secondly, privatization of systems in newly developed townships, housing colonies, business and commercial complexes, etc. There are some inherent problems due to which privatization could not be introduced in the existing water supply systems. For

instance, many local bodies and water supply departments, which are responsible at the local level for the operation and maintenance of such systems, are unable to recover even the operation and maintenance cost from the beneficiaries. By and large, the tariff rates being charged from the consumers are very low and there is a general reluctance for enhancing the same. Under the circumstances, without aiming at full cost recovery, privatization cannot be a successful proposition.

#### **1.4 NECESSITY FOR AN O&M MANUAL**

The Manual on Operation and Maintenance is a long felt need of the sector. At present, there is no Technical Manual on this subject to benefit the field personnel and to help the O&M authorities to prepare their own specific manuals suitable to their organizations. The Chief Engineer's Conferences held in previous occasions including that held at Chandigarh, in November 1998 had also emphasized the need and requested the Ministry of Urban Development & Poverty Alleviation to take initiative to prepare the said Manual. Realizing the need, the Ministry has decided to prepare the said Manual and make it available to the field agencies.

#### **1.5 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.

In engineering parlance, operation refers to timely and daily operation of the components of a Water Supply system such as headworks, treatment plant, machinery and equipment, conveying mains, service reservoirs and distribution system etc. effectively by various technical personnel, which is a routine function. The term maintenance is defined as the art of keeping the structures, plants, machinery and equipment and other facilities in an optimum working order. Maintenance includes preventive maintenance or corrective maintenance, mechanical adjustments, repairs, corrective action and planned maintenance. However, replacements, correction of defects etc. are considered as actions excluded from preventive maintenance.

The O&M Manual is required to encompass various issues pertaining to an effective O&M such as technical, managerial, administrative, HRD, financial & social aspects etc.

##### **1.5.1 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.

##### **1.5.2 WHO WILL USE THE MANUAL**

This manual is intended primarily for the managers and technicians in-charge of the operation and maintenance of the urban drinking water supply systems.

### **1.5.3 HOW TO USE THE MANUAL AND LIMITATIONS OF THE MANUAL**

The procedures mentioned in the manual are intended to be guidelines for ensuring effective O&M of the water supply systems. This manual is not exhaustive but will serve as a reference volume for the agencies incharge of the water supply systems to develop their O&M programmes to suit their specific problems depending on the size of the system, type of agency and location of the water supply system. This manual should be used as a supplement and not to replace existing manuals which describe procedures and techniques for O&M. Any agency desirous of formulating O&M programmes should do so only on the basis of an exhaustive assessment of their existing water supply systems.

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## CHAPTER 2

# STRATEGY

### 2.1 INTRODUCTION

The large investments made to construct utilities intended to provide facilities for water supply are becoming unproductive in the sense that the objective for which they have been installed is not achieved mainly on account of poor Maintenance. Often the investments become unproductive, and a larger amount of money is required to replace and rebuild the system components. Interruptions in service occur owing to the breakdown of equipment as a result of poor maintenance. The utility control organisations are not able to ensure that the maintenance staff follow valid practices to achieve proper maintenance. The management of water supply systems in the water authorities is receiving relatively lower priority. Lack of funds coupled with lack of enthusiasm among the operation and maintenance staff to keep schemes in working condition; lack of training, lack of motivation among the staff may be reasons for the present status of the water supply systems.

### 2.2 DEFINITION OF OPERATION AND MAINTENANCE

In an engineering sense, operation refers to hourly and daily operations of the components of a system such as plant, machinery and equipment (valves etc.) which is done by an operator or his assistant. 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. Maintenance includes preventive maintenance or corrective maintenance, mechanical adjustments, repairs and corrective action and planned maintenance. Often repairs, replacements and corrections of defects (of material or workmanship) are considered as actions excluded from preventive maintenance. In some organisations the normal actions taken by operation staff are considered as maintenance activities whereas a separate unit or cell does repairs and replacements. Often both corrective and preventive maintenance are included in the job functions of operators and limits to which operators are expected to do normal maintenance are set forth for various equipment. Budgetary provisions of operation and maintenance organisations also incorporate heads of expenditure under maintenance for cost of spare parts and cost of labour or contract amount for repairs and replacements.

### 2.3 STRATEGY FOR GOOD OPERATION AND MAINTENANCE

#### 2.3.1 INTRODUCTION

The minimum requirements for good operation and maintenance are:

- (a) Preparation of a plan for operation and maintenance.
- (b) Providing required personnel to operate and maintain.
- (c) Providing Capacity building programmes for the O&M personnel
- (d) Availability of spares and tools for ensuring maintenance.
- (e) Preparation of GIS based maps of the system
- (f) Preparation of a water audit and leakage control plan
- (g) Maintaining MIS records on the system including history of equipment, costs, life etc.
- (h) Action Plan for energy audit for saving on energy
- (i) Establishing a sound financial management system.

### **2.3.2 PREPARATION OF A PLAN**

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 organisation 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 staff 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. Check lists for various units of O&M of water supply and treatment are listed in the respective chapters.



### **2.3.3 MANAGEMENT REORIENTATION**

The management shall become service oriented and be prepared to run the organisations on a commercial basis. The management must be able to motivate the staff to perform better. It is essential that the organisation responsible for O&M is well qualified, experienced, efficient and still economical. Management is obliged to maintain the facilities in a reasonably good manner and hence they shall decide to produce a maintenance programme. Relevant persons with aptitudes must be chosen to work with available facilities. The persons should be trained to carry out the actions.

They should be supervised to ensure that all people do their duties. Spares and tools should be made available when needed. A good record system covering all equipment facilities and units should be established. The funds necessary to carry out the programme should be provided.

While in most of the cities, a large work force has been already created over a number of years and is being used for O&M of the systems, the suitability of skills and experience has not necessarily been tested. At the same time a radical change in the set up is also not possible in a short period. The strategy is therefore to define the optimum organisation required for O&M and work towards achievement of that, whenever there is opportunity available, to re-organise.

### **2.3.4 CATEGORIES**

The O&M function is performed by

- (a) operating staff and
- (b) supervisory staff.

While the former actually run the system, the latter monitor the operations and provide managerial support. It is difficult to propose a rigid organisational structure model for use at all places. It is likely to vary from place to place due to factors like site-specific requirements, availability of suitable manpower and age-old practices.

### **2.3.5 JOB DESCRIPTION**

When the plan or programme containing procedures to be adopted or actions to be taken is prepared for each piece of equipment, the person to carry out this action is to be identified. This person's job description should contain reference to the maintenance plan/programme. The job description of operating personnel shall clearly define the limits up to which these personnel can carry out normal maintenance. The job description of the Supervisor/Manager shall include the requirement that they shall ensure that the operating personnel conform to these limits and thus ensure the safety of the equipment.

### **2.3.6 TRAINING**

The personnel who are already available or chosen to carry out the actions contained in the programme may have to be trained through special courses or by "on the job training" to ensure that these personnel are thoroughly trained to carry out the actions listed in the plan of maintenance. This training is essential to prevent experimentation by operating personnel to meddle with equipment since often these operating personnel may not be capable to take

up the required maintenance. On the job training is preferred to class room training. The supervisors can be trained initially and they can later train their operators.

### **2.3.7 PRIVATIZATION**

Privatization of some or all functions of Operation and Maintenance can be considered to achieve (i) efficiency (ii) economy (iii) professionalism and (iv) financial viability of the system. In order to achieve the above stated objectives, the private entrepreneur needs to possess (i) adequately trained, qualified manpower for operation and supervision of the services (ii) infrastructure like equipment, material, testing and repairing facilities (iii) experience in operating similar systems (iv) financial soundness (v) capacity to meet the emergency situations.

### **2.3.8 COMPONENTS SUITABLE FOR PRIVATIZATION**

Based on the above requirements and the limited experience of a few organisations, the possibility of involvement of private agencies in O&M of entire or part of water treatment plants, pumping stations, distribution system and other components is analysed and indicated below.

### **2.3.9 STRATEGY FOR PRIVATIZATION**

There is a need to have alternative institutional mechanism for O&M of water supply utilities. In this regard, introduction of private agencies in O&M may be desirable to achieve efficiency and economy. It may make the existing O&M staff surplus. In most of the places operating staff has been appointed on a large scale in the permanent establishment and their removal or discontinuation of sanctioned posts will be a major hurdle in the effort of privatization. However when new systems are set up, it is possible to introduce some element of privatization. Suitable private agencies may develop in course of time, if they feel that they will work for a reasonably long period and if their fee is remunerative. Petty or minor repair and maintenance jobs can be let out on an annual contract basis. However the agency responsible for O&M should have a close control on the performance of private agencies and its own organisation. This calls for a set up somewhat similar to the one suggested below:

- i) Supervisory organisation of engineers, accountants, managers belonging to the O&M agency.
- ii) Day to day operation and maintenance of units like treatment plant, pumping stations and large transmissions with private agencies.
- iii) Day to day operation and maintenance of transmission mains and distribution system with private agency.
- iv) Repairs with private agencies: such as meter repairs, upkeep of chlorinators, chemical dosers, and instrumentation repair, maintenance and calibration.
- v) Supply of chemicals and spares to be arranged by O&M agency.
- vi) Payment of energy charges, raw water charges, telephone bills etc. to be made by O&M agency directly.
- vii) The organisation itself can decide to hand over to private agencies such duties which cannot be discharged by it economically/efficiently.

### **2.3.10 ROLE OF VOLUNTARY / NON GOVERNMENTAL ORGANISATIONS (NGOS)**

The role of Voluntary/NGOs can be important especially in the creation of public awareness on matters like water conservation, proper use of water by people and the need to pay price of water at affordable level. Water users' committees can be formed by active involvement of NGOs to periodically review the local problems, advise the agencies on improvements needed and future course of planning, upkeep of utilities within their jurisdiction, encourage the people to remit water charges regularly and encourage hygienic habits.

#### **2.3.10.1 Information Education Communication (IEC)**

The utility organisation can prepare Information-Education-Communication material and use the services of Voluntary organisation/NGOs in disseminating the information among the consumers and create awareness among the public

### **2.3.11 AVAILABILITY OF TOOLS & PLANTS AND SPARES**

The availability of spare parts for repairs and replacements is to be ensured by ordering and delivery of spare parts by organising an inventory system. Efficient management of stores is required to ensure that the required spare parts are available at all times. The list of spare parts to be procured can be drafted on the basis of manufacturers recommendations in the absence of which a list of spare parts can be prepared from the records of spare parts actually used in the previous years.

A good starting part is to start with the maintenance program and list item wise likely spares to be ordered for repairs and replacements. Spare parts which are difficult to be procured i.e. delivery times are longer shall be identified and the list of spares shall contain as to when these are to be ordered. Managers will have to review the list and take advance actions to ensure that spare parts are on hand when they are needed. Alternatively the required spares for five year periods are procured at the time the equipment is initially installed. The next important task is to ensure the availability of tools necessary to properly repair and correct both the routine problems and for facilitating repairs and replacements. Hence a list of tools and plants has to be prepared, again starting from the plan of maintenance for each unit and the final list of tools and plants is prepared to cover repairs of all the pieces of equipment. It will be also necessary to arrange for routine maintenance of tools and plants, for ensuring that they are in a fit state to be used when repairs and replacements are taken up.

A well organised stores unit shall be available, and accessible at all times to the operation and maintenance staff from which all required spare parts, tools etc., to enable the operation and maintenance staff to carry out the servicing, repairs or replacement, contained in the maintenance plan.

### **2.3.12 MAINTENANCE OF RECORDS**

The necessity for good maintenance records is often overlooked. The maintenance plan programme contains as to what should be done and when. But to decide as to how long an equipment is to be allowed to be kept in service requires information as to when it was installed, what is its normal life etc. Budgets for operation and maintenance can be prepared only on the basis of records of previous years maintenance. The managers shall realise that most of the 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 specialised services for important equipment.

Good record system shall include the following minimum information to ensure the required maintenance.

1. Name of equipment and location of equipment
2. Number available or installed
3. Serial number
4. Type and class
5. Date of procurement/installation
6. Cost of procurement and installation
7. Name of manufacturer with address and telephone No.
8. Name of distributor/dealer if purchased through them with address and telephone number.
9. Name of servicing firm with address and telephone number.
10. Service manuals
11. Descriptive technical pamphlets
12. Major overhauls: Details of date, nature of cost
13. When next overhaul is due.
14. Date, type and cost of repairs and replacement
15. Cost of spares and cost of labour for repairs.

### **2.3.13 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 break up 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%.

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.

## **2.4 SUGGESTED STRATEGY**

This manual sets forth guidelines for maintenance programmes for most installations. This manual can be adopted as basis for the preparation of operation and maintenance programme.

### **2.4.1 ORGANISATION**

The organisation shall have sufficient autonomy with some checks and counter checks. Further the organisation shall be given the freedom to redeploy if not reduce the surplus personnel. Before attempting to reform the organisation, the managers shall be provided training. The managerial staff have to be trained in the management aspects so as to enable them to render customer oriented service. The need to manage the organisation to ensure financial viability shall be also taught to them. The need to have a performance evaluation to identify accountability for lapses and rewards for improved performance is to be highlighted. Training to managers shall also include financial, accounting, computer applications for efficient use of management information systems, apart from improved technologies.

### **2.4.2 OPERATION AND MAINTENANCE PLAN**

A comprehensive operation and maintenance plan shall be prepared to cover all the facilities. This plan shall contain what actions are to be taken, when these activities are to be taken, how these actions are to be taken and why these actions are required. Good house keeping is required to ensure that all equipment, buildings, surrounding areas and facilities are kept clean and orderly and shall look that it is being frequently cleaned and attended to. A central operation and maintenance cell shall be created which will have responsibility for supervision, monitoring and analysing all operation maintenance activities contained in the operation and maintenance plan. Supervisors shall be assigned duties to check the operation and maintenance by adopting check lists prepared by the management with reference to the plan. Officers shall be identified for monitoring whether the operation maintenance plans are followed or whether supervision of the plan is being done. The supervisor's check lists, checked by monitoring officers shall be analysed by the top management to locate persistent deficiencies and initiate corrective action. The first line supervisors shall be rewarded for timely identifying deficiencies in O&M.

### **2.4.3 TRAINING**

A job description shall be prepared for each operator, which shall contain detailed instructions as to how he will carry out the actions required of him in the operation and maintenance plan. The training shall evolve a personnel management policy, which will provide for a job training followed by performance evaluations and promotions. The supervisors shall be

trained to train the operators. Every operator who is assigned a job in the operation and maintenance plan/programme shall be given appropriate (on the job) training on how to perform the actions assigned to him. Inducements can be offered by way of incentives to those who have improved their performance by training.

#### **2.4.4 EVALUATION**

The success of operation and maintenance programme is shown by a decline of frequency of prearranged shutdowns, and emergency repairs. Improved O&M may result in increased availability of water to be sold, hence yielding more revenue and may also obviate the need to revise the tariffs. Further, the cost of repairs may also decline and equipment life may increase by the proper implementation of a maintenance program. However, funds required for upkeep and maintenance of the system components should be provided for, without which any strategy is bound to fail.

#### **2.4.5 RECORDS AND REPORTS**

A record and report system shall be enforced to list all basic data of each piece of equipment and the history of the equipment. A separate wing may be created to update information on the maps, and coordinate with local Municipal authorities, Urban Development authorities, Housing Boards, Industries, Infrastructure Corporations, Electricity Boards and Telecom Departments. A reporting system shall be provided for the operator to inform the supervisor/manager the problems of each equipment requiring the attention of repair and replacement crew or other specialised service personnel.

### **2.5 LIMITATIONS OF O&M STRATEGY**

#### **2.5.1 TYPE AND SCALE OF ORGANISATION**

Financial sustainability may not be feasible for the utility/organisation which is found to be overstaffed. Actions may have to be initiated to redeploy or reduce the excess staff.

#### **2.5.2 RECORDS**

Though an awareness can be created among the managers of water supply system about the importance of good maintenance, it will not be easy to initiate action in writing down the maintenance procedures. The foremost reason for such situation is the lack of reliable records, in the absence of which one may be forced to take decisions purely on guess work instead of taking decisions on the basis of reliable records.

#### **2.5.3 INADEQUACY OF FUNDS**

Inadequate investments in O&M is a common feature in several organisations which may say that there are no funds for maintenance of facilities or training of staff. Often, they may say that budgets meant for such items as procurement of spare parts or for painting to prevent corrosion or for training have been diverted to other works, on the premise that these works are not important. However lack of funds may not be a valid reason for routine maintenance, house keeping or minor adjustments etc., which can be attended to by the operation and maintenance staff even in the absence of funds. Maintenance of infrastructure is required to enhance the revenues which also requires budgetary provisions.

#### **2.5.4 METERING POLICY**

In most of the utilities the supply is intermittent and often this is cited as a reason for non working of meters. Correct selection of meters and good practice of fixing meters may obviate this. Meters are owned by consumers in several utilities and hence are not repaired promptly. Often there may be no bulk-flow meters available to provide data for evolving a policy regarding metering. Attention to metering may be initially required in high/bulk consumption areas. Several organisations may be having a metering policy regarding ownership and provision of bulk meters. A review of the metering policy may be required to ensure financial sustainability of the organisation.

#### **2.5.5 REMOTE LOCATION**

The facilities may be located at inaccessible places and it may take more time for qualified personnel to reach such places for attending to repairs or replacements.

#### **2.5.6 AGE OF EQUIPMENT**

In several installations the equipment might have outlived its life or out of previous neglect or misuse might have deteriorated up to a stage at which replacement of the equipment is absolutely necessary.

#### **2.5.7 TRAINED PERSONNEL**

The water works utilities are so diversified that simple training methods cannot be prescribed for general application. Sometimes it is difficult to find, in the utilities, well motivated personnel and the available staff may not be amenable for training. The availability of trained personnel who possess the knowledge to undertake the maintenance of complicated equipment may also become a limitation. Often those engineers who are accustomed to dealing with the equipment might have been transferred, making it difficult to maintain the continuity.

#### **2.5.8 STRENGTH OF ORGANISATION**

Some of the limitations, in trying any new strategy are organisations which are not ready to change its management attitude to run the water utility on financially viable lines, lack of motivation on the part of the staff etc.

### **2.6 IMPROVING O&M**

#### **2.6.1 ASSESSING THE STATUS OF O&M**

The status of O&M of any existing system can be assessed through a deficiency analysis after which the improvements can be planned. A possible line of action is indicated below:

#### **2.6.2 INSTITUTIONAL STUDY**

An institutional study is done wherein the parameters for operating and maintaining the facilities are fixed and the job requirements of various O&M personnel are identified along with their qualifications and or experience. The study should also explore possibility of providing on the job training to make up for the lack of qualifications and experience to discharge the job requirements. A realistic assessment of staff required is made and surplus

personnel if any are identified. In case of deficit of staff, the possibility shall be examined for entrusting some of the O&M activities to outside agencies on contract basis.

### **2.6.3 TRAINING REQUIREMENTS**

As a result of the institutional study it would be possible to list out the training requirements of individual personnel. Prepare a programme of training with time bound targets. Identify the facility to train and prepare training material. Implement the training programme. Assess the performance of O&M staff after training. Change or update the training programme to suit the situation as per the assessment.

### **2.6.4 MANAGEMENT INFORMATION SYSTEM (MIS)**

Quite often there is an acute dearth of information on material inventories, tools, spares, staffing pattern, costs etc. Hence setting up a Management Information System is one of the most important tasks in the institutional development which could lead to sustainable O&M. The authority must decide what information is important, who is to keep the record, periodicity of reporting system and formats of reporting. MIS is used to analyse and evaluate the performance of system. The MIS could also be used in assigning responsibilities and in distribution of human, material and financial resources to ensure sustainable O&M.

### **2.6.5 WATER AUDIT**

There are considerable losses in the water produced and distributed which leads to reduction in the income of the utility. Some of these losses are physical leakage of water and some are revenue losses. Hence a water audit will be required to be done to get fairly accurate figures of the following - Water production, Water assessed, Losses both Physical and revenue. Water audit could lead to prioritizing actions required to reduce the physical and revenue losses.

### **2.6.6 ENERGY AUDIT**

Power charges are likely to be as high as 30 to 50% of the total O&M cost. Hence an efficient use of power and reducing wastage of power will go a long way in efficient functioning of the utility. This could be achieved by a systematic energy audit which can identify the possible means to save energy and reduce power consumption.

### **2.6.7 PLANNING FOR EMERGENCIES**

It is possible that normal water supply may be disrupted due to any event, natural or man-made. Such disruptions occur suddenly leaving no time for planning to meet such contingencies. It is therefore essential that an advance plan be prepared to meet such exigencies. Past experience of emergencies in the system as well as of other systems is very useful in drawing up an emergency plan. Some of the events or emergencies that may arise are: power failure, storms and flooding, fire, earthquakes, explosions, breakdown of water supply system units like pumps and pumping mains, strikes by workmen, sabotage or vandalism and water supply bio-terrorism.

### **2.6.8 SAFETY IN O&M OPERATIONS**

Operations in O&M of a Water Supply System also may result in accidents. Hence there is a need for safety practices to be followed by the O&M personnel. Adoption of safe practices



and use of safety equipment may largely minimize accidents. Many accidents occur due to the human factor. Though the ultimate responsibility may be that of management, the operator cannot also be relieved of his responsibility. Hence a Safety Programme is to be written down for every organisation and it must be ensured that every one in the organisation scrupulously follows the safety practices.

### **2.6.9 PLUMBING PRACTICES**

In most Water Supply System, the leakages are occurring in consumer connections. This is mainly attributed to poor plumbing practices. The water supply regulations shall provide for a correct practice of giving connections and fixing meters, which shall be strictly enforced.

### **2.6.10 IMPROVEMENTS IN WATER QUALITY CONTROL**

At several places though the water treatment plants are equipped with good water testing laboratories, the required water quality control by testing is not followed or achieved. This has to be ensured.

### **2.6.11 COST RECOVERY**

For any water utility to be financially self sustained the tariffs should be reasonably fixed and water charges levied and collected and accounted as accurately as possible. The cost of production of water shall be worked out inclusive of debt servicing and expenditure incurred for O&M shall be reviewed. Reasonable tariffs shall be provided to ensure for full cost recovery.

### **2.6.12 ROLE OF PUBLIC PRIVATE PARTNERSHIP**

Improving the efficiency of O&M depends to a great extent on the proper functioning of instrumentation in alum coagulation, chlorination. However it is not always possible to find and employ personnel with specialized skills for the maintenance of flow meters, other instrumentation in water treatment plants and pumping installations, chlorination plants and alum dosers. Instead of trying to recruit additional staff for repairs and maintenance of these specialized equipment, it is always a better alternative to obtain on contract, the specialized services for maintenance of the above mentioned equipment. Such a practice may ensure proper functioning of the equipment with least cost.

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## CHAPTER 3

# SOURCES OF WATER SUPPLY

### 3.1 OBJECTIVE

The objectives of operation and maintenance of sources of water supply schemes are:

1. The water sources should be able to supply water which is safe to drink after treatment.
2. The water sources should be perennial and should ensure sustainable yield.
3. The quality of water should not be allowed to deteriorate.
4. There should be least or no disruption in water supply systems due to depletion of water sources.
5. There should be least possible expenditure on the repair and maintenance of the water sources.
6. Proper record of the water sources should be maintained so that their time to time performance could be known.
7. 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.
8. 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.

### 3.2 SOURCES

#### 3.2.1 NATURAL SOURCES

Rain, snow, hail and sleet are precipitated upon the surface of the earth as meteorological water and may be considered as the original source of all the water supplied. Water, as source of drinking water, occurs as surface water and ground water. Three aspects should be considered in appraising water resources e.g., the quantity, the quality, and the reliability of available water.

#### 3.2.2 SURFACE WATER

Surface water accumulates mainly as a result of direct runoff from precipitation (rain or snow). Precipitation that does not enter the ground through infiltration or is not returned to the atmosphere by evaporation, flows over the ground surface and is classified as direct runoff. Direct runoff is water that drains from saturated or impermeable surfaces, into stream

channels, and then into natural or artificial storage sites (or into the ocean in coastal areas).

The amount of available surface water depends largely upon rainfall. When rainfall is limited, the supply of surface water will vary considerably between wet and dry years.

Surface water supplies may be further divided into river, lake, and reservoir supplies. Dams are constructed to create artificial storage. Canals or open channels can be constructed to convey surface water to the project sites. The water is also conveyed through pipes by gravity or pumping.

In general, the surface sources are characterized by soft water, turbidity, suspended solids, some colour and microbial contamination.

### **3.2.3 GROUND WATER**

Part of the precipitation that falls infiltrates the soil. This water replenishes the soil moisture, or is used by growing plants and returned to the atmosphere by transpiration. Water that drains downward (percolates) below the root zone finally reaches a level at which all the openings or voids in the earth's materials are filled with water. This zone is called the zone of saturation. The water in the zone of saturation is called the ground water.

Ground waters are, generally, characterized by higher concentrations of dissolved solids, lower levels of colour, higher hardness (as compared with surface water), dissolved gasses and freedom from microbial contamination.

A well that penetrates the water table can be used to extract water from the ground basin. The extraction of ground water is mainly by:

1. Dug well with or without steining walls
2. Dug cum bore wells
3. Cavity Bore
4. Radial collector wells
5. Infiltration galleries
6. Tubewells & bore wells.

Ground water that flows naturally from the ground is called a Spring.

## **3.3 SURFACE WATER MANAGEMENT AND MAJOR SOURCES OF POLLUTION**

### **3.3.1 USE OF SURFACE RESERVOIRS**

Methods of managing lakes and reservoirs used for domestic supplies vary widely depending on local conditions. In addition to serving domestic water needs, a reservoir may be used for flood control purposes, for hydroelectric power generation, for regulating releases, for recreational purposes or for providing water for agricultural, municipal and industrial uses. The amount and type of public use allowed on reservoirs also varies according to individual situations.

The methods of treating water depend upon raw water quality and range from disinfection only to complete treatment.

### **3.3.2 FACTORS AFFECTING WATER QUALITY**

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.

### **3.3.3 CAUSES OF WATER QUALITY PROBLEMS**

#### **3.3.3.1 Nutrients**

1 Moderate or large quantities of nutrients such as phosphates, nitrates and organic nitrogen compounds may act as a fertilizer in a reservoir to stimulate the growth of algae which may cause algal bloom.

The problems related to algal blooms are:

- i) Taste, odour and colour,
- ii) Increased pH
- iii) Shortened filter runs of treatment plants,
- iv) Dissolved Oxygen variation,
- v) Organic loading.

#### **3.3.3.2 Thermal Stratification**

Thermal stratification develops in lakes and reservoirs when the surface water begins to warm. The warm surface waters expand and become lighter than the lower waters. The water temperature difference causes variation in water densities, which create resistance to mixing. This ultimately results in Anaerobic Conditions in lower zones.

#### **3.3.3.3 Anaerobic Conditions**

Anaerobic conditions make water unpalatable due to colour and odour which are difficult to treat. Another major problem in anaerobic water occurs when iron and/or manganese exist in bottom sediments in the reduced state and pass into solution. Due to the presence of either iron or manganese in appreciable quantities within the domestic supply the water looks reddish, brown or just plain dirty and may stain clothes during washing and stain porcelain fixtures.

## **3.4 GROUND WATER MANAGEMENT AND MAJOR SOURCES OF POLLUTION**

### **3.4.1 USE OF GROUND WATER**

Important requirements of managing ground water are:

1. Regulation of Ground Water,
2. Prevention of pollution of ground water,
3. Conservation of ground water,
4. Effective preventive maintenance,
5. Artificial recharge of ground water.

### **3.4.2 MAJOR SOURCES OF POLLUTION**

- i) Landfills,
- ii) Mining activities,
- iii) Abandoned sites,
- iv) Abandoned wells,
- v) Agricultural practices,
- vi) Underground storage tanks and pipeline,
- vii) Increased salinity and salt water encroachment,
- viii) Septic tank and soakage pit system,
- ix) Petroleum exploration,
- x) Radioactive wastes.

## **3.5 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.

### **3.5.1 SURFACE WATER**

- i) Proximity to watershed and character of sources of contamination including industrial wastes, oil field brines, acid waters from mines, sanitary landfills, and agricultural drain waters.
- ii) Population and wastewater collection, treatment and disposal on the watershed.
- iii) Closeness of sources of fecal pollution to intake of water supply.

- iv) Wind direction and velocity data; drift of pollution; algal growth potential in case of lake or reservoir supplies.
- v) Character and quality of raw water.
- vi) Protective measures in connection with the use of watershed to control fishing, boating, swimming, wading, ice cutting, and permitting animals on shoreline areas.
- vii) Efficiency and constancy of policing activities on the watershed and around the lake.

### **3.5.2 GROUND WATER**

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

## **3.6 SURFACE WATER SOURCES**

Surface water sources may be divided into rivers, lakes and reservoirs as explained in para 3.2.2. Dams are constructed to create artificial storage. Some of the salient features of Dams are given below.

### **3.6.1 DAMS (GENERAL)**

#### **3.6.1.1 Location**

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 current 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.

#### **3.6.1.2 Types of Dams**

Dams may be classified into two main categories

##### **(i) Rigid dams**

These include dams of concrete, masonry, steel or timber.

##### **(ii) 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.

### **3.6.1.3 Dams-Operational Functions**

#### **1. General**

The releases through the Outlet-works shall be made according to the predetermined regulations to suit the availability and demand.

#### **2. Spillway**

The water in excess of demand can be stored up to a predetermined level. Surplus water shall be automatically released through the pre-designed spillway.

#### **3. Outlet works**

During normal operation, the supplies shall be released through the outlet pipe. The downstream valve shall be used for regulation purposes and the upstream valve for emergency operation.

#### **4. Gauging facilities**

Gauges should be installed at suitable locations in approach channel, stilling basin and escape channel etc. and read at predetermined times.

#### **5. Initial filling of reservoir**

After completion of all works the impounding shall be carried out in stages. During initial filling a gradual rise in reservoir level is desired to avoid chances of a possible mishap due to leakage.

#### **6. Water level measurements**

Water level in the reservoir shall be recorded once a day during non-monsoon period and thrice a day during monsoon period or as decided by the Authorities keeping in view the local conditions.

#### **7. Storage Utilisation**

The initial live storage goes on reducing due to silting with passage of time. This point should be kept in mind while utilising the stored water.

#### **8. Outlet operation**

While the outlet starts operating, careful watch shall be kept to see if there is any formation of vortices or swirl around the intake structure. Precautions shall be taken to regulate the flow through outlet by operating control valves.

#### **9. General Precautions**

- Before the beginning of the monsoon season every year, it shall be ensured that all electrical and mechanical equipments are in perfect working order.
- Spillway and outlet structures shall be free of any unauthorised installation or devices.
- General vigilance shall be maintained on inflow conditions.
- Flood warnings shall be issued to all concerned.
- Strict watch shall be kept on the magnitude of inflow and outflow discharge.

#### **10. Flood Control**

Changing characteristics of the inflow, reservoir sedimentation and variations in water

use shall demand reassessment of flood retaining capacity and requirements. River downstream of dam must be periodically inspected for alterations in water use or obstruction and/or possible danger of damage from flooding to life and property.

#### **11. Emergency precautions and operations**

Emergency action plans shall deal with the following aspects

- Hydrological observations and flood warning schemes;
- Drawdown and flood control operation of reservoir;
- Emergency emptying of the reservoir;
- Evacuation of the flood threatened areas;
- Rescue operations and other emergency provisions;
- Equipment, material and support available for emergency relief;
- Emergency stand by of the public utilities;
- Emergency warning;
- Emergency communication and transportation;
- Emergency access to remote sites.

#### **3.6.1.4 Inspection of Dams**

For proper Operation and Maintenance of a dam and adopting remedial measures, regular inspection of the dam, appurtenant structures, reservoir area, and downstream channel in the vicinity of the dam should be conducted in a systematic manner.

Adequacy and quality of maintenance and operating procedures and operation of control facilities should be properly examined and all possible remedial measures should be taken to set right the deficiencies so detected.

Particular attention should be given to detecting evidences of leakage, erosion, seepage, excessive wetness or slushiness in the area downstream of dam, presence of sand boils, change in water table conditions downstream, slope instability, undue settlement, displacement, tilting, cracking, deterioration and improper functioning of the drains and relief wells, evidence of excessive pore pressure conditions, encroachment on the free board allowance.

Following guidelines outline some of the factors to be duly considered to ensure implementation of the operation and maintenance procedures.

##### **(a) Embankment Structures**

###### *1. Settlement*

The embankments and downstream toe areas should be examined for any evidence of localized or overall settlement, depressions or sinkholes.

###### *2. Slope Stability*

Embankment slopes should be examined for irregularities in alignment and variances from smooth uniform slopes, unusual changes from original crest alignment and elevation, evidence of movement at or beyond the toe, and surface cracks which indicate movement.



3. *Seepage*

The 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.

4. *Drainage Systems*

The slope protection should be examined to determine whether the systems could freely pass discharge and that the discharge water is not carrying embankment material.

5. *Slope Protection*

The adequacy of 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.

**(b) *Spillway Structures***

Examination should be made of the structures and important features of all service and auxiliary spillways, which serve as principal or emergency spillways.

1. Control gates and operating machinery.
2. Unlined saddle spillways.
3. Approach and Outlet channels.
4. Stilling basin (Energy dissipators).

**(c) *Outlet Works***

The outlet works examination should include all structures and features designed to release reservoir water below the spillway crest through or around the Dam.

1. *Intake Structure:*

Entrances to intake structure should be examined for conditions such as silt or debris accumulation, which may reduce the discharge capabilities of the outlet works.

2. Operation and emergency control gates.
3. Conduits, sluices, water passages etc.
4. Stilling Basin (Energy dissipators).
5. Approach and outlet channels.
6. Drawdown facilities.

Facilities provided for drawdown of the reservoir to avert impending failure of the dam or to facilitate repair in the event of stability or foundation problems should be examined.

**(d) *Concrete Structure in General***

The examination of concrete structures shall include the following:

1. Concrete surfaces.
2. Structural cracking.
3. Movement - horizontal and vertical alignment.

4. Junctions.
5. Drains-Foundation, Joint, Face.
6. Water Passages.
7. Seepage or leakages.
8. Monolith joints-construction joints.
9. Foundations.
10. Abutments.

**(e) Reservoir**

The following features of the reservoir should be examined to determine to what extent the water impounded by the dam would constitute a danger to the safety of the dam or a hazard to human life or property.

1. *Shore Line*

The landforms around the reservoir should be examined for indications of major landslide areas which may reduce reservoir capacity or create waves that might overtop the dam.

2. *Sedimentation*

The reservoir and drainage area should be examined for excessive sedimentation or recent developments in the drainage basin, which could cause a sudden increase in sediment load thereby reducing the reservoir capacity.

3. *Backwater flooding*

The reservoir area should be examined for features subject to potential backwater flooding resulting in loss of human life and property.

4. *Watershed Runoff Potential*

The drainage basin should be examined for extensive alterations to the surface of the drainage basin such as changed agricultural practices, timber clearing, railroad or highway construction or real estate developments that might extensively affect the runoff characteristics. Upstream projects that might have impact on the safety of the dam should be identified.

**(f) Downstream Channel**

The channel immediately downstream of the dam should be examined for conditions, which might impose any constraints on the operation of the dam.

**(g) Special Observations**

1. Every attempt should be made to anticipate and have engineer-observers present on site at items of large spillway and outlet discharge.
2. Warning, safety and performance instrumentations:
  - piezometers, flow recorders, accelerometers, seismoscopes, joint meters, and gauge points, strain meters, stress meters, inclinometers, direct and inverted plumb lines, surface reference monument, stage recorders, extensimeters,

- serviceability,
  - access to readout stations,
  - need for recalibration,
  - faulty readings and reasons,
  - alarm systems.
3. *During and after floods:*
- drift marked high water-lines,
  - evidence of taxed spillway capacity,
  - undesirable or dangerous spillway flow patterns,
4. *During and after large outlet releases:*
- Undesirable or dangerous spillway flow patterns, dynamic pressures, vibrations cavitation sonics.
5. *After earthquakes:*
- cracks, displacement offsets in structural features,
  - cracks, slumps, slides, displacements, settlements in embankments, cut-slopes, and fill slopes,
  - broken stalactites in galleries, tunnels, chambers,
  - toppled mechanical equipment,
  - sand boils.
6. *Surface evaporation*

Direct evaporation from water surface is influenced by temperature, barometric pressure, mean wind velocity, vapour pressure of saturated vapour and vapour pressure of saturated air.

Measurement of evaporation from water surfaces are commonly made by exposing pans of water to the air and recording the evaporation losses.

The evaporation from lakes, dams, impounding reservoirs, various structures in which water surface is exposed to the atmosphere, may result in considerable loss of water. Evaporation is a direct function of the surface area. An attempt should be made to minimize the surface area.

Evaporation is a continuous process. It cannot be eliminated though it can be controlled by use of certain chemicals developed specially for this purpose. Such chemicals are generally available in paste form and can be brought into the liquid form by mixing water. This can then be spread over the surface of water so as to form a thin film. This film is normally retained on the surface for more than 24 hours and needs to be replenished by spreading the chemical again. The film is transparent and sun rays can pass through it and the aquatic life is thus protected. The film is likely to be disturbed by wind which affects its covering efficiency. The cost of this process is quite high. Calculations should be made on the cost of this treatment versus the extra cost in arranging additional water. In certain circumstances, when alternative sources are not available, this process will be very useful.

### **3.6.1.5 Earthen Dams**

Following features should be examined for proper operation and maintenance.

#### **(a) Stress and Strain: Evidence and clues**

1. Settlement,
2. Consolidation,
3. Subsidence,
4. Compressibility,
5. Cracks, displacement, offsets, joint opening changes in concrete facing on rock fills,
6. Loss of freeboard from settlement,
7. Zones of extension and compression visible along dam crest or elsewhere,
8. Crushing of rock points of contact,
9. Differential settlement of embankment cross sectional zones visible along dam crest.

#### **(b) Stability : Evidence and clues**

1. Cracks, displacements etc., on embankment crest and slopes.
2. Sags and misalignments in parapet wall etc.,
3. Irregularities in alignment and variances from smooth, uniform face planes,
4. Bulges in ground surfaces beyond toes of slopes.

#### **(c) Inadequate seepage control: Evidence and clues**

1. Wet spots,
2. New vegetal growth,
3. Seepage and leakage,
4. Boils,
5. Saturation patterns on slopes, hillsides and in streambed,
6. Depressions and sinkholes,
7. Evidence of high escape gradients.

#### **(d) Erosion Control**

1. Loss, displacement, and deterioration of upstream face riprap, underlayment and downstream face slope protection,
2. Leaching.

#### **(e) Foundation**

1. Piping of weathering products,
2. Efficiency of foundation seepage control systems,
3. History of shear zones, faults, openings,
4. Zones of varying permeability,

5. Effect on permeability, uplift, foundation stability,
6. Subsurface erosion and piping etc.

#### **3.6.1.6 O&M of Concrete Dams**

(these observations are applicable also to impounding reservoirs, intake structures, spillway control structures, lock walls).

Examine for evidence and clues for

**(a) *Stress and Strain: Evidence and Clues:***

1. Cracks, crushing, displacements, offsets in concrete monoliths, buttresses, face slabs, arch barrels visible on exterior surfaces and in galleries, valve and operating chambers, and conduit interior surfaces,
2. Typical stress and temperature crack patterns in buttresses, pilasters, diaphragms and arch barrels,

**(b) *Stability:***

1. Uplift pressures, pressure spurts from foundation drain holes, construction joints, and cracks,
2. Differential displacements of adjacent monoliths, buttresses and supported arch barrels or face slabs,
3. Disparities in regions near the interface between arches and thrust blocks,
4. Movement along construction joints,
5. Uplift on horizontal surfaces.

**(c) *Hillslides and river channels along the downstream toe of the dam:***

1. Leakage,
2. Seepage,
3. Stability,
4. Boils.

**(d) *Stability and seepage control at discontinuities and junctures:***

1. Embankment wrap around sections,
2. Water stops in monoliths and face slabs,
3. Reservoir impounding backfill at spillway control sections and retaining walls.

**(f) *Foundations:***

1. Piping of weathering products,
2. Foundation seepage control systems,
3. History of shear zones, faults, cavernous openings,
4. Zones of varying permeability,
5. Effect on permeability, uplift, foundation stability,
6. Subsurface erosion and piping.

### **3.6.1.7 Miscellaneous Items**

Observe following features:

*(a) Service reliability of outlet, spillway sump pump mechanical-electrical equipment*

- i) Broken or disconnected lift chains and cables,
- ii) Test operation including auxiliary power sources,
- iii) Reliability and service connections of primary sources,
- iv) Verification of operators understanding and ability to operate,
- v) Ease and assurance of access to control stations,
- vi) Functioning of lubrication systems.

*(b) Gate chamber, Galleries, Tunnels and Conduits*

Ventilation and heat control of damp, corrosive environment of mechanical-electrical equipment.

*(c) Accessibility and Visibility*

- i) Vegetable overgrowth,
- ii) Galleries-access ladders, lighting,
- iii) Access roads and bridges,
- iv) Communication and remote control lines, cables and telemetering systems.

*(d) Control of vegetation and burrowing animals*

- i) Harmful vegetation in embankments-oversize, dead root channels,
- ii) Harmful vegetation in structural concrete joints,
- iii) Obstructing vegetal growth in hydraulic flow channels,
- iv) Ground squirrels, rats and beavers.

### **3.6.1.8 Records of operation of Reservoir**

In order to ensure continued safe operation of dam and appurtenant works, including mechanical and electrical equipment installed therein, a record of operation and inspection of various works/equipment shall be maintained on suitable history sheets for future reference and guidance. Details of maintenance of all works undertaken and modifications, if any, carried out shall be carefully recorded so that proper assessment can be made subsequently in respect of adequacy/efficacy of repairs and modifications carried out. History sheets shall be prepared subsequently for civil, mechanical and electrical works. The record thus maintained shall be carefully scrutinized from time to time and remedial measures, as considered necessary, be taken.

The records shall include all items mentioned in item 3.6.1.4. (Operation and Maintenance).

## **3.7 INTAKES**

### **3.7.1 GENERAL**

An Intake is a device or structure placed in a surface water source to permit withdrawal of water from this source and its discharge into an intake conduit through which it will flow

into the water works system. Types of intake structures consist of intake towers, submerged intakes, intake pipes or conduits, movable intakes, and shore intakes. Intake structures over the inlet ends of intake conduits are necessary to protect against wave action, floods, stoppage, navigation, ice, pollution, and other interference with the proper functioning of the intake.

Intake towers are used for large waterworks drawing water from lakes, reservoirs and rivers in which there is either or both a wide fluctuation in water level or the desire to draw water at a depth that will give water of the best quality to avoid clogging or for other reasons.

### **3.7.2 PROBLEMS IN OPERATION**

Some of the problems that may arise during the operation of Intakes are given below. Necessary steps should be taken to set right the same.

- i) Fluctuations in water level,
- ii) Water withdrawal at various depths,
- iii) Hydraulic surges, ice, floods, floating debris, boats and barges,
- iv) Withdrawal of water of the best available quality to avoid pollution, and to provide structural stability,
- v) Operation of racks and screens to prevent entry of objects that might damage pumps and treatment facilities,
- vi) Minimising damage to aquatic life,
- vii) Preservation of space for
  - a) Equipment cleaning,
  - b) Removal and repair of machinery,
  - c) Storing, movement and feeding of chemicals.

### **3.7.3 OPERATION AND MAINTENANCE**

- i) Operating criteria, equipment manufacturer's operating instructions and standard operating procedures should be bound into a manual and used for reference by operators. If written references are not available for a particular facility, they should be prepared with the assistance of knowledgeable operators, engineers and manufacturers.
- ii) Screens should be regularly inspected, maintained and cleaned.
- iii) Mechanical or hydraulic jet cleaning devices should be used to clean the screens.
- iv) Intake structures and related facilities should be inspected, operated and tested periodically at regular intervals.
- v) Proper service and lubrication of intake facilities is important.
- vi) Operation of Gates and Valves.

Some of the causes of faulty operation are as under:

- Settlement or shifting of supporting structures which could cause binding of gates and valves,
- Worn, corroded, loose or broken parts,

- Lack of use,
- Lack of lubrication,
- Vibration,
- Improper operating procedures,
- Design errors or deficiencies,
- Failure of power source or circuit failure, and
- Vandalism.

#### **3.7.4 RECORD KEEPING**

The records to be maintained shall include the following aspects:

- i) A history of operations and maintenance performed on Intake facilities.
- ii) When and under what conditions, failure or malfunctions occur.

#### **3.7.5 SAFETY**

When working around Intake Structures proper safety procedure involving use of electrical and mechanical equipment and water safety should be observed. Proper safety procedures should be documented and included in the manual containing the operating procedure. For more details please refer to the Chapter 19 on 'Safety Practices'.

### **3.8 GROUND WATER**

#### **3.8.1 PREVENTIVE MAINTENANCE**

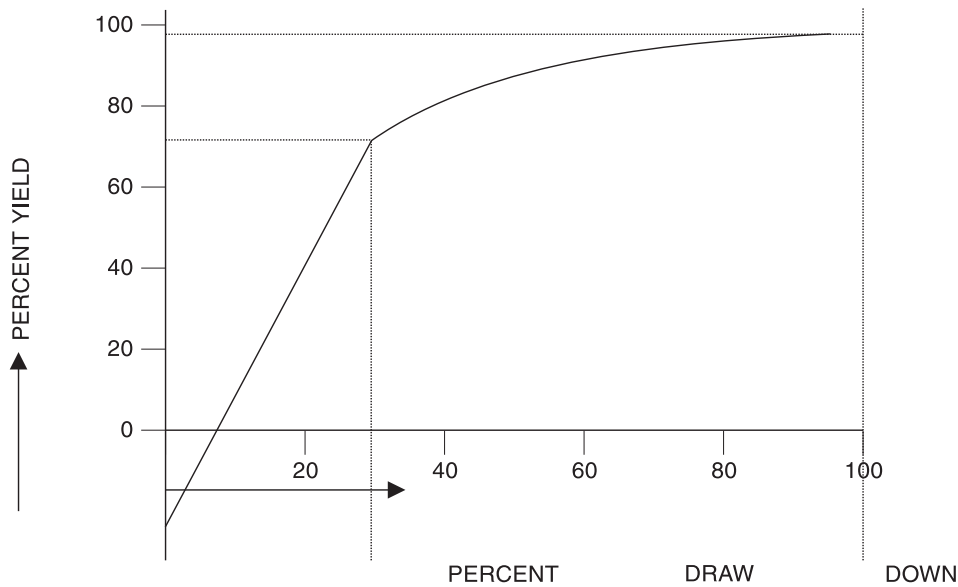
According to available data the specific capacity of wells should be measured at regular intervals either monthly or bi-monthly and it should be compared with the original specific capacity. As soon as 10 to 15% decrease in specific capacity is observed steps should be taken to determine the cause and 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:

- i) Static water level in the production well,
- ii) Pumping rate after a specific period of continuous pumping,
- iii) Specific capacity after a specified period of continuous pumping,
- iv) Sand content in a water sample after a specified period of continuous pumping,
- v) Total depth of the well,
- vi) Efficiency of the well,
- vii) Normal pumping rate and hours per day of operation,
- viii) General trend in water levels in wells in the area,
- ix) 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. This data is normally in the form of a discharge draw-down curve (called yield draw down curve). According to this curve there is a straight line up to certain stage of draw down beyond, which the draw down increases disproportionately to yield. The end point of straight line is the point of optimum efficiency for the operation of well as shown in the attached figure.



This is generally found to be 70% of yield at draw down which can be created

### 3.8.1.1 Static Water Level (S.W.L.)

Pumping water level and Draw Down can be measured with the help of an electrical depth gauge of an Air line gauge.

In case of measurement by an electrical depth gauge an electrode is suspended in the tube well by a metallic cloth tape. The conductor terminal clip is fixed with the metallic casing of the tube well. The electric circuit is completed when the electrode touches the water surface which is indicated by the galvanometer. The corresponding depth is read on the tape.

Air line gauge method is most commonly used for measurement of S.W.L., Pumping Water Level and draw down. Air pipe can be lowered in tube well through a slot or a hole provided in the flange in case of flanged assembly and in the annular space in case of socketed assembly. In this method air is pumped into the line until the maximum possible pressure is reached. Normally the air line is full of water up to the level of water in the well (static or pumping water level). When air is forced into the line, it creates pressure which forces water out of the lower end until it is completely expelled and the line is full of air. If more air is pumped in, air, instead of water, is expelled and it is not possible to increase the pressure further. The head of water, C or E (as shown in the figure), above the end of the line maintains this pressure,

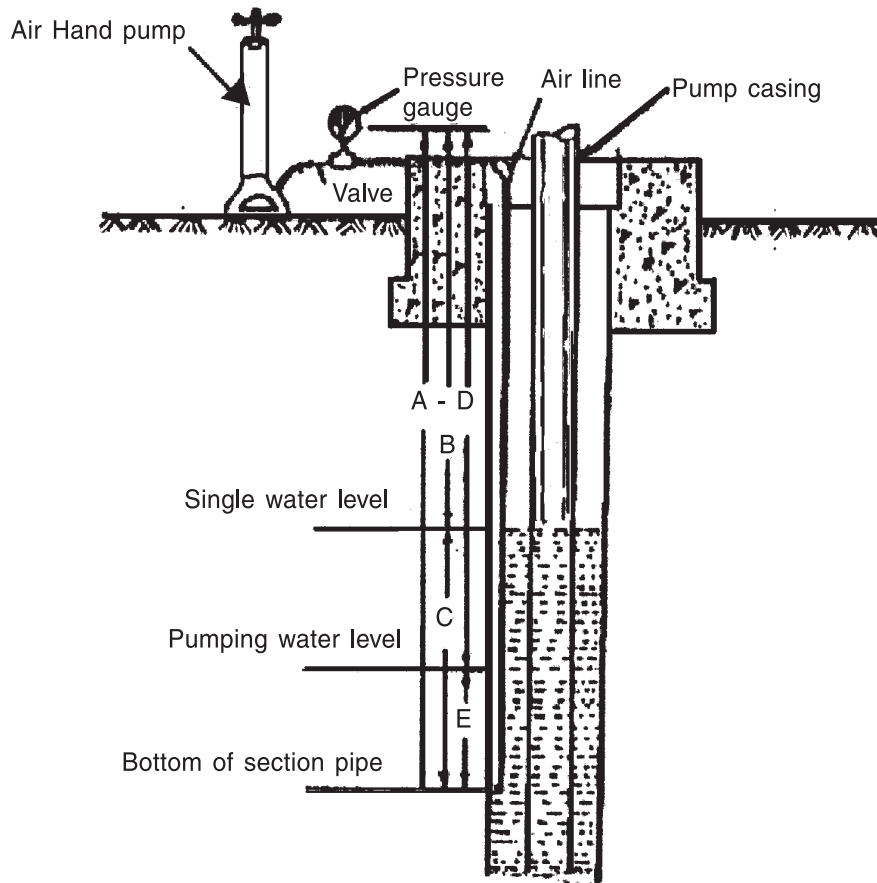


FIG. 3.0: AIR LINE INSTALLED IN A TUBEWELL FOR MEASURING WATER LEVEL

and the gauge shows the pressure or head above the end of the line. If the gauge is graduated in meters of water, it registers directly the amount of submergence of the end of the line. This reading subtracted from the length A of the line, gives the water level B or D (static or pumping water level).

### 3.8.1.2 Tubewell sounding

For identification of lithological details electrical logging can be used for uncased bores while Gamma logging can be used for both, cased and uncased bores. Bore hole camera can be used for identification of the condition of bore hole, casing and strainer pipes. These devices are commonly available in the market.

### 3.8.2 CONSERVATION OF GROUND WATER

Following are the steps for conservation of ground water:

- i) Improvement of home plumbing systems.
- ii) Reuse of recycled water.
- iii) By creating public awareness by Information, Education and Communication (IEC) activities.
- iv) By introducing sustainable water tariff.
- v) By rain water harvesting.

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.

### **3.8.3 CAUSES OF FAILURE OF WELLS**

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 categorised 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 table at Annexure-3.1 indicates all causes of failure according to type of source.

### **3.8.4 REHABILITATION OF TUBEWELLS & BORE WELLS**

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).

#### **3.8.4.1 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.

#### **3.8.4.2 Adverse Aquifer Conditions**

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

#### **3.8.4.3 Mechanical Failure**

The falling of pumping set assembly and its components into the bore hole can be minimised 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. Following are the steps taken for fishing out the fallen objects in the bore holes:

##### ***(a) Impression Block***

An impression block is used to obtain an impression of the top of the object before attempting any fishing operation. Impression blocks are of many forms and design. Figure 3.1 illustrates an impression block made from a block of soft wood turned on a lathe. The diameter of the block is 2 cm less than that of drilled hole. The upper portion is shaped in the form of a pin and driven to fit tightly into the box collar of a drill pipe. To ensure further safety, the wooden block is tied with wire or pinned securely to the collar. Alternatively, the block could be fixed to a bailer. A number of nails are driven to the lower end of the block with about 1 cm of it projecting out. A sheet metal cylinder of about 5 to 7 cm is temporarily nailed around the block to hold molten wax, which is poured into it. Warm paraffin wax, soap or other plastic material poured into the cylinder is left to cool and solidify. The metal cylinder is then removed. The nail heads hold the plastic material to the block. To locate the position of a lost object, the impression block is carefully lowered into the hole until the object is reached. After a proper stamp is ensured, the tool is raised to the ground surface, where the impression made in the plastic material is examined for identifying the position of the lost object and designing or selecting the right fishing tool.

##### ***(b) Fishing Tools to Recover Fallen Objects***

'The term 'fish', as used in tube well technology, describes a well drilling tool, pump component or other foreign body accidentally fallen or struck in bored wells & wells. The type of fishing tools required for a specific job will depend on the object to be lifted and the position in which it is lying in the well. It may often be necessary to design a fishing tool to suit a particular job. However, series of fishing tools suitable for different jobs are available in the market, which could be adapted or modified to suit a particular requirement.

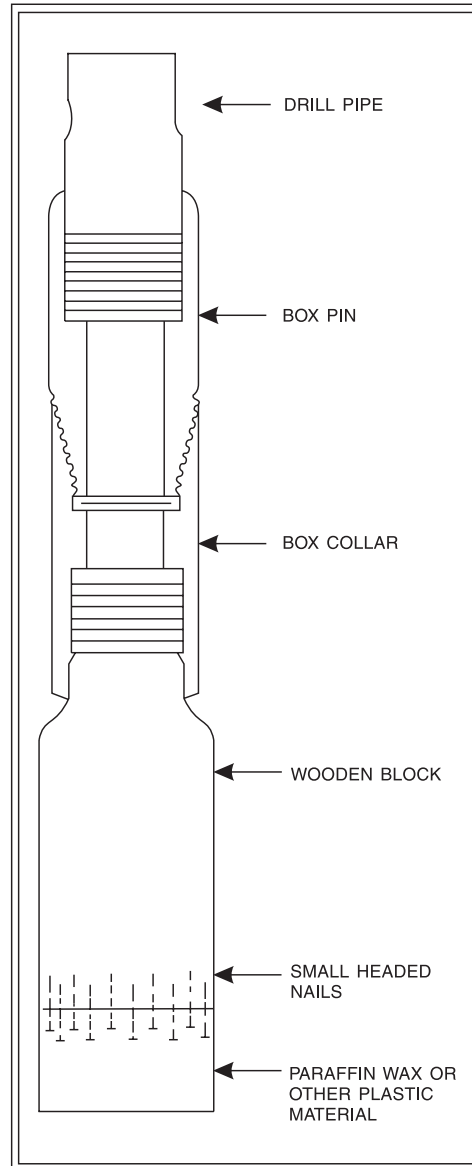


FIG. 3.1: IMPRESSION BLOCK

### 3.8.5 INCRUSTATION

#### 3.8.5.1 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.

### 3.8.5.2 Types of Incrustation

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

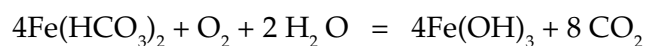
- Precipitation of carbonates, sulphates and silicates of calcium and magnesium.
- Precipitation of hydroxides, oxides and other compounds of iron and manganese.
- Slime produced by iron bacteria and other slime producing organisms.
- Deposition of soil materials (Mechanical Incrustation).

#### (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 rust. 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.



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.

### **3.8.6 REHABILITATION OF INCRUSTATED TUBE WELLS AND BORE 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.

The most important factor in treatment by chemicals is an effective contact between the chemical and the deposit on the well screen as well as in the aquifer adjacent to it. The chemical solution tends to penetrate only those parts of the aquifer where it gets the least resistance, i.e. which are comparatively free from clogging. Hence it is very necessary to agitate the solution vigorously and to surge it so as to force it into areas which offer resistance. A treatment may have to be repeated a couple of times and the second or subsequent treatment will open up the more heavily clogged up areas.

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.

Different methods of rehabilitating incrustated wells are given below:

#### **3.8.6.1 Hydrochloric Acid Treatment**

*(a) Inhibitor*

Carbonate-type incrustation (mineral scale) is removed by hydrochloric acid treatment. Concentrated hydrochloric acid of commercial grade (28% strength) is usually used in well treatment. It should contain a suitable inhibitor which helps in the quick dissolution of calcium and magnesium carbonates. It also slows down the acid attack on mild-steel well casings. Hence, the possibility of any damage to the pipe during treatment is minimised. If inhibited

acid cannot be obtained, a home-made inhibitor can be used. A solution of about 0.7 kgs of gelatine in warm water, added to 100 litres of acid is usually adequate.

**(b) Treatment procedure**

1. The arrangement of equipment required for hydrochloric acid treatment is shown in Fig. 3.2. It consists of a 2 to 2.5 cm diameter plastic pipe which is long enough to reach the bottom of the well. The pipe, supported by suitable clamps, is lowered into the well. The upper end of the pipe is provided with a funnel inlet and overflow arrangement with a T-joint. The overflow takes care of any sudden blow out.
2. A solution of hydrochloric acid is prepared as indicated above. The acid solution required for one treatment should be 1.5 to 2 times the volume of water in the screened portion of the well. Sufficient acid is poured into the well to fill the bottom 1.5m depth of the screen. The acid-feeding pipe is then raised to about 1.5m and more acid poured. Even though acid is heavier than water and will displace it, the two will mix readily when stirred and the acid becomes easily diluted.

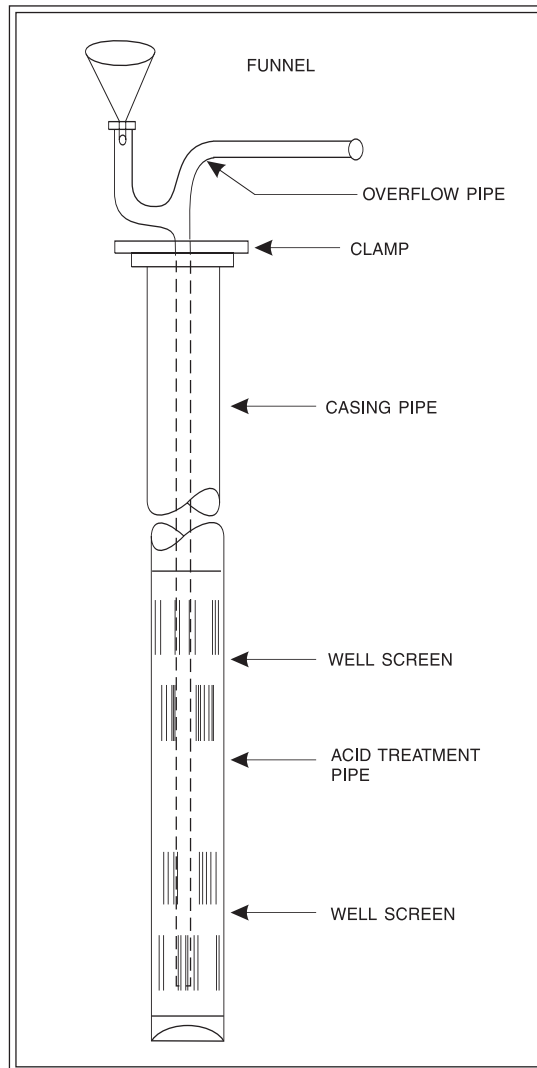


FIG. 3.2: SET UP FOR ACID TREATMENT OF TUBE WELLS



3. The effectiveness of acid treatment depends upon the contact between the chemical and the deposits on the well screen as well as in the adjacent aquifer. Chemical penetration will follow the path of least resistance. Hence, it is difficult to treat a clogged aquifer. It is, therefore, essential to agitate the acid solution vigorously and to surge it with a view to forcing the solution into the aquifer formations offering resistance. As soon as the acid solution is poured, it should be agitated in the well for one to two hours, with the help of a surge plunger. The solution should then be bailed out. Bailing is continued until almost clear water is obtained.
4. In the second stage of treatment, the process is repeated using the same quantity of acid. Surging is continued for a longer period before bailing out the water. Generally, two treatments should be sufficient to achieve the desired results. During acid treatment, neighbouring wells within a 60m radius should not be operated.

*(c) Adaptability*

Hydrochloric acid treatment is best suited when incrustation is due to calcium and magnesium carbonates. The treatment may not be successful in removing iron and manganese crusts. It attacks the steel well casing to some extent. However, damage can be minimised by using suitable inhibitors. Hydrochloric acid treatment is not suitable for agricultural strainers which consist of brass wire-mesh wrapped over a perforated galvanized iron pipe. In such a screen, treatment will result in rapid electrolytic corrosion of the screen.

*(d) Safety measures*

Hydrochloric acid is harmful to skin and can result in serious injury to eyes, if handled carelessly. Similarly, formation of gases, when the acid is poured into the well, can cause suffocation which could be fatal. Therefore, necessary care should be taken while treating the well. Good ventilation should be provided in the area around the pump house. All persons handling the acid should use rubber gloves and protective masks. A box of baking soda is kept handy, to neutralise the effect of acid if it falls on the body.

### **3.8.6.2 Sulphamic Acid Treatment**

1. Hydrochloric acid and sulphamic acid are used when calcium carbonate is the principal incrusting material. Although it is more expensive than hydrochloric acid but it has number. of advantages i.e. it is less aggressive, it is relatively safe to handle and it does not attack M.S. well casings like hydrochloric acid. Hence, sulphamic acid is commonly used for treatment in case of wells having mild steel screens or casings with deposits of calcium and magnesium salts. Sulphamic acid ( $\text{NH}_2\text{SO}_3\text{H}$ ), is commercially available in granular and pelletised forms. It is available under different trade names having a corrosion inhibitor and a wetting agent. A colour indicator is also introduced in the pellet which would change the colour of the solution from violet to orange yellow, once the incrustation is completely dissolved. Sulphamic acid is soluble in water and the weak solution does not give any hazardours fumes nor irritates the skin.
2. Sulphamic acid in granular form is poured into the well through a plastic or iron pipe. The material so poured is agitated to dissolve it in water. Sometimes it is poured into the well in a 20 per cent solution with water. In this case, first the solution is prepared

by dissolving one bag of acid (powder or pellets) at a time in a 200 litre capacity drum. Arrangement is made for pouring the solution to the bottom end of the tube well. This is done by a 25 mm or suitable diameter PVC siphon tube, keeping one end of it in a funnel at the top of another 25 mm pipe already lowered into the bottom of the tube well through the space between the pump and well casing. The end of the siphon is to be kept in the tank containing the sulphamic acid solution. The solution is then poured into the tube well through the pipe. The rate of feeding of the solution is controlled by a valve provided at the end of the delivery pipe so that the solution enters the tube well gradually in order to avoid faster chemical reaction at the initial stage. The feeding rate is regulated in such a way that the entire solution is added over a period of 2 to 3 hours. The solution is allowed to remain in the tube well for about 24 hours.

3. When the acid is available in pelletised form, the pellets could be dropped directly into the well in small quantities. Additional granular material is added to the well, as the reaction proceeds so as to keep the required strength of the solution. With surging, the reaction can be completed in 16 to 24 hours. After this period of 16-24 hours, about 4 to 6 hours of adding the chemical, the well is developed by compressed air or pump. This will loosen the incrustated chemical on the tube well screen and the surrounding aquifer. The tube well water is then pumped out. Pumping is continued intermittently for about 10 hours, till clean water is obtained.
4. The quantity of the sulphamic acid required depends on the quantity of water in the well. The usually recommended quantity of sulphamic acid (by weight) to be added in a tube well is about 7 to 10 per cent of the weight of water in the well. Thus, in a 20 cm diameter tubewell with a water column of 100m, the volume of water being 3.14 m<sup>3</sup>, the total quantity of sulphamic acid required for a treatment is about 250kg. It is often desirable to add a corrosion inhibitor and a wetting agent (low detergent soap) to improve the performance of the acid. The quantities of both these additives are about 10 per cent each of the weight of sulphamic acid. The corrosion inhibitor prevents corrosive action of the acid on the metal of the well pipe. The wetting agent improves the dispersing and cleaning action of the acid. Fluronic F-68 or Pluronic L-62 are commonly used as wetting agents. When the two additives are used with the acid, it is necessary to mix them in a bucket containing clean water, so as to form a heavy but pourable slurry, and add this slurry to the well through a tube.
5. The solubility of sulphamic acid decreases with decrease in temperature as shown in Table No.1

**TABLE 1: SOLUBILITY OF SULPHAMIC ACID IN WATER**

Temperature °C	5	10	15	25
Dry acid solubility in 100 litres of water, kg	17	18	20	23
Acid concentration of saturated solution, %	14	15	17	19

## 6. Safety precautions

Sulphamic acid in granular and pelletised forms, though less aggressive than hydrochloric acid, should be handled with caution. However, when used as a concentrated solution, it should be very carefully handled. Water-proof gloves and goggles should be worn by those handling it. Hydrogen sulphide and carbon dioxide gases are produced in considerable volumes during the reaction. The former is produced when iron sulphate is present. Both these gases are heavier than air. Hence, no person should be allowed to stand in a depression or a pit near the well during treatment.

## 7. Necessary conditions for acid treatment

The following are the major requirements for acid treatment of water wells:

- i) The metal of the well screen must be such that it is not damaged by the acid.
- ii) The well screen must be constructed of a single metal in order to avoid electrolytic corrosion, as in the case of a bi-metallic alloy.
- iii) A fair knowledge of the kind of incrusting material is essential to determine the proper procedure in well treatment. Samples of incrustations taken from other wells in the same formation are useful indicators of the causes of incrustation. Water quality analysis is also useful to obtain information on the kind of incrusting material.
- iv) Adequate ventilation of well treatment site is necessary.
- v) Wells located in the neighbourhood (within 30m) of the well must be shut down during the process of treatment.

In all acid treatments, the acid should be handled with care. Good ventilation should be provided when operating in a confined area, like a pump house. Adequate provision should be made for disposing the waste water which is pumped out during its treatment. The waste water must be kept away from domestic wells, ponds or other water bodies used for human or cattle consumption. The waste, when diluted, will not adversely affect plants. Pumping the waste during acid treatment is a process of brisk surging, followed by slow pumping until the water becomes clear and free of odour and foam.

### 3.8.6.3 Aquifer Conditions which may not Respond to Acid Treatment

Acid treatment of water wells, though suitable under most conditions, may not result in any appreciable improvement under the following aquifer conditions:

- i) Shallow limited aquifers, subjected to recurring periods of over-draft.
- ii) Deeply buried narrow aquifers approaching over-development.
- iii) Aquifers of low permeability where operating heads are large.

Controlled pumping tests to determine well efficiencies and the hydraulic characteristics of aquifers are essential in determining the effectiveness of acid treatment or other development methods to increase the yield of water wells.

#### **3.8.6.4 Glassy Phosphate Treatment**

Glassy phosphate or polyphosphates are used for well treatment when iron oxide, manganese oxide, silt and clay are the materials causing incrustation. Sodium hexameta phosphate ( $\text{NaPO}_3$ )<sub>6</sub> is one of the most commonly used polyphosphates. They do not dissolve the incrusting material and fuming or boiling does not take place. Phosphates have cleaning and dispersing properties which, when coupled with vigorous agitation, break the incrusting material. Thus, the incrustation gets dispersed and is easily pumped out. Calcium hypochlorite is also added to it in small quantities. It helps in chlorinating the well and killing the iron bacteria or similar organisms which may be present in well water.

##### *(a) Treatment procedure:*

Glassy phosphate solution is prepared in a tank or drum. The amount of glassy phosphate to be added depends on the quantity of water in the well. Generally, 15 to 30kg of glassy phosphate is used for every 1000 litres of water in the well. It should be dissolved in water by suspending it in a tank in a cloth net or gunny bag, and should not be simply dumped. A mixture of about 1.2 kg of calcium hypochlorite per 1000 liters of water is desirable. It helps kill iron bacteria and other organisms. The solution so prepared is poured into the well. This is followed by vigorous surging, which will help the chemical loosen and disperse the deposits inside the pipe as well as outside. The dispersed material passes out through the screen openings. Surging can be done using a surge plunger, compressed air, or by horizontal jetting. If the pump installed in the well is not removed, the same can be used for surging. Surging by pumping is not very effective but can be used for convenience. Surging with a pump is done by starting and stopping it as often as possible. Operation is continued for a period of about four hours. The pump is then left idle for about two hours. The process is repeated twice or thrice. When the chemical has been in the well for about 24 hours, surging is again repeated several times. The waste is then pumped out and the well flushed thoroughly. Even while the well is being flushed out, surging is done a few times at intervals, and pumping continued until fairly clean water is obtained. The entire procedure may be repeated two or three times, using a fresh charge of polyphosphates and calcium hypochloride. The chemical is quite safe to use and does not require any special safety precautions.

##### *(b) Removal of Hydrogen Sulphide (H<sub>2</sub>S) Bio Fouling:*

Sulphate reducing bacteria in ground water reduce the sulphates in the water to hydrogen sulphide, which produces foul smell known as bio fouling. This bio fouling can be removed by the method mentioned above. This can also be removed by super chlorination of water. Aeration method as mentioned at para 7.2 of Manual of Water Supply and Treatment (1999 Edition) can also be used for removal of the H<sub>2</sub>S bio fouling.

#### **3.8.6.5 Chlorine Treatment**

In case of wells incrustated with bacterial growth and slime deposits, chlorine treatment has been found most effective. Though acid may kill the bacteria, it is unable to remove the slime. Chlorine kills the bacteria as well as oxidises the organic slime, thus loosening it.

Calcium hypochlorite  $\text{Ca}(\text{OCI})_2$  is often used for chlorine treatment. It is available in powder form, containing about 70 per cent free chlorine. The quantity required is generally 20 to 25kg

for deep wells. Sodium hypochlorite Na OCl can also be used. Sometimes chlorine gas in water solution is also used but special equipment is required for its application.

### **Treatment procedure**

The desired amount of the chemical is put in the well directly, or in a water solution, to give the proper concentration of chlorine. When chlorine solution is used, it can be introduced into the well slowly through a plastic pipe of small diameter, over a period of about 12 hours in case of large wells. About 14 to 18 kgs of chlorine will be required for this purpose. Small wells require less chlorine and the period of application can be decreased accordingly.

Chlorine is corrosive in the presence of water. It should, therefore, be handled carefully so that it does not harm the pump, well casing and screen. It is not necessary to remove the pump, but it should be ensured that the plastic pipe carrying concentrated chlorine solution is not discharging the liquid directly on any part of the pump, well casing or screen. As soon as the chlorine solution is introduced, a sufficient quantity of water (50 to 100 times the volume of water standing in the well) is added to the well from an outside source, with a view to forcing the chlorine solution into the water-bearing formation. The well is then surged, using any of the standard techniques of surging. In case the pump has not been removed, the same can be used for surging, though not very effectively. Successful chlorine treatment of a well may require three or four successive operations.

#### **3.8.6.6 Combined Hydrochloric Acid and Chlorine Treatment**

Hydrochloric acid treatment followed by chlorine treatment is highly effective. The acid readily dissolves the carbonates while the chlorine helps to remove the slime deposited by iron bacteria. The two treatments are alternated, the acid treatment being performed first. The cycle may be repeated two or more times.

#### **3.8.6.7 Dry Ice Treatment**

The use of dry ice to open up incrustated screens is still in the experimental stage. Dry ice is carbon dioxide gas which is solidified by application of a large pressure. When it is put into a well, it is quickly converted into gas is not allowed to escape and is forced through the screen. In this process the material choking the screen is loosened. There may also be some reconversion of salts into soluble bicarbonates due to the action of dry ice. Dry ice can also be used after acid treatment for agitating and creating back pressures for surging. It may cause severe burns if it comes in contact with the body. Hence heavy gloves or tongs should be used while handling it.

#### **3.8.6.8 Hydro Fracturing**

This process is, generally, not used in this country for development purposes. Hydro fracturing is a process used to open-up clogged fractures and fissures in the rock surrounding the bore well by injecting water at a very high pressure. Hydro fracturing method can be used for rejuvenation of a low yielding or nearly dry bore well at a cost of 10 to 70% of the cost of bore well.

##### **(a) Conditions necessary for hydro fracturing**

1. Low yield/dry bore wells shall be considered for hydro fracturing.

2. Lithology of each bore well should be known.
3. Well-logging to be conducted to confirm the lithology and fracture zones of the bore well.
4. Quality of the water to be known.
5. Bore well should be of sufficient depth.
6. Bore well should be in good condition (like uniform diameter and verticality).

**(b) Basic components of hydro fracturing unit**

The basic components of the hydro fracturing unit include packer assembly, hydraulic pump for packing, supercharge pump for injecting water under high pressure, water tank, generator and submersible pumps of different horse powers. The packer assembly is supported by hydraulic hose and steel rope.

**(c) Operation**

Hydro fracturing can be carried out by

- Single Packer
- Double Packer

In the single packer technique, the packer will be placed above the fracture/work zone in the bore well and the bottom of the bore well acts as the closed end. In the double packer system, the packers are placed at the predetermined depths within the bore well.

The verticality of the bore well is checked up to the depth of packer setting and the packer is lowered and fixed by applying hydraulic pressure up to 300-350 bars and followed by injection of water into the bore well under great pressure, depending upon the depth, dimension and area of fracture. The pressure ranges from few tens to 170 bars. Once the maximum pressure builds up, the fractures, fissures, joints will break and interconnects among them and the pressure drops down suddenly indicating the development of fresh fractures or interconnection of existing fractures. Thus, this process can be repeated for lower fracture zones also. Subsequently, well logging and pump test will be conducted to assess the degree of hydro fracturing and improvement in yield.

Figure 3.3 indicates a set up of hydro fracturing unit.

**3.8.6.9 Explosives**

These are sometimes employed to develop and enlarge incrustated crevices and fissures of bore wells. Charges are used according to the hardness of the rock and the depth at which the charge is to be detonated.

**3.8.7 INADEQUATE DEVELOPMENT**

**3.8.7.1 General**

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 redevelopment of tubewell will have following effects :

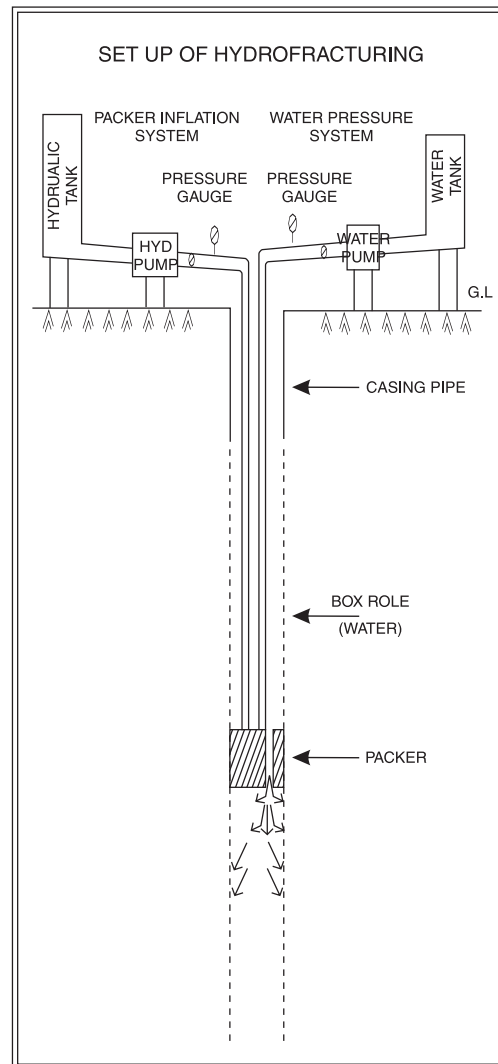


FIG. 3.3: SETUP OF HYDRO FRACTURING

1. Redevelopment of well involves removal of finer material from around the well screen, thereby enlarging the passages in the water-bearing formation to facilitate entry of water.
2. Redevelopment removes clogging of the water-bearing formation.
3. It increases the porosity and permeability of the water-bearing formation in the vicinity of the well.
4. It stabilize the formations around the well screen so that the well will yield sand-free water.
5. Redevelopment increases the effective radius of the well and, consequently, its yield.

### 3.8.7.2 Methods of Redevelopment

Following are the methods of well redevelopment :

- i) Over-pumping with pump.
- ii) Surging with surge block and bailing.

- iii) Surging and pumping with air compressor.
- iv) Back-washing.
- v) High-velocity jetting.
- vi) Dynamiting and acid treatment.

For rehabilitation purpose any suitable method of redevelopment can be used as mentioned above. The largely used method is surging and pumping with compressed air. In this method surging with compressed air is a combination of surging and pumping. In the process a large volume of air is released suddenly into the well casing pipe, which produces a strong surge. Pumping is done with an ordinary air lift pump. To achieve successful redevelopment of the well the submergence ratio (along with two airlines in water divided by its total length) is important. For obtaining the best results the ideal submergence ratio should be about 60%. The efficiency of development reduces rapidly if the desired submergence ratio is not maintained.

The equipment required for surging and pumping operation consist of an air compressor and a tank of required size, drop pipe and an airline with a suitable arrangements for raising and lowering each independently, flexible high pressure air hose for the supply of compressed air to the air pipe, pressure gauge, relief valve, a quick opening wall in the outlet of the tank, tee joint and pipe jointing material.

Normally, air compressors of 500 cum. per hour at 7kg/cm<sup>2</sup> to 800 cum. per hour at 17kgs/cm<sup>2</sup> are used for development/redevelopment work of the tubewell. Whenever under capacity air compressor is used for the development of the well, in such condition proper development is not possible and such wells become sick after a short period of use. These tubewells can only be rehabilitated by adopting the procedure of development of well which is known as redevelopment of the well.

### 3.8.7.3 Submergence Requirement of the Airline and Selection of Air Compressor

#### Submergence Requirements of the Airline

For achieving successful development/redevelopment of a well, submergence requirement of the airline is given below in table 3.2.

**TABLE 3.2**

Lift m	Maximum submergence %	Optimum submergence %	Minimum submergence %
6	70	66	55
10	70	66	55
15	70	66	50
20	70	64	50
25	70	63	50
30	70	60	45
40	65	60	45
50	65	60	45
60	60	50	40
70	55	50	40



#### **3.8.7.4 Selection of Air-Compressor**

The two most important factors in the selection of an air compressor for well development/redevelopment are the requirement of pressure and capacity. The required air pressure is determined, based on the length of air pipe below the static water level. Before air can be discharged from the lower end of the air pipe, the compressed air must push all the water out of the pipe. To do this, the air pressure must be greater than the water pressure before starting to pump water. The required pressure of compressor will be slightly more than submergence of the airline in the water.

A useful rule of thumb to estimate the compressor capacity is to provide about 0.28 m<sup>3</sup>/l of free air for each litre per minute of water at the anticipated pumping rate.

#### **3.8.7.5 Redevelopment Procedure**

For redevelopment of the tube well following steps are to be followed:

- Lower the drop pipe and air line in the well up to the desired submergence. The bottom of the drop pipe should be kept about 60cm above the bottom of the screen and the air line is kept about 30cm higher than the bottom end of the drop pipe.
- Turn on the air from the compressor and the well pumped by the conventional air lift principle until the discharge water is free from sand.
- Air entry into the well is then cut off by closing the valve between the tank and the compressor and in the meantime, the air line is lowered so that it is about 30cm below the bottom of the drop pipe. The airline is thus at the same position as in the back-washing method.
- The air valve is quickly opened to allow the compressed air from the tank into the well. This tends to surge water outwards through the well screen openings.
- The air pipe is raised again and the cycle repeated until the water discharged from the well is relatively free of sand. The above operation of back-washing and pumping completes one operation of surging.
- The entire assembly is then raised to a height of about one metre and the operations repeated until the well section along the entire length of the screen has been developed.
- Finally, the air pipe is lowered again to the bottom of the well and the equipment operated as a pump to flush out any sand that might have accumulated inside the screen.

Normally, with this method of redevelopment all the wells drilled in alluvial formation with inadequate development can be successfully redeveloped. This method has also been tried for sick wells drilled in rocky formations and encouraging results have been noticed. The use of disbursing agents like Polyphosphates have also been found useful in rehabilitating the wells with redevelopment method drilled in alluvial formation with inadequate development.

### **3.9 PREVENTION OF INCRUSTATION AND CORROSION**

At the time of construction of wells and even afterwards some steps can be taken for the prevention of incrustation and corrosion. These steps are given below:

### 3.9.1 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.

### 3.9.2 PREVENTION OF CORROSION

#### 3.9.2.1 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.

#### **Cathodic protection of mild steel tube wells in corrosive ground water:**

The following are two methods for applying cathodic protection against corrosion of mild steel pipes :

- (a) Sacrificial anode
- (b) Impressed current

**(a) *Sacrificial anode:*** For wells sacrificial anode cathodic protection is used which is detailed below:

In case of the sacrificial anode system of cathodic protection, a metal of higher negative potential than that of the material of the pipe to be protected is used as the anode. The metal pipe acts as the Cathode and the intervening water as electrolyte (Fig. 3.4), thus establishing the flow of electrons from the anode to this cathode. During electrolysis, the anode gets dissolved slowly and the metal ions in the solution are deposited at the Cathode. Thus, the main pipe (well pipe) is protected from corrosion by sacrificing the metal of the anode. Sacrificial anodes are easy to install and no power costs are involved. They are effective in prolonging the service life of mild steel tube wells in corrosive water. However, the anodes have to be replaced periodically at the end of their useful life.

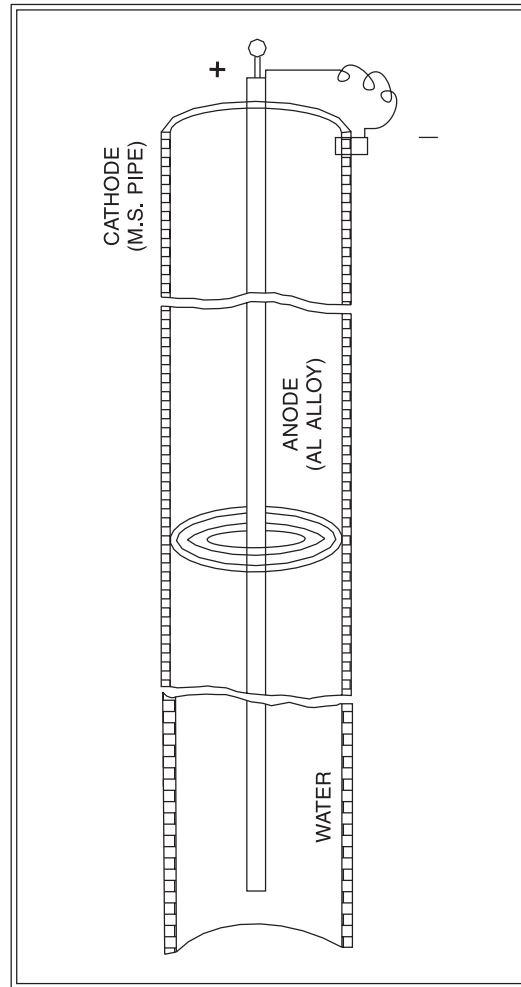


FIG. 3.4: CATHODIC PROTECTING ARRANGEMENT OF TUBE WELL

The anodes may be made of magnesium, zinc, aluminium, tin or their alloys. They are commercially available\* in diameters ranging from 1.5 to 8 cm and lengths of 1 to 3 m. Research findings have established the adaptability of Aluminium-zinc-tin alloy in the cathodic protection of tube wells (a commonly used alloy has Al 90%, Zn 7% and Sn 3%). Alloys cast in steel core pipes of 1 cm diameter are also available. The anode rods are threaded at their ends for jointing with each other through sockets or couplings.

(b) **Impressed Current:** In the Impressed current method electric current is passed from current source through anodes buried in the soil some distance from a mild steel pipeline. This method is extensively used in protecting mild steel pipelines in water supply projects but its applicability in wells has not yet been established.

### 3.10 ARTIFICIAL RECHARGE OF GROUND WATER

Artificial recharge of ground water can be achieved by the following:

- i) *Stream flow harvesting comprising of*
  - Anicuts
  - Gully plugging

- Loose stone check dams (LSCD)
- Dams
- ii) *Surface flow harvesting*
  - Tank
  - Ponds
- iii) *Direct recharge*
  - Recharge of wells
  - Through injected wells
  - Through roof top rain water harvesting structures

### **WELL PROBLEMS AND THEIR SUGGESTED SOLUTIONS**

These are given in Annexure 3.1 and 3.2.

## ANNEXURE: 3.1

**CAUSES OF FAILURE OF WELLS***Causes of failure marked as \*\**

S.No.	Types of Sources	Causes of failure							
		Incorrect design	Poor construction	Corrosion	Faulty operation	Adverse aquifer conditions	Mechanical failure	Incrustation	Inadequate development including silting
		(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)
1.	Dug well with or without steining	**			**	**			**
2.	Dug cum bore wells								
	(i) With PVC casing	**	**		**	**	**		**
	(ii) With MS casing	**	**	**	**	**	**		**
3.	Cavity bores								
	(i) With PVC casing	**	**		**	**	**		**
	(ii) With MS casing	**	**	**	**	**	**		**
4.	Infiltration galleries								
	(i) Lined with brick masonry	**	**		**	**			**
	(ii) Lined with non-metallic perforated pipes	**	**		**	**		**	**
	(iii) Lined with non-ferrous metallic perforated pipes	**	**		**	**		**	**
	(iv) Lined with M.S. perforated pipes	**	**	**	**	**		**	**
5.	Radial collector wells								
	(i) Radial with non-metallic perforated pipes	**	**		**	**		**	**
	(ii) Radial with Non-Ferrous metallic perforated pipes	**	**		**	**		**	**
	(iii) Radial with M.S. perforated pipes	**	**	**	**	**		**	**
6.	Tubewells (borewells)								
	(i) With PVC casing & screen pipes	**	**		**	**	**	**	**
	(ii) With M.S. casing & screen pipes	**	**	**	**	**	**	**	**
7.	Borewells	**	**		**	**	**	**	**

## ANNEXURE: 3.2

**WELL PROBLEMS AND THEIR SUGGESTED SOLUTIONS**

S.No.	Type of well	Problem	Probable cause	Solution suggested
1.	Dug well	1. Silting 2. Decrease in yield	1. Over pumping 2. Adverse aquifer conditions	1. Disilting can be done manually with buckets. 2. Disilting can be done by using submersible mud pumps 3. Discharge should be reduced so that there is no inflow of silt with water. Rehabilitation procedure as per 3.8.4.1 should be followed.
2.	Dug cum bore well	1. Silting 2. Decrease in yield 3. Mechanical failure	1. Over pumping 2. Adverse aquifer conditions 3. Falling of foreign objects in the bore	Apart from solution suggested for S.No.1, the rehabilitation procedure for mechanical failure mentioned at 3.8.4.3 should be followed. Development should be done with the help of air compressor using surging and pumping technique.
3.	Cavity bore	1. Bore silting 2. Decrease in yield 3. Mechanical failure	1. Over pumping 2. Adverse aquifer conditions 3. Falling of foreign objects in the bore 4. Collapse of cavity	For mechanical failure rehabilitation procedure mentioned at 3.8.4.3 should be followed. The cavity reconstruction & desilting of bore should be done with the help of air compressor using surging and pumping technique.
4.	(i) Radial collector wells (ii) Infiltration galleries	1. Silting in well caisson/Sump well 2. Decrease in yield	1. Over pumping 2. Adverse aquifer conditions 3. Incrustation of radials 4. Blocking of screens with sand 5. Damage of M.S. screens due to corrosion.	Apart from the solution suggested for S.No.1 rehabilitation procedures mentioned at 3.8.5 may be followed. For flushing of sand from the blocked screens, backwashing with the help of air compressor should be done. Screens should not be allowed to become aerated and should not be kept unused for long periods.
5.	Tube well	1. Silting of tube 2. Decrease in yield 3. Mechanical failure	1. Over pumping 2. Adverse aquifer conditions 3. Incrustation of screens & aquifers 4. Falling of foreign objects in the bore 5. Damage of M.S. screens due to corrosion.	Rehabilitation procedures suggested 3.8.4.1, 3.8.4.2, 3.8.4.3, 3.8.5, 3.8.7 may be followed.
6.	Borewell	1. Silting of bore-well 2. Decrease in yield 3. Drying up of borewell 4. Mechanical failure	1. Over pumping 2. Adverse aquifer conditions 3. Incrustation and silting of fractures & fissures. 4. Falling of foreign objects in the bore	Rehabilitation procedures suggested 3.8.4.1, 3.8.4.2, 3.8.4.3, 3.8.5 may be followed

## CHAPTER 4

# TRANSMISSION OF WATER

### 4.1 GENERAL

#### 4.1.1 OBJECTIVE OF TRANSMISSION SYSTEM

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.

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 agency 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.

Routine and emergency operating procedures should be in writing and clear to all operators with the authority to act in emergencies. Further specific operational procedures are required for inspecting, monitoring, testing, repairing and disinfecting the system as well as for locating the buried pipes and valves. System records and maps should be updated and have sufficient details of the system facilities.

#### 4.1.2 NORMAL CONDITIONS

##### 4.1.2.1 Routine Operations

Normally the operations involve transmission of required water within the available head or within the pumping head. Operation 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.

##### 4.1.2.2 Record of Flow, water levels and pressures

###### *(a) Gravity Channels and pipes*

A record is kept at the transmitting and receiving reservoirs about the valve operations, water levels and flows. Flow meters are installed at start and end points of transmission channels/pipes for monitoring the flows. Water levels in the reservoirs from which the channels/pipes transmit water and water levels in the receiving reservoirs are measured either by visible gauges or by automatic instruments.

### *(b) 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.

### *(c) 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.

## **4.2 TRANSMISSION THROUGH CANALS OR OPEN CHANNELS**

### **4.2.1 INTRODUCTION**

Open channels and Canals are exposed watercourses for transmission of water from one specific point to another. Whereas 'Open Channel' is a general name for such a watercourse, a 'Canal' normally forms a part of canal network taken off from a river, a dam or a reservoir. Following discussion relates to a canal. The criteria for design, operation, and maintenance for open channels are identical to those of a canal.

The canals are meant primarily for irrigation purposes. The canal water is, however, liberally made available for drinking water supply schemes. While designing new canal projects the requirement for drinking purposes is pre-determined and necessary provision made in the design of the canal projects.

Under special circumstances, however, a specific canal may be constructed exclusively for a drinking water supply project. There are, however, a large number of small water channels taken off from the main canal system and are meant exclusively for the drinking water supply schemes.

### **4.2.2 MAPS**

Survey maps may be procured or prepared for the entire existing and proposed canal net work, which could be the probable source of raw water for drinking water supply projects. These maps shall show the contours, spot levels and important land features for the whole area where the water supply schemes are to be implemented or augmented.

Alignment of all main canals, branches, distributaries and smaller major and minor channels shall be marked on the maps. The old maps shall be updated from time to time particularly when an important project is to be undertaken.



Following information shall be obtained for all important points along the alignment from where the connections are likely to be taken.

- i) Natural surface level,
- ii) Full supply levels,
- iii) Bed levels,
- iv) Free board,
- v) Water surface slope,
- vi) Bed width, side slopes, velocity,
- vii) Subsoil water levels,
- viii) Hydraulic data of outlets, regulators, bridges, drainage crossings, off take channels.

### **4.2.3 WATER DISTRIBUTION PRACTICES**

The canals may run continuously or on rotational basis, depending on the availability of water and demand. Depending on the closure period of a canal, adequate storage of raw water has to be created at the site of the waterworks to endure uninterrupted water supply. Such storage is in the form of open square or rectangular tanks whose side slopes and bed are properly lined. Surfaces of such storage tanks are identical to those of the canals with a difference that the canal surfaces are exposed to flowing water whereas, the water in the storage tanks is comparative static.

### **4.2.4 OPERATION**

The key objective of proper operation and maintenance of the canal system is to ensure uninterrupted, assured, authorized water supply from head to tail of a canal distribution system, ensure efficient conveyance of water, saving seepage losses en-route, at economical maintenance cost. Hence well planned and executed programme of operation, maintenance and repair of canal system, timely and methodically, is very important.

The availability of canal water is far below the requirements except during the active monsoon months. In order to overcome this problem arising due to less availability of canal water as compared with the overall requirement the entire canal network is divided into different groups which are run strictly according to the sanctioned/notified rotational programme. Each feeding channel has a full supply turn followed by a closure turn. No supply can be allowed to go out of turn.

### **4.2.5 RECORD KEEPING**

An accurate and systematic record of the performance of a canal should be maintained by periodic observations of roughness coefficient, evaporation and seepage losses, life and behavior of the lining adopted, surge wave heights and performance of any special design features like pressure release systems, provision of humps or regulators etc.

### **4.2.6 MAINTENANCE OF UNLINED CANALS**

#### **4.2.6.1 Some of the most desirable requirements are**

- A clean bed.
- Straight clean slopes.

- Uniform berm widths.
- Uniform regular top width.

#### **4.2.6.2 Bed and Berms**

The beds and berms should be correctly aligned. These should be scraped, where necessary and especially in tail reaches. The canal should be straightened. The kinks and irregularities should be removed and curves should be eased off where scouring or silting takes place. Clearing operation should be started from downstream to upstream.

#### **4.2.6.3 Bed**

All grass should be scraped and weeds removed from the silted bed wherever they are found to exist since their presence induces silt deposits.

All accumulation or deposits or mounds of silt should be removed.

Beds should be levelled and their gradient regularized.

The canals that carry silt-free water from the reservoirs generally get infested with aquatic weed growth which reduces their capacity and impairs proper functioning. Such canals should be kept clear of aquatic weeds.

#### **4.2.6.4 Berms**

Berms should be kept straight by trimming projections after aligning them correctly.

#### **4.2.6.5 Silt Clearance**

Silt ejectors/desilting basins, wherever provided should be operated regularly to prevent accumulation of silt. Longitudinal sections of the silted bed of canals should be taken during closure immediately after monsoons and the gradient at which silt should be removed should be ascertained.

#### **4.2.6.6 Bridges and Siphons**

When a canal is running brushwood that collects at bridges, siphons and falls should be removed away from the banks, dried and burnt. When trees fall into a canal they should be removed at once. Silt and rubbish should be cleared from under the bridges.

#### **4.2.6.7 Scouring**

In case of excessive scouring at any point adequate measures should be taken to stop these.

#### **4.2.6.8 Flow and Gauges**

To have effective control in regulation, it is desirable to observe discharge at conspicuous places. Gauges should be installed at the head and tail of all the channels and at important points in between. Their readings should be observed and recorded daily.

#### **4.2.6.9 Banks**

- i) The banks should be brought up and maintained to full section. All holes should be traced out and fully opened up. The fallen or loose lumps of earth should be removed. Filling and repairing should be properly done. Both edges of the bank especially the

inner ones should be neatly aligned parallel to the canal. Both inner and outer slopes and toes of the banks should be free from irregularities. The top of both the banks should be kept smooth and free from holes.

- ii) Side slopes are usually kept 1:1 in cutting and 1.5:1 in filling. If the soil is comparatively sandy gentler slopes say 1.5:1 in cutting and 2:1 may be provided.
- iii) Following precautions may be taken to ensure stability of the Embankments and to maintain their slopes.
  - Adequate compaction to avoid settling on saturation,
  - Prevention of cracks due to settling of fills,
  - Prevention of seepage,
  - Protection from burrowing animals.

#### **4.2.6.10 Roads and Ramps**

Roads and ramps should be kept smooth and shall have a regular longitudinal grade. At outlets and bridge crossings the road should be specially attended. A dowel should be made to the desired size.

#### **4.2.6.11 Cross Drainage Works**

A canal has to intercept various drainage systems along its route. Most of the crossings are of the following types.

- (a) *Crossing the canal over the drainage*
  - Aqueducts
  - Syphon Aqueducts
- (b) *Crossing the Drainage over the Canal*
  - Supper Passage
  - Syphon

The water passages through these drainage works are usually restricted. These are liable to get damaged due to the obstructions created by floating objects like logs, trees, trunks, dead animals, soft material like twigs and leaves. Adequate measures have to be taken to avoid damage to these water passages.

### **4.2.7 MAINTENANCE OF LINED CANALS**

#### **4.2.7.1 Desirable Requirement**

It should maintain its imperviousness. It should continue to have the same discharge capacity for which it was designed. The reduction in discharge may be due to:

- i) accumulation of silt
- ii) cracking of lining
- iii) failure of drainage
- iv) growth of weeds, algae etc.
- v) seepage and evaporation.

No silt should be normally permitted to take place in a lined canal. Sometimes the canal may have to be run at less than the designed full supply demands on account of fluctuating water demands. Such condition may cause deposition of silt over the bed owing to low velocities of flow. Consequently discharge carrying capacity is adversely affected. The silt deposition in lined canals can be minimized by judicious operation of gates or cross regulators, silt ejectors/desilting basins, wherever provided.

#### **4.2.7.2 Inspection of Lining**

During the canal closure period the lining, its auxiliaries and special design features should be carefully inspected. Following points should be noted:

- i) Whether any cavities or pockets have been formed behind the lining.
- ii) Development of any cracks or displacement or damage to the lining.
- iii) Whether the filter material in the joints of the lining is sound, intact and leak proof and any weed growth in the joints has taken place.
- iv) Whether any pressure release arrangements and humps or regulators function effectively.
- v) Whether pipes and openings provided in the crest of the falls are choked.
- vi) Silt deposits and weed growth.
- vii) Full supply water level, gauges, bench marks etc.

#### **4.2.7.3 Lining - Defects and their Repairs**

##### **i) Defects**

Defects ranging from small settlement cracks to excessive heaving displacement and sinking of the lining may be due to following reasons:

- Cuts in soft fine ground soils especially when lining was laid on the soil without any special preparation of the subgrade.
- High water table situated considerably above the canal bed, especially in fine grained soils, where weep holes or other simple drainage devices are not very effective.
- Freshly laid embankments.
- High continuous spoil banks, left too near the canal excavation without sufficiently wide berms and adequate arrangement for draining the rain water away from the canal and similar situations permitting surface drainage to enter behind the lining.
- Cavities behind the lining caused due to sucking out action on subgrade material by oscillating waves or fluctuating supplies of water of the canal through cracks, open joints and holes in lining.

##### **ii) Remedies**

- Pockets or any activities detected behind the lining should be carefully packed with sand or other suitable material. During such operations, however, care should be taken to ensure that the lining does not get damaged or displaced.

- Damaged or displaced portions of lining should be removed and replaced by fresh lining of a quality comparable to the original lining. The subgrade should be thoroughly compacted and prepared before laying the fresh lining. The cracks (other than hair cracks ) should be filled so as to ensure water-tightness of the lining . A more effective sealing of the cracks may be obtained by cutting a V-groove along the face of the cracks before filling with sealing compound. Dumping powdered clay upstream of the cracks may seal minor cracks on the lining.
- The damaged or displaced portions of the joint filter should be carefully removed. The joint should be cleaned of dirt weed etc., before filling in fresh filter material.
- The choked pressure release pipes should be cleaned by intermittent application of air and water by rodding. Defective flap valves or other parts should be repaired or replaced. The humps or regulators should be well maintained and repaired.
- All drainage and pressure release pipes and openings should be cleaned of any dirt, debris etc. and water accumulating upstream of the fall, if any, should be drained.
- In pervious linings, such as boulder lining, any portion in which excessive settlement has taken place, should be repaired by dismantling, making up the subgrade and relaying the lining.
- The lining should be protected from ingress of rain water behind the lining.

#### **4.2.7.4 Reaches with High Subsoil Water Level**

The subsoil water level should be observed carefully and regularly during and after rainy season besides routine observations from time to time. In case of rise, the adequacy of pressure release systems or other remedial measures like humps, regulators etc. provided for the safety of the lining should be reviewed and further measures adopted.

#### **4.2.7.5 Seepage through Embankments**

Seepage through embankments, if any, should be observed at reasonable intervals of time. Observations of seepage flow should be made and abnormal increase in the seepage rate and soil particles should be reviewed with caution, its possible causes investigated and remedial measures taken.

#### **4.2.7.6 Silt Clearance**

If any silt deposition is detected during inspection, steps should be taken to investigate causes thereof and to take remedial measures for the same. Only in exceptional circumstances it may be necessary to excavate the silt and remove it. If any silting tendency is noticed in the form of reduction of discharge carrying capacity, cross-sections of the lined canal should be taken at frequent intervals to determine the extent of silting and to see if the silt deposited during monsoons can be flushed out during non-monsoon periods when the water is silt free. Where silt clearance is unavoidable, it should be done carefully by manual labour to prevent damage to the lining.

#### **4.2.7.7 Weed Removal**

Aquatic weed growth, if observed below the supply level should be removed. Land weed growing over the free board should also be controlled.

#### **4.2.7.8 Canal Banks and Ramps**

The canal banks should be inspected for the seepage conditions at the outer slope and for some distance beyond the toe, especially in high fill reaches. The roads and ramps should be properly maintained.

### **4.3 TRANSMISSION THROUGH PIPES**

#### **4.3.1 PROBLEMS IN TRANSMISSION MAINS**

##### **4.3.1.1 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.

##### **4.3.1.2 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.

##### **4.3.1.3 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.

##### **4.3.1.4 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.

##### **4.3.1.5 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.

#### **4.3.1.6 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.

### **4.3.2 OPERATION SCHEDULE**

#### **4.3.2.1 Mapping and inventory of pipes and fittings in the water supply system**

Availability of updated transmission system maps with location of valves, flow meters and pressure gauges is the first requirement for preparation of operation schedule. The agency should set up routine procedures for preparing and updating the maps and inventory of pipes, valves and tapplings if any on the transmission mains. The maps shall be exchanged with other public utilities and also contain information about the location of other utility services like electricity, communications etc. with reference to the alignment of transmission.

Valve location maps, apart from indicating location of valves, also show the direction to open the valve, number of turns to open, make of valve and date of fixing of valve. At times plan and profile drawings are also available which show the depth of pipe, pipe location vertically and horizontally and distance from reference point. Hydraulic gradient lines are also to be marked to indicate the pressures in the transmission system. They can be used for identifying high pressure or problem areas with low pressures.

The activities involved in mapping are :

- Establishment of consultative process with management of other utility services like electricity, communications etc.
- Definition of maps such as layout, scale, representation of pipes, valves, trappings/connections etc.
- Establishment of procedures for storage and retrieval and updating of maps and inventory information including intersections.
- Setting up procedures for collecting map information in the field including verification in the field for compliance of the as built drawings with design.

**Field Survey :** Existing maps are used or conventional survey is carried out for preparation and up-dation of maps. As an alternative to traditional survey and map preparation, total station method is gaining popularity. Total station instruments can be used for survey and mapping of pipelines where data is not readily available.

#### **4.3.2.2 Normal operations of the water supply distribution system**

The efficiency and effectiveness of a water supply transmission system depends on the operating personnel's knowledge of the variables that affect the continuity, reliability, and quantity of water transmitted. The operational staff should be able to carry out changes in the hydraulic status of the system as required depending on those variables promptly and effectively. Routine operations shall be specified which are activities for adjusting the valves and operation of pumps to match the prevailing conditions (flows, pressures, levels and operation of pumps).

Valve and pump operations will have to be controlled as per a schedule. The schedule shall contain operations for operating the transmission system. It should contain procedures to obtain, process, and analyse the variables related to water flows, pressures and levels as well as the consequences of manipulating control devices, such as operation of valves and/or pumps so that the hydraulic status of the system can match the required capacity of the system for transmission of water. When operators change their shifts information on valve closure and opening must be exchanged.

#### **4.3.2.3 Operations in abnormal conditions**

Operations other than routine viz. during breakdowns and emergencies have to be specified to be carried out in specific circumstances when normal conditions change i.e., when flows, pressures and levels and operation of pumps change.

#### **4.3.2.4 Evaluation of Hydraulic Conditions**

A continuous evaluation of the hydraulic conditions of the water supply system can be done by the O&M personnel after obtaining the data on water volumes in the reservoirs, flow meter readings from and into the reservoirs connected to a transmission system and compared with the expected performance. This evaluation shall lead to identification of operational problems and/or system faults. Depending on the type of problems actions have to be initiated to ensure that the system functions as per the requirement.

#### **4.3.2.5 System Pressures**

Maintenance of a continuous positive pressures in the mains at the time of transmission of water is required. Locations along the transmission mains which show low pressures have to be promptly investigated if necessary by measuring pressures with pressure gauges. Low pressures may be due to:

- i) purposefully or accidentally a line valve is left closed or partly closed or blockage may occur due to any material causing loss of pressure,
- ii) high velocities in small pipelines,
- iii) low water levels in service reservoir (SR) feeding into the transmission main,
- iv) failure of pumps either due to power failure or mechanical failure feeding the transmission system.

#### **4.3.2.6 Simulation of Transmission Network**

Operations have to be planned for specific circumstances such as failure at source, failure of pumps, leakages or bursts. Criteria have to be determined on the basis of analysis of the effects of particular operations on the hydraulic configuration of the water supply transmission system. These effects can be seen in simulated operating conditions. Mathematical simulation models can be developed from basic data on the network such as length, size, flow, characteristics of pumps, valves, reservoir levels etc. This approach can be very useful for analysing the effects of variables on large and complex water supply transmission systems.



#### **4.3.2.7 Sampling for Quality of Water**

The agency operating the water supply system is charged with the primary responsibility of ensuring that the water supplied to the consumer is of an appropriate quality. To achieve this objective it is necessary that the physical, chemical and bacteriological tests are carried out for the water samples collected at frequent intervals. The minimum number of samples to be collected from a water supply system should be as prescribed in the Chapter 15 of the Manual on Water Supply & Treatment. Samples should be taken at different points of the transmission system on each occasion to enable overall assessment. In the event of epidemic or danger of pollution more frequent sampling may be required especially for bacteriological quality.

#### **4.3.2.8 System Surveillance**

*Surveillance of Transmission system is done*

- To detect and correct sanitary hazards.
- To detect and correct any deterioration of the transmission system facilities.
- To detect encroachment of transmission system facilities by other utilities such as sewer and storm water lines, power cables, telecom cables etc. and
- To detect and correct damages to the system facilities by vandalism.

These checks are done routinely. In addition checks are done under special circumstances for assessing damage of the transmission system after flooding along the alignment following a heavy storm. All these checks are also done for above ground water facilities such as valves and valve chambers or exposed pipelines. Any activity or situation that might endanger the water facility or water quality shall be investigated and corrective action is to be taken. Surveillance shall also include looking for unauthorised construction activity on or near the utility's pipelines which may pose a physical threat to the mains. Any digging or excavation or blasting near the mains shall be closely supervised by the utility staff. Surveillance of Valve chambers and valves of the transmission system shall be done as noted in para 4.3.3.

### **4.3.3 MAINTENANCE SCHEDULE**

A maintenance schedule is required to be prepared to improve the level of maintenance of water Transmission system through improved co-ordination and planning of administrative and field work and through the use of adequate techniques, equipment and materials for field maintenance. The schedule has to be flexible so that it can achieve team action with the available vehicles and tools. Co-ordination of activities is required for spares and fittings, quality control of materials used and services rendered. Training of maintenance staff shall, apart from the technical skills, include training to achieve better public relations with consumers.

#### **4.3.3.1 Activities in Maintenance Schedule**

Following activities are to be included in the schedule:

- i) Develop and conduct a surveillance programme for leaks in pipelines, pipe joints and valves,
- ii) Develop and conduct a water quality surveillance programme,

- iii) Develop and conduct a programme for locating and repairing leaks including rectifying cross connections if any, arrange for flushing, cleaning and disinfecting the mains,
- iv) Establish procedures for setting up maintenance schedules and obtain and process the information provided by the public and the maintenance teams about the pipeline leaks,
- v) Establish repair procedures for standard services and with provision for continuous training of the team members,
- vi) Procure appropriate machinery, equipment and tools for repair of leaks and replacement of pipes and valves,
- vii) Allocate suitable transport, tools and equipment to each maintenance team,
- viii) Establish time, labour and material requirement and output expected, time required and other standards for each maintenance task, and
- ix) Arrange for monitoring the productivity of each team.

#### **4.3.3.2 Preventive Maintenance Schedule**

A preventive maintenance schedule has to be prepared for:

- i) Maintenance of the pipelines with particulars of the tasks to be undertaken, works not completed, works completed,
- ii) Servicing of valves, expansion joints etc.
- iii) Maintenance of valve chambers,
- iv) Maintenance of record of tools, materials, labour, and
- iv) Costs required to carry out each task.

##### ***(a) Servicing of Valves***

Seating of Valves which are subject to operations several times is likely to become leaky or pass the flow downstream even after closing tight. Periodical servicing will be required for valves, expansion joints, flow meters and pressure gauges. Corrosion of valves is the main problem in some areas and can cause failure of bonnet and gland bolts. Leaks from spindle rods occur and bonnet separates from the body. Stainless steel bolts can be used for replacement and the valve can be wrapped in polyethylene wrap to prevent corrosion.

##### ***(b) Manufacturers' Catalogues***

The manufacturer's catalogues may be referred and comprehensive servicing procedures should be prepared for the periodical servicing. These procedures shall contain manufacturer's name, address telephone number etc. and also the technical information furnished by the manufacturers of the equipment used in the transmission system such as sluice valves, BF valves, air valves, pressure gauges, flow meters, etc. The test certificates, inspection reports and warranty certificates of these equipment shall also be kept along with the manual.

##### ***(c) List of Spares***

A list of spares required for the transmission system shall be prepared and the spares shall be procured and kept for use. The list of probable spares to be kept in stock may include the following:

Spare check nuts and spindle rods and assorted bolts; nuts and washers for the flanged joints, gaskets for flanged joints for all sizes of sluice valves installed in the transmission system, spare manhole covers and consumables like the gland rope, grease, cotton waste, jointing material like rubber gaskets, spun yarn, pig lead and lead wool.

*(d) List of Tools*

The necessary tools equipment to properly repair and correct both the routine problems and for facilitating repairs and replacements in a Transmission system have to be identified and provided to the maintenance staff. Some of the tools for the maintenance work in a Transmission system : Key rods for operation of all sluice valves, hooks for lifting manhole covers, pipe wrench of appropriate sizes (200, 300 or 450 mm) DE spanner set, ring spanner set, screw drivers, pliers, hammers, chisels, caulking tools for lead and spun yarn, ladles and pans for melting and pouring lead joints, excavation tools such as crow bars, spades, iron baskets, buckets and de-watering pumps. In case of large diameter transmission system excavators, cranes, diesel welding sets, welding electrodes, gas cutting accessories and gas cylinders will also be required .

*(e) Maintenance of Chambers for appurtenances*

Valve chambers shall be checked to ensure that they are not damaged, nor filled up with earth or buried in pavement. Cover of valve chambers are stolen or broken up by vandalism or accidentally leading to damage to the valve itself or will lead to accidental fall into the open valve chamber; such situations have to be corrected on priority. Road improvement works require constant attention of water utility staff since the valves may be lost or at times the valve chambers in the roads have to be reconstructed to match the renewed road surface. Valve Chambers on cross country pipelines are likely to be tampered to collect water and are likely to be affected by floods and agricultural and industrial activities. Leakages at such places will affect the water quality by cross connections and hence these leaks require to be attended on priority.

#### **4.3.4 MAINTENANCE OF PIPELINES**

##### **4.3.4.1 Main Breaks**

Pipeline bursts/main breaks can occur at any time and the utility shall have a plan for attending to such events. This plan must be written down, disseminated to all concerned and the agency must always be in readiness to implement the plan immediately after the pipe break is reported. After a pipe break is located, determine which valve is to be closed to isolate the section where the break has occurred. Some important consumers may be on the transmission system and having an industrial process dependent on water supply which cannot be shut down as fast as the water supply lines are cut off and should be notified about the break. These consumers have to be informed about the probable interruption in water supply and also the estimated time of resumption of water supply.

After the closure of the valve the dewatering/mud pumps are used to drain the pipe break points. The sides of trenches have to be properly protected before the workers enter the pit. The damaged pipe is removed, and the accumulated silt is removed from inside the pipe and the damaged pipe is replaced and the line is disinfected before bringing into use. A report shall be prepared following every pipe break about the cause of such break, the resources

required for rectification and the time and cost required for repairing etc. so that the agency can follow up with measures for avoiding such breaks and also modify their plan to address such breaks in future.

#### **4.3.4.2 Deterioration of Pipes**

Pipes deteriorate on the inside because of water corrosion and erosion and on the outside because of corrosion from aggressive soil and water/moisture. Depending upon the material of the pipes these are subject to some deterioration, loss of water carrying capacity, leaks, corrosion and pitting, tuberculation, deposition of sediment and slime growth. Preventive maintenance of transmission system assures the twin objectives of preserving the bacteriological quality of water carried in the transmission mains 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 aspects in the 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 the Chapter 15 on Water Audit and Leakage Control in this manual

#### **4.3.4.3 Flushing of pipelines**

Flushing is done to clean the transmission lines by removing impurities or sediment that may be present in the pipe; this is particularly essential in the case of transmission lines carrying raw water. Routine flushing of raw water pipelines is often necessary. It is advisable that a programme for flushing is prepared and followed so that water mains are flushed before the water quality deteriorates and consumers start complaining. Since flushing is not the only solution to the water quality problems of a transmission system, proper operation of treatment process and cleaning of service reservoirs supplying water to the transmission system shall also be planned along with the flushing of distribution system. Flushing is usually done in 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.

#### **4.3.4.4 Flushing and 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. The topics of cleaning of pipelines including cleaning and swabbing are dealt in Chapter 10 of Manual on Water Supply & Treatment.

#### **4.3.4.5 Cement Mortar Lining**

The present trend is to use cement mortar lined DI pipes or MS pipes so that they will not lose their carrying capacity with use and age. Still many new pipelines are proposed with unlined metal pipes and there are several existing pipelines with bare metal surface such as CI or MS. With passage of time these pipelines deteriorate and require rehabilitation. Cement mortar lining is done which stifles corrosion through its ability to develop high alkalinity. In-situ cement mortar lining of existing metal water mains has been beneficial where:

- i) Pipe carrying capacity has reduced due to tuberculation,
- ii) Water quality is affected due to release of corrosion products from the pipes to the water, and
- iii) Leaks occur through joints and pipe walls.

#### **4.3.5 LEAKAGE CONTROL**

Leakage of water in the transmission system occurs by way of leakage from pipes, joints & fittings, reservoirs & overflows of reservoirs & sumps. The objective of leakage control programme is to reduce to a minimum the time that elapses between the occurrence of a leak and its repair. The volume of water lost through each leak should be reduced by taking whatever action is technically and economically feasible to ensure that the leak is repaired as quickly as possible. To achieve this, the agency shall prescribe procedures for identifying, reporting, repairing and accounting for all visible leaks. It will be beneficial for the agency if the procedures involve the conscious and active participation of the population served by the agency apart from its own staff.

##### **4.3.5.1 Procedures for reporting Visible Leaks**

Utility has to establish procedures whereby the population residing along the transmission mains can notify the visible leaks to the agency. The agency staff can also report visible leaks found by them while carrying out other works on the water supply system. Utility has to establish procedures for prompt repair of leaks and for attending efficiently and accurately to the leaks. Critical areas where leaks often occur have to be identified and appropriate corrective measures have to be implemented.

##### **4.3.5.2 Procedures for detecting invisible Leaks**

In the case of transmission mains the leaks become visible due to the high pressures. However if it is necessary to identify the invisible leaks procedures have to be established for detecting and locating non visible leaks. Selection and procurement of equipment for detection and location of leaks must take into account the cost effectiveness and the financial capability of the agency. Description of equipment for leak detection and location and the methodology are described is given in the Chapter 15 of this manual. Management has to process the data and evaluate the work on detection and location of leaks and for dissemination of the results and initiate actions to control the overall problem of water loss.

#### **4.3.6 CHLORINE RESIDUAL TESTING**

A minimum free chlorine residual of about 0.2 mg/l at the receiving reservoir of a transmission system is often maintained to ensure that contamination is destroyed by the chlorine. Hence absence of residual chlorine could indicate potential presence of heavy contamination in the transmission system. If routine checks of the incoming water at the end of the transmission system are revealing, required chlorine residuals and any sudden absence of residual chlorine should alert the operating staff to take up prompt investigations. Immediate steps to be taken are:

- i) Re-testing of residual chlorine,
- ii) Checking chlorination equipment at the start of the transmission system,

- iii) Searching for source of contamination along the transmission system which has caused the increased chlorine demand,
- iv) Immediate rectification of source of contamination.

#### **4.3.6.1 Cross Connections**

Contaminated water through cross connections of water supply lines with sewers and drains is a problem prevailing widely. Regular survey along the alignment of transmission system has to be undertaken to identify potential areas likely to be affected by cross connections and back-flow. All field personnel should be constantly alert for situations where cross connections are likely to exist. Densely populated areas and slums without sanitation facilities located along the transmission lines are some of the locations prone for cross connections. After identifying the cross connections, remedial measures are taken up which include: providing horizontal and vertical separation between the water main and the sewer/drain, (refer to para 10.11.1 of Chapter 10 of this manual on Water Supply & Treatment).

#### **4.3.7 TELEMETRY AND SCADA SYSTEMS**

##### **Manual Monitoring**

Normally the Managers of O&M of water utilities monitor levels in service reservoirs fed by the transmission system and also monitor the flow meter readings of upstream and downstream reservoirs connected by a transmission system. The pressures of the pipeline at salient points are also monitored. Data on operation of pumps such as hours of pumping and failure of pumps and on water quality by measuring residual chlorine is also monitored. The manager usually uses the telephone line or wireless unit to gather the data, analyses the same and uses his discretion gained with experience and takes decisions to ensure that the system is operating with required efficiency. Manual collection of data and analysis may not be helpful in large undertakings if water utilities have to aim at enhanced customer service by improving water quality and service level with reduced costs. These days acquisition of such data by Telemetry and SCADA is being adopted. This Topic is discussed in Chapter 12 on Distribution system of this manual.

#### **4.3.8 RECORDS AND REPORTS**

##### **4.3.8.1 Record System**

A record system has to be developed which should be realistic and applicable to the operating problems involved in the Transmission system. Management must be clear as to why the data/information are collected, as to who will review the data and who will respond to the results of review. The most efficient way to keep records is to plan what data is essential and then prepare the formats followed by guidelines, fill the data, frequency and to send the record to for review and report. Sample records to be maintained are given below for guidance.

- i) Updated transmission system map with alignment plan and longitudinal section of the pipeline showing the invert levels and hydraulic grade lines of the pipelines and location of appurtenances, flow meters and pressure gauges,
- ii) Record of flow meter readings at upstream and downstream ends of the transmission system,

- iii) Record of water levels of the reservoirs at both upstream and downstream ends of the transmission system,
- iv) Pressure readings of the transmission system pipelines,
- v) Review of record of pressures and flows,
- vi) Identify the persistent low pressures in the transmission system,
- vii) Record on age of pipes/quality of pipes,
- viii) Identify pipelines to be replaced,
- ix) Presence of corrosive water in the system,
- x) Identify the source of leaks,
- xi) Identify the persistent leak points,
- xii) Status of bulk meters – functional,
- xiii) Identify the residual chlorine levels at the receiving and transmitting ends of the transmission system,
- xiv) Identify the bacteriological quality of the water sampled from the reservoirs linked to the transmission system,
- xv) Identify reasons for residual chlorine being absent/where bacteriological samples are unwholesome,
- xvi) Record on when the pipeline leaks were repaired or pipes changed and the cost of materials and labour cost thereof,
- xvii) Record on when the gland ropes of the valves distribution system were changed and the cost of materials and labour cost thereof,
- xviii) Record on when the spares of the valves were changed and the cost of materials and labour cost thereof,
- xix) Record on when the expansion joints were serviced and the cost of materials and labour spent for repairing the same,
- xx) Record on when the manholes on the valve chambers were changed and the cost of materials and labour cost thereof,
- xxi) Record on man-hours spent on routine operations in the transmission system in the previous year and the cost thereof,
- xxii) Record on total cost of repairs and replacements in previous year along with break up of material cost and labour cost with amount spent on outside agencies for repairs and replacements,
- xxiii) Record on when the exposed piping was last painted and the cost of materials and labour cost thereof.

#### **4.3.8.2 Reports**

With the accumulation of all essential data a report can be prepared evaluating the O&M of the facility. The report can identify the deficiencies in the system and its appurtenances and then plan future repairs to the transmission system, valves and other equipment or for replacement of defective valves or other equipment.

### 4.3.9 CHECKS TO BE CARRIED OUT IN TRANSMISSION SYSTEM

#### 4.3.9.1 Programme for carrying out checks in the transmission system

A programme has to be prepared for each zone of the transmission system which shall contain procedures for routine tasks, checks and inspections at intervals viz. Daily, weekly, quarterly semi-annually or annually. This plan shall fix responsibility, timing for action, ways and means of completing the action as to when and who should take the action and the need to take these actions. Simple checklists for use by the managerial staff can be prepared to ensure that the O&M staff have completed the tasks assigned to them.

#### 4.3.9.2 Check Lists

S. No.	Checks required/undertaken	Status	Suggested frequency of reporting
1.	Check whether the operation of valves is smooth without any abrupt stoppage during closure		
2.	Check whether closure of a valve results in complete stoppage of flow or if any flow passes the valve (passing valve)		
3.	Check for status of scouring and then proper closure of washout valves		
4.	Check for leaks through pipes		
5.	Check for leakage through valves at gland, bolts or any other place		
6.	Check for leaks at the appurtenances including expansion joints		
7.	Check for any signs of corrosion of pipelines		
8.	Check for the status of manhole covers over the chamber covers; are they corroded		
9.	Inspect for any possibilities of pollution of the transmission system		
10.	Check status of out-fall drain for scour valves and chances of contamination at scours		
11.	Assess the need for painting of the exposed piping work		
12.	Check for availability of spares for Valves, expansion joints and pipes and jointing materials		
13.	Carry out review of pressures		
14.	Carry out review of flows		
15.	Check age of pipes/C value of pipes		
16.	Check for corrosive water		
17.	Study inflows and outflows into the reservoirs linked to the transmission system		
18.	Identify source of leakage		
19.	Metering		
	Status of bulk metering		
	Review facilities for repair of meters		
20.	Availability of updated system map		