GOVERNMENT OF JAPAN
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

STATE OF ERITREA
MINISTRY OF LAND, WATER AND ENVIRONMENT

STUDY
ON
GROUNDWATER DEVELOPMENT AND WATER SUPPLY
FOR
SEVEN TOWNS IN SOUTHERN REGION
OF
ERITREA

TRAINING MANUAL FOR STAFF OF WSA

JANUARY 1999

SANYU CONSULTANTS INC.

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CHAPTER 1 PURPOSE AND POLICY

1.1 Introduction

Water is essential to man, animals and plants and without water life on earth would not exist. From the very beginning of human life, people have settled close to water sources, along rivers, besides lakes or near natural springs. In deep, where people live, some water is normally available for drinking, domestic use and possibly for watering animals. This does not imply, however, that the source of water is convenient and of sufficient capacity, nor that the water is safe and wholesome. On the contrary, in many countries people live in areas where water is scarce. Often it has to be carried over long distances, particularly during dry periods. Scarcity of water may also lead people to use sources that are contaminated by human or animal feces, and are thus dangerous to human health.

In most small towns and rural communities in developing countries, the prevailing water supply conditions are very different from urban installations. Trained personnel for planning, designing, operating and managing are generally not available and in most cases they are dependent on external sources.

Therefore, this Training Manual is aimed to increase the skills of the staff engaged in water supply system for groundwater development and water supply for seven towns in southern Region of Eritrea in terms of planning, designing and efficient O&M of the supply facilities which will best meet the actual social conditions of their locality.

1.2 Preliminary Remarks

Construction of water facilities and their maintenance are, both sides of the shield. Therefore, at the stage of planning, designing and construction of facilities, the problem of maintenance, and, in actual maintenance of facilities, the object and intention of their planning and designing must be fully reflected on for their safe and efficient operation.

In the planning and designing of water facilities, therefore, you are advised to study the contents of the present volume in full, along with investigation of the function and operational results of the existing facilities, and aim to establish such facilities as will best meet the actual conditions of your system. Although we have given adequate considerations to the problem of maintenance of facilities, you are urged to make better and more effective use of the book by studying also the "Operation & Maintenance Manual".

In addition, when you have need to adopt a new technique or, for other reasons, to build any other facilities than those introduced in this book, you have to study its function and efficiency and ascertain whether their functional quality is equal at least or superior to that described herein prior to actual work.

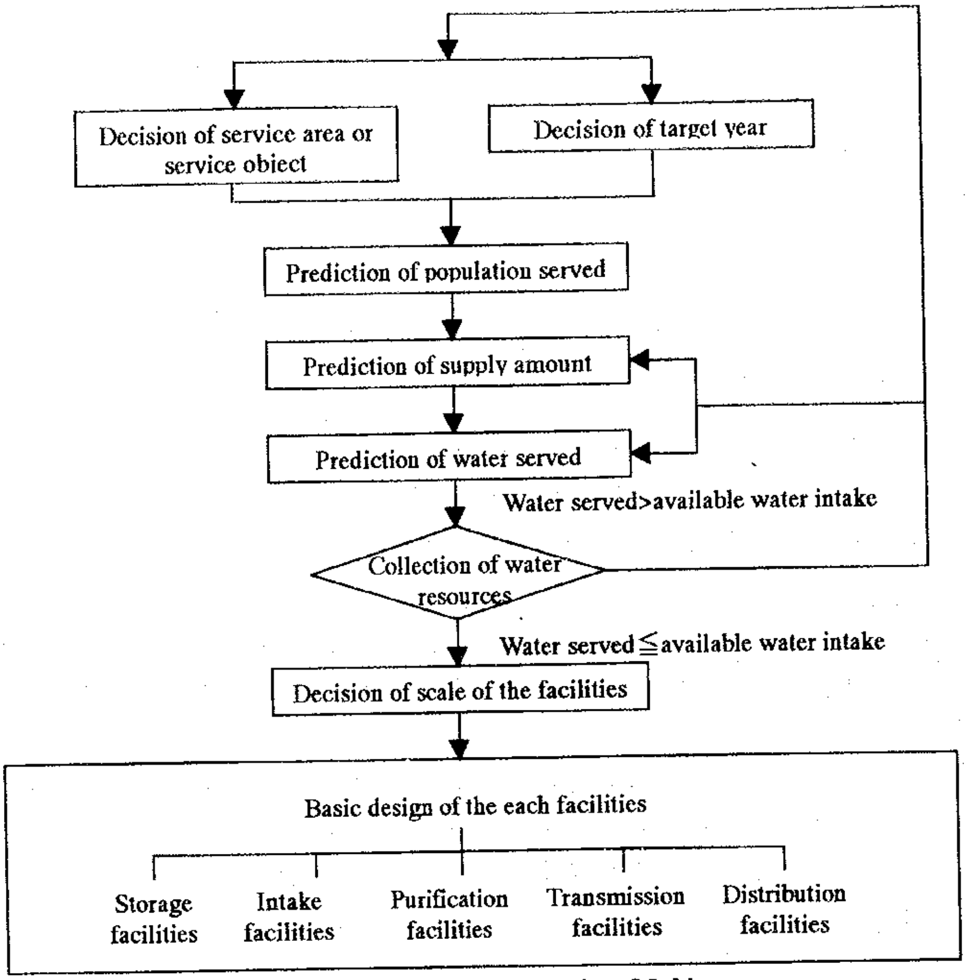

Fig. 1. Procedure for Project Making

1.3 Basic Policy

Waterworks is an important public utility of permanent nature for supplying water necessary for our daily life as well as for the activities of our communities. It follows from this that all-out survey and planning are prerequisite for construction or expansion of water facilities.

Before construction of waterworks facilities, the project goes through stages of initial idea, planning and designing for materialization of the plan. The basic plan includes initial idea for water facilities construction based on the trend of water demand, conditions of water resources, and of other waterworks and water supplying authorities in the neighboring areas. On the basis of such information gained, primary investigations are carried out in order to decide the scale of construction, water source and main designing for the project. Followed by detailed designing for actual construction of each component unit after minute surveys.

Throughout the stages of waterworks construction basic planning plays the most important part in that it always influences the stability, safety and economy of water industry; accordingly, in the decision or adoption of basic planning, both minute and comprehensive checking is an indispensable step.

Moreover, the subjects to be determined in basic construction plan are itemized below, and also, with these technical items, estimates for financial balance carries as grave in importance as these.

1) Scope of facilities........ service area, amount of supply (designed year population served)

2) Water resource .... type of water source, intake spot, amount of intake

3) Basic designs .... laying-out of important structures, type of construction, hydraulic calculations, structural computations and cost estimates

In deciding waterworks construction basic plan, the following plans should be considered, because of their relations with water works construction and expansion:

(1) Plans which have relations with water demand

Plans related with urban rearrangement
Plans related with housing construction
Plans related with industrial location
Plans related with sewerage rearrangement

(2) Plans concerning water resources

Plans related with water source development
Plans related with river administration
Plans related with water quality safety
Plans related with ground subsidence prevention

(3) Plan having connections with water facilities construction

Plans related with urban rearrangement
Plans related with road rearrangement
Plans related with environment protection

1.4 General Layout of Water Equipment

As regards general layout of water equipment and water levels, decisions should be reached after a comparative survey of the following items:

(1) Adaptability to its topographical conditions and their rational use.

(2) Safety and facility in construction and maintenance

(3) Low costs of construction and management

(4) Adaptability to expected municipal development

(5) Convenience for future extension of facilities

1.5 Principles of Construction

The general principles in waterworks construction are as follows:

(1) The water facilities shall be safe and endurable in structure against outer forces and loads such as gravity, loaded gravity, water pressure, earth pressure, air pressure, earthquake-shock, snow load, ice pressure, thermal stress, etc.

(2) The facilities shall be free from leaks and pollution in structure; especially in the case of facilities handing purified water, not only in structure, but in the choice of materials and the work upon these hygienic and watertight.

(3) Since some of the facilities have such portions and undergo friction, or are exposed to chemicals erosion or corrosion, care shall be taken of the choice of materials and work proceeding and, when needed, anti-erosion or anti-friction materials or work shall be adopted.

(4) Since a structure or pipeline laid where the level of groundwater is high, is often raised or slanted by buoyancy when empty, causing accidents, countermeasures for protection shall be perfect.

1.6 Facilities and Materials

Decision on machines and materials used in water facilities must be made after taking into consideration each item of the following instructions:

(1) Endurability in service

(2) Safety in quality in contact with supplied water for communities

(3) Facility in maintenance and management

(4) Adaptability to environment

CHAPTER 2 STORAGE AND INTAKE FACILITIES

2.1 Storage Facility

Roughly, storage facilities can be classified into three major categories, ie., waterworks reservoir, multi-purpose reservoir and tidal weir. In case ground water of good quality or natural river flow can be used, there is little need of storage facilities, but, in general, when new utilization of river water is projected, there might arise a concurrence of water rights and either the construction of its own reservoir or participation in the program of multi-purpose reservoirs for getting share of the expected water becomes inevitable.

In cases like the above, the shape and scale of storage facilities must be decided after comprehensive considerations on the river flow condition, the configuration and geological features of the site of the projected reservoir, areal development trend, economy in its construction and management, etc., along with the subject of projected intake amount and quality of water to be stored.

When it cannot be helped to provide storage or intake facilities where the quality of water is not necessarily good, adequate survey and investigation required for construction of raw water retaining equipment solely for purposes of strengthening purification system and maintaining safety of supplied water.

Adequate care should be required at the time of storage facility construction as to its possible effects upon the surroundings for fear of the structure deteriorating the environmental conditions. In recent years there is seen the tendency that prior to the start of developing activities of various sorts, sufficient estimation and assessments that the project development be carried out within the scope of environment protection. Since such principles are becoming introduced into the environment protective administration; therefore, reservoir construction needs to be viewed from this angle in order to meet its requirements.

Construction of reservoirs of more than normal scale means an act of environs alteration and the degree and scale of the project will be the rule to decide whether it threatens to reduce the safety of environment or not. At the time of planning or alteration of the project, therefore, an estimation as reliable as possible must be made of its effects upon the environs so that necessary steps can be taken to prevent its deterioration.

2.2 Intake Facility

2.2.1 General Principles

Water is generally classified into two categories, surface and ground waters; surface water includes river water, lake and marsh waters and reservoir water.

For intake facilities, intake weir, gate, tower, crib and conduit are used; in designing of these, by deciding its location, direction, height, section and structural style in accord with the river aspect at the site on the basis of an exact highest flood water level and drought water level, you should make possible, in time of the highest flood, operation of the flash-board weir, gates, etc. with safety. At the same time, the facilities must be strong enough against such pressures, scouring, floating log, stone and floe as at the time of maximum flood water. In case, some inpredictable interruptions might take place because of the peculiarity of the river, particular precautions required for protection of the facilities.

Intake facilities must be built at such a place as is free from inflow of any sort of polluted water and intrusion of sea-water. In selection of the site, without too much concern about the favorable conditions at the time, possible environmental change in the future must be taken into consideration.

2.2.2 Types of Intake Facility

(1) For River Source

Intake facilities shall be in accordance with the following conditions:

1) Intake facilities must be of such construction as will inflict the least possible effect upon the safety of the embankment or upon the flood flow from the respect of the water level, amount and condition of the river at the time of a flood.
2) It is desirable that intake facilities be provided with metering instruments for water levels and quantities and if need be, monitoring system for water quality.
3) For intake facilities, measures must be adopted for protection from peril and pollution such as setting of fences around them.

(2) For Groundwater Source

Ground water is classified into two categories; one is free ground water, and the other, pressure ground water. Free groundwater is such water as is contained in the stratum consisting of surface sands and gravels, the surface of which keeps contact with the rainwater seeping through the crevices and cracks in the earth, so its water surface fluctuates with the conditions of rain or snow; the quantity also changes and the temperature and quality of it is subject to be conditions of atmospheric temperature and pollution. For intaking of this kind of water, shallow wells are in general use. On the other hand, artesian groundwater has naturally a pressure of its own since it is inclose above and below by impermeable state, and, in some cases, spurts up; this kind of groundwater is usually found in a porous layer. In case this sport of groundwater is drawn up in excess, ground sinking results frequently. As a means of intaking this kind of groundwater, deep wells are in general use.

Subsoil water is such a kind of water as flows lurkingly about the riverbed, lakebed and thereabout. For intake of this category of water, shallow wells or infiltration galleries.

Spring water is a particular kind of ground water including stratum and fissure water.

Since the rate of recharge in ground water is much lower than that in surface water, excessive intake in a single well or area will give rise to a ground-subsidence and saltish water. Therefore, the following considerations are required for rational intaking by controlling each delivery well.

1) The pumping facilities should be of such construction as if free from clogging of the strainer throughout the year or for a longer period.

2) Proper pumpage for the well should be determined after sufficient investigations such as various kinds of pumping tests.

3) Provision of metering instruments for water levels, amount, intended to secure the planned intake and/or control it.

4) Ground water is a quality-blessed resource and so deserve our attention to preventing pollution from outside. Particularly, for intake facilities for spring water, roofing required.

(3) Shallow Well

Shallow well is a well of shallow depth for taking in free ground water or subsoil water from an aquifer; in general, these kind of wells are consituted of reinforced concrete pipeshape structure or steel strainers built underground and from the collecting apertures provided in the bottom (of the well) or on the wall, water is taken into the structure and then boosted by a pump. There is another kind of well (commonly called a Manchurian well in Japan) in which multipored collecting pipes are projected horizontally and radially from the wall, for intaking water into the pipe.

With this kind of structure when there is an aquifer containing good quality water in abundance, a small scaled, stable intake is possible.

However, for stabilized intake, the following considerations are required; (i) selection of adequate aquifer, (ii) construction of a well of such quality as will suit the conditions of the spoted and, (iii) adequate location of its bottom, reliable pumping capacity, prevention of pollution, etc.

(4) Deep Well

Deep wells are such facilities of steel made as are used to collect water direct from the underground artesian aquifer by means of a strainer inserted into the intake stratum. The depth is, in general, upwards of 30m, but, in some cases, there are found ones of even 400m.

While, in the case of a shallow well, out main interests lie in the areal extension of the aquifer, in the case of a deep well, longitudinal extension, ie, depth of aquifer is out principal concern; therefore, the strainer of a deep well should be long enough for the thickness of an aquifer.

The deep well consists of casing, strainer, the lift pipe hung within the casing and pump, and by use of the facilities, we are able to collect a comparatively large amount of water in a small site. However, to secure a stable intake, the following should be noted:

(i) adequate preliminary surveys, (ii) selection of good, reliable aquifer, (iii) installation of proper strainer, and (iv) selection of pump of capacity corresponding with the intake amount per unit hour, etc.

CHAPTER 3 PURIFICATION FACILITY

Purification facility is necessary in case that the source is river water. In case of ground water, only disinfecting facility is essential in general. Although there is no purification facility in the seven towns, it is one of main facility in the water works. Therefore, this chapter is given engineering knowledge for the stuff.

3.1 General Principles

Plans on purification plant site shall be decided in consideration of the relations with intake, conveyance, transmission and distribution facilities costs of construction and maintenance, safety in management and operation, efficiency prevention of pollution and geographical conditions, etc. For this purpose, surveys on natural environment, social surroundings, conditions of neighborhood land use, arranged conditions of neighboring rivers, of sewerage systems and the status quo of city or urban planning, etc. shall be conducted, along with an outlook for future state of things affecting our project. In site determination, survey shall be made about the following items:

(1) Well-balanced Layout of the Whole System

The location of purification facilities shall be so determined as each unit facilities may give the most rational function both economically and operationally.

(2) Sanitary Environment

Since the purification plan is a place where water for drinking and cooking purposes is produced, unhealthful conditions around are not to be left unimproved from prevention of pollution or from esthetic effects upon the sentiment of citizens.

(3) Advantage over Disasters and Uninterrupted Discharge of Flood Water

Water works enterprises are held responsible for supplying water to their customers all the time. As damages brought about by disasters are liable to cause a long-period water suspension and also often invite secondary public hazards, which must require our attention in initiating our program, too.

The type of disasters which water facilities undergo include; local intensive rainstorms, floods and earthquakes.

As is often the case, purification plant is located near a river, for reasons of intake convenience. However, in this connection, such a location should be avoided as is subjected to inundation at the time of a flood. In addition, a low land is extremely handicapped in layout of unit facilities, and difficult of waste water discharge, too.

Further, the level of ground water is usually high in a low land, which involves high cost of construction and difficulty in execution of the work.

It is also desirable that such a river exists in the neighborhood of the plant as receives overflows, rainwater and waste waters.

In construction project of purification plant, such location shall be chosen as has no national or local government-authorized property (historical remains, etc.) in its compound, no complications about obtaining, and favored with geological and geographical advantages.

As it is quite natural that all of the above requisites cannot be met, favorable location must be selected from a broad, composite viewpoint of assessment.

Choice and combination of purification processes shall be made in consideration of the quality of raw water, which varies according to the sort and surroundings of water resources and also to seasonal and weather conditions. Even in the same source, the quality of water changes with intake spot and intake period and in rainy or snowy seasons, not only its turbidity but pH, alkalinity, the number of bacterial colonies also reveal extreme fluctuations. The quality of ground or spring water is rather stable in comparison with that of surface water, but when pumpage changes or with shallow ground water and subsurface (or riverbed) water, change in quality may be perceived on some occasions.

Facilities of purification should desirably be planned in a composite way, i.e. both for purification facilities and for those of waste water treatment. Surveys should be made under the following items:

1) Decision on purification method should be made after checking on the quality of raw water in consideration once per month at least for the period of one year, along with surveys on the water source areal surroundings. Speaking about surveys of this kind, the more tests, the longer the period of the surveys, the more accurate must be the judgement; tests at the time of high turbidity, in period of drought and low temperatures, also needed.

2) As for surveys on raw water, besides the items specified in the water quality standards, checking on erosive free carbonic ackds, alkalining, BOD, SS, plankton algae, etc. required. The usual way adopted is performing tests from three different angles, i.e. physio-chemical, bateriological and biological fields. The final judgement is reached in a comprehensive way on the basis of the results obtained.

3) In addition to surveys on raw water, treatment of the water in question, and referential documents, surveys are desired on the filter plants in operation at present. By choosing some out of those where the same source is employed, similar qualitied water is employed or the facilities of which closely resembles the planned facilities in scale, the following items should be studied:

   a) Balance of water quantity and that of materials in the entire facilities
   b) The quality of raw and treated waters
   c) The basic plan and the present states
   d) Style and scale of purification facilities
   e) Sedimentability and filtrability of flocs
   f) Kinds of chemicals and feeding conditions
   g) The state of sludge removed from settling basins
   h) The state of backwashing of rapid filters and that standscraping of slow filters
   i) Quantity and quality of waste water discharged from other unit facilities

In particular, in the planning of waste water treatment it is absolutely necessary to grasp the quantity and quality of sludge discharged at each step of purification process. Moreover, the following surveys should also be carried out.

(1) Topographical Surveys

These surveys shall be conducted for the purpose of, (i) layout of facilities, (ii) temporary works, (iii) road building for the work, (iv) ground arranging by cutting, banking of earth, counter accident measures, etc.

(2) Geological Surveys

Geological surveys including boring tests, loading tests, soil tests, groundwater level measurings, etc. shall be conducted for dual purposes of foundation work plan and provisional construction program for the plan.

3.2 Receiving Well

Receiving well should be installed with the object of stabilizing the level of raw water led from conveyance facilities, regulating and grasping its amount so that the subsequent purifying processes of chemical feeding, settling and filtration be conducted with precision and facility. Therefore, for stabilization of water level, adequate baffling devices, surface area and detention period are needed, and for regulation and group of the raw water quantity, measurement equipment must be provided. However, at such filtration plans as the above objects and functions can satisfactorily be achieved, part or all of those facilities may be omitted.

3.3 Chemical Feeding Facility

In rapid filtration system, coagulation of the raw water by chemical agent is indispensable as pretreatment step. The tiny particles suspended in the water do not easily settle on the bottom, when left untouched, and when put to rapid filtration, they will pass on without being arrested by the filter layers. Therefore, it is of urgent need to coagulate these particles so as to make possible the separation of particles from water by help of the chemical coagulant.

In slow filtration, when the turbidity exceeds 30 degrees, that after settling process of common style is also high, causing clogging of the filter beds; therefore, reduction of turbidity beforehand by coagulo-settling process is also justified.

Feeding equipment for coagulation chemicals, therefore, must be provided for the facilities described above.

The chemical used for coagulation include: coagulants, alkaline agents and coagulo-assisting agents. Coagulants are used for congregating the suspended matter into flocs which easily settle in the water and liable to be arrested in the filter basin. Alkaline agents, for waters lacking alkalinity and coagulo-assisting chemicals, for promoting the effect of flocculation, sedimentation and filtration. Each of these is used in conjunction with coagulants. The chemicals to be used for this purpose must be examined and confirmed of their treatment effect, and not only flowless in appearance, toxicity and other hygenic respects after feeding of them but be easy to handle in transportation, too.

The dosage of the chemicals applied, which will naturally be conditioned according to the nature of raw water, must be decided after sufficient studies.

Storage facilities for the coagulant chemicals should be properly designed in consideration of the consumption and the feeding facilities, which is to meet both the max. and the min. dosage in precise measurement; the number and capacity per unit must also be correspondence to these factors. Feeding type must be determined in consideration of the property of each agent and the amount of water to be handled, that is, solid type or liquid type, fixed rate feeding or flow-relative feeding, any way adequate for consumption conditions. Since most of these chemicals are strongly either acidic or alkaline, feeding facilities must be of anti-erosive materials.

3.4 Chemical Sedimentation

Chemical sedimentation basin shall be built for purposes of removing most of the flocs that have grown large through the processes of chemical feeding, mixing and flocculation, by means of settling, separation process to lighten the load for the succeeding rapid filters. Settling basins must be equipped with the three functions, i.e. settling, buffering and draining. Actual conditions, however, should be studied further, in view of the whole picture of purification process.

For ensuring settling function all the time, the basin must be equipped with such sludgedraining device as suits the structure of the basin. In case satisfactory drainage seems difficult, it may be required to suspend the operation of the basin itself. In view of this kind of trouble, the drainage facilities must be of such quality as will satisfactorily handle the sludges without failure. In designing this facility, full consideration required in the light of its relations with the succeeding facilities for sludge disposal, as a link in the whole mechanism of waste disposal.

3.5 Rapid Sand Filter

Rapid sand filter is defined as filtration basin of rapid filtration system where the S.S. and other impurities in the water are separated after coagulation effected by chemical agent. In rapid filters, turbid removal is expected by passing water at a rapid rate through the relatively coarse grain layers of sand, and by their adhesion to the filtration media and sifting by the filtration layers. It is required, therefore, that the suspended matter, i.e. the object of removal, be beforehand coagulated and formed into flocs suitable for adhesion and sifting.

As regards the mechanism of suspended-matter removal in the filter layers, two stages (in removal) are considered. The first is a stage where the suspended particles of turbidity are transported near the surface of the filter media, where the functions of intercepting, arresting and subsequently, settling by gravity are supposed to remarkably progress.

The second is a stage where the transported particles are arrested by the media. This is interpreted to be ascribed to the interrelations between the suspended particles and arresting surfaces (the surfaces of media themselves in the beginning and subsequently, the surfaces formed by the arrested S.S.).

3.6 Normal Sedimentation Basin

Normal Sedimentation (or settling) basin is built for the purpose of separating suspended solids by natural (or physical) sedimentation and reducing the load charged upon slow (system) filtration basin.

For this purpose, it is necessary to design the shape of basin, inflow and outflow openings and training devices in such a manner as to check the growth of flow interrupting settling action.

Also, the basin should be designed to meet chemical treatment when it is known that the raw water turbidity exceeds 30° maximum during the year.

It is to be noted that in case of impounding reservoir of groundwater is employed as resources, the turbidity of raw water is always 10° or under, normal settling basin may be saved.

3.7 Slow Sand Filter

Slow filtration is a method of filtration which depends upon oxidation and decomposition of the impurities by groups of microorganisms growing in and on the sand surface. Unless there are conditions which interrupt organic life; in slow filter basins, suspended matter and bacteria in the water are not only arrested but, to a certain degree, ammonia nitrogen, odor, iron, manganese, synthetic detergent, phenol can also be removed.

The mechanism of slow sand filtration is described below.

When the infiltrated water passes through the layer of fine sands at a slow rate, the suspended matter contained in the water is arrested on the surface of the sand layer mainly by mechanical sifting action of the sand surface and adsorption to the surface of sand particles exerted by the minimal particles in the water. The arrested matter grows into mudlike layer by force of attached humus and nutrient salts, and on this layer, algae microorganism and group of bacteria which decompose these algae and organisms. Thus, these suspended matter microorganisms and their secretions get together and form an organism membrane or film. Most part of the purifying function of slow filtration is performed by sifting, adsorption and organic oxidation of this bio-film, correctly termed "biotic filter membrane".

The merit of slow filtration consists, as stated above, in the fact that high level purification can steadily be obtained without high operational technique. Therefore, in designing of slow filter basin, consideration must used not to lessen these advantages.

While, on the other hand, weak points are found in the fact that they need specious area for building the facilities and that labor required for scraping of soiled sands.

3.8 Disinfection Facility

Drinking water must be hygienically safe from bacterial pollution. It is impossible to completely remove the bacteria in the water only by means of normal purification processes, e.g. Settling and filtration. For this reason, in purification plants, in disregard of purifying method or the scale of facilities, disinfection facilities must be provided. It is to be remarked that in the days past because of absence of disinfection equipment or imperfect disinfecting procedure, there have been number of instances of collective outbreaks of epidemics resulting from city water.

As merits of chlorine agent, can be mentioned, 1) disinfective effect is perfect, and can treat even large quantities of water and 2) the effect of disinfection continues, etc.

Selection of chlorine agent put to use should be decided in consideration of the scale of facilities, conditions in handling, etc. Since dosage varies with the quality of water to be supplied, close studies required before the determination of capacity of the facilities.

Capacity of the storage facilities for chlorine agent should be adequate for the consumption, and the feeding equipment should be such as will feed by measuring and adjusting precisely from maximal to minimal dosage. What is required is adequate number and capacity of the equipment inclusive of spare ones.

Feeding type should be decided, based on the condition of chlorine (ie. Liquid or solid), quantity of water to be treated, that is, wet or dry feeding, definite dosage or flow-relative feed, etc. Leakage of chlorine gas involves great danger, counterdevices must be equipped with sufficient neutralizing strength.

3.9 Pre-chlorination Equipment

Chlorine is usually injected into the (filtered) water after filtration process for purposes of disinfection; while, on the other hand, it is sometimes added to the water yet to be filtered. This practice is called pre-chlorination. As chlorine, together with its sterilizing and algal destroying power, has a forcible oxidizing strength, with advancement of water pollution, prechlorination has come into practice as a step of water purification procedures. Prechlorination is conducted for the following purposes:

1) For advancing the safety of pre-filtration water in case there is detected 5,000 or upwards of gen, bacteria in ml or over 2,500 b. coli in 100 ml of water and at the same time, for maintaining the interior of settling basin or of filter basin healthful.
2) For killing or checking proliferation of alagae, tiny living thing, iron bacteria, and the like when these are living in the water exuberantly.
3) For oxidation of ammonia nitrogen, nitrite nitrogen, hydrogen sulphide, phenols, microorganisms and other organic matters. Besides, as regards taste and odor of the water, addition of chlorine is sometimes effective, but at others, new odor generated because of the addition.

Further, in slow filtration system, the addition of C1 affects the organisms of the filter membrane, so prechlorination is in principle, omitted.

Prechlorination is, as described above, carried out for such objectives, but according to the nature of raw waters, not only adequate effects fail to be gained but in some cases, deterioration of the water quality may result and high degree of water-quality administration is also required. Careful studies should be made, therefore, prior to its adoption.

3.10 Aeration Facility

Facilities for aeration is provided when there is need for removing great amounts of errosive free carbon, iron or bad smell contained in the raw water. Aeration of water is generally conducted at intake spots or filter plants prior to settling and filtration of the raw water, the effects of which are as follows:

1. Raising pH rating by removal of free carbon in the water.

2. By supplying the oxygen in the air to the water, advancing oxidation of the iron dissolved in the water. eg. $Fe(HCO_3)_2 \rightarrow FeCO_3 + CO_2 + H_2O$

   and by hydrolysis. $FeCO_3 + H_2O \rightarrow Fe(OH)_2 + CO_2$

   $Fe(OH)_2$ is further oxidated and produces $Fe(OH)_3$ which is hard to dissolve.

   $2Fe(OH)_2 + 1/2O_2 + H_2O \rightarrow 2Fe(OH)_3$

   However, dependent upon iron form, perfect oxidation may be impossible through aeration alone.

3. Removing bad smelling matter like hydrogen sulphide, but according to the water quality, perfect removal cannot be expected.

Aeration technique includes jet-type, air-blower type, cascade type and contact type; combined type also utilized. Jet-type aeration is subclassified into one in which jetting is performed by arranged pored pipe, and another in which mist-like jetting produced through fixed or revolving nozzle. Nozzled one is more effective.

Air-blower type means blowing air into the water. The quantity of air to be blown in varies with the water quality, and decision must be made through series of tests.

Cascade type consists of slope like cascade or stair of more than ten steps on which water with 5~10m head is precipitated, thus, oxidated. In this case the area of the cascade room may be smaller than with the jet type oxidation.

Contact type means leading the water through filter media such as coke, gravels, thus its contact with the air achieved. Out of these, the most common and effective method is nozzle-jet system.

3.11 Activated Carbon Treatment

Activated-carbon treatment is applied in removal of such matters as cannot be eliminated by usual purifying techniques, eg. order, synthetic detergent phenols and other organic substances. Activated carbon consists of black, porous carbonized substances made from coconut crust sawdust, coal, etc. activated and has a property of absorbing the particle impurities in gas or liquid form.

In filtration the above-mentioned substances are removed by use of this absorbing force. The features of this method are that removing capability for minimum quantity of organic matter is great and that unlike chemical treatment no remains of dissolved substances are left in the treated water.

As regards activated carbon treatment the characteristics of activated carbon must be so utilized as the required treatment can be performed perfectly. In its practices, preliminary surveys including experiments must be carried out on the actual conditions of the object substances and treatment effect. These surveys should not only be concerned with the present status but prospected tenrd in the future, also, for determining an adequate scale and type of the treatment facilities to be realized.

In general treatment by powder carbon is considered proper for emergency or short-period use, and for continued or fairly long-period use, granular carbon considered advantageous, and in some cases according the kind and density of the object of removal, joint use of both is practiced. Also, it is remembered that the property of adsorption of activated carbon varies not only with the kind but the brand of the chemical also, which requires our minutes care in selection of the chemical.

Facilities for activated carbon treatment should not only be adequate for handling the estimated maximum load but at the same time be easy to managed and maintain in the style and structure of the equipment. In activated carbon treatment, in particular, human labor is required in many cases, and growth of the dust of powder is also feared, leading to poor efficiency in the work. It is desired, therefore, that so far as possible economically man-power saving system be mapped out.

3.12 Facilities for Organisms Removal

For such troubles brought about as by organisms, facilities for removal of biological troubles must be provided. Facilities for these can be classified into two categories; one type consists of removal of organisms by filtration, and the other, killing these by chemical agents, and removing through settling process. The former includes filtration by tiny gravels and filtration by microstrainers; the latter means feeding copper sulphate or chlorine agents in liquid or gaseous form.

Troubles by organisms in the case of reservoirs, lake and marshes; clogging of filter basins or growth of odor resulting from pralific growth of plankton algae.

Troubles by organism in the case of rivers; clogging of filter basins, growth of odor or leak in then filtrate resulting from floating off of algae and tiny creatures attaching to the rocks of river-bottom and walls of settling basins, filter basins, conveyance channels, etc.

Those in the case of ground waters; flowing-out of bacteria and colored water sometimes subterranean life resulting from exuberant growth of iron bacteria, etc.

In removal of these biological troubles, such water area as they proliferate should be hit as our ideal, but in the case of natural lakes or marshes multi-purpose reservoir or rivers, impact upon their environments must be considered, and so counter measures should be put in practice in the facilities after the intake station.

3.13 Facilities for Iron and Manganese Removal

When considerable quantities of iron is contained in city water, metallic odor is added to the water and what is worse still, when it is used for washing and cleansing purposes, the clothing and utensils are stained reddish brown. Colored water is not acceptable in industrial facilities, either. According to the water quality standards of city water, the content of iron in city water should be less than 0.3 ppm, so, in case any larger concentration is suspected, removal is just in order. However, in many cases, iron in the water is to be removed to some degrees during the processes of sedimentation and filtration, need or no need of iron removal facilities must be finally decided after positive and considerate surveys on the rate of iron contained, its peculiarity and the facilities of water utility in question.

When city water contains manganese, even the concentration is in the limit (0.3 ppm or under) stipulated in the standards of water quality, 300~400 times of color against the contents of manganese will be added affected by the free residual C1, or blackish attachment grows inside the pipe, causing not only blackish water but utensils and washings will be spotted black. Further when iron and manganese coexist mixed blackish brown color will appear. Since manganese contained in raw water can hardly be eliminated by normal filtration practice, manganese removing treatment must be resorted to. According to administration instructions, manganese concentration in the clear water shall be lower than 0.05 ppm, but for perfect control of the ill effect manganese removing facilities assured of its effectivity must be provided.

In addition, there are many instances where manganese coexists in a water of high concentration of iron and so on the occasion of iron checking the need of manganese removal must also be studied.

3.14 Other Special Treatment

The occurrence of fluorine in water is due mainly to geological composition and present in the groundwater or spring water of granite strata. Adequate treatment or a step must be adopted for its removal. If color-causing matters is contained in the water and normal filtration process fails to remove it, treatment for color removal is required.

3.15 Operation and Management Facility

(1) Administrative Building

Buildings for administration should be such as meet the object of economic and rational management of water works facilities. In designing the buildings although there are various restrictions from techniques scale and topographical conditions, the principle must be rational management and maintenance and future extensions of them should also be in views. In addition, esthetic and environmental elements must also be included in designing.

In filter plant equipment, the functions to be accommodated in the buildings might be roughly classified into two types, i.e., administrative unction and technical operational function. Ideally speaking, there are to be consolidated into one and single building as an entity. In fact, however, two or three buildings are used for the purpose for convenience.

(2) Water Measuring Equipment

For supplying water steadily for meeting daily demand from filtration plant, it is important to grasp the quantity to be delivered and at the same time, quantity for introduction from intake station to filter plant. Hourly variations in delivery amount invite a dangerous water level in distribution reservoir at the peak of demand and, in the contrary, high water level due to decreased demand in the night hours should overflow the distribution reservoir.

For chemical treatment such as coagulo-sedimentation and chlorination, correct dosage must be observed, for which grasp of the correct flow amount at the respective feeding points forms the prerequisite.

Thus, for adequate management of the filtration facilities, correct grasp of the amount of received water, the filtered water, distributed water is indispensable.

(3) Equipment for Water Quality Test

The object of water tests of ①grasping of the quality of raw water, ②proper managing of purification process and its watching, ③confirmation of safety of serviced water and handling of troubles resulting from problematic quality of water served.

Changes in raw water for water supply exert a great influence upon filtration program and it is of absolute necessity to check such unusualities in water sources and facilities where pollution has advanced to a regrettable extent, provision of testing facilities or pollution-monitoring system is urgently desired.

The quality of filtered water has a direct connection with the tap water of consumers' household; therefore, filtreation facilities must be provided with adequate facilities of water examination according to their scale and treatment method.

The confirmed safety of serviced water and solution of problems concerning water quality are essential for keeping up consumers' reliance in our water service.

The system of water quality tests should in principle be planned to be capable of carrying such tests as are necessary for managing and maintaining of filtration program and the gamut from sources to supply lines in accordance with the laws and rules concerned. However, in water utilities of small scale, provision of test facilities covering the whole items of water tests is difficult, it is required to entrust periodical water examinations to other public organs in behalf of them.

(4) Other in-plant Equipment

In filtration plant, such equipment is necessary for maintaining sufficient filtration efficiency and for adequate administration of the facilities.

Since filter plant is responsible for production of drinking water, not only for the water produced but for its processes of purification of water, safety in sanitation must always be maintained. For these purposes, besides the equipment for security of production of water, provision of such equipment as is capable of hygienic safety is required.

CHAPTER 4 WATER TRANSMISSION FACILITY

4.1 General Principles

Planned amount of water to be transmitted so long as the transmission facilities are adequately operated should be safe from a leak so that it will not affect the delivery. Therefore, the maximum daily supply can be considered the standard.

Type or method of transmission shall comply with the following:

(1) Type or method of transmission must be decided through comparative study of land elevation between the filter plant or groundwater source and distribution reservoir, planned amount of transmission, land conditions of pipe line, etc.

(2) Transmission type should, in principle, be pipe line system; in case an open conduit is adopted, it must be either tunnel or watertight closed conduit.

(3) When pure water is supplied to a water utility by the transmission facilities of waterworks industry, provision of an equalization basin desired.

4.2 Transmission Pipe

Generally, transmission pipe is laid as a single pipeline extending from the filtration plant or groundwater source to the distribution reservoir, but in some cases, according to the confronting locations between the respectives facilities and the service area, plural distribution reservoirs may be supplied by plural distribution pipes. In any case, the required amount must be steadily furnished to the object reservoirs. Further, in other cases, the water is supplied direct to the service area by branching distribution piping from the transmission main on the way. In this case, the transmission pipe down to the branching point, in addition to the planned amount, must be enough to furnish the planned amount for distribution, under an adequate dynamic pressure. In addition, it is necessary to install flow meter near the branching, in order to grasp daily distributed amount and hourly variations. At the same time, it is desired to install flow regulating device for the time of small supply and metering instrument on the bypass so as to give

CHAPTER 5 WATER DISTRIBUTION FACILITY

5.1 General Principles

Planned amount of distribution is to be the basis for decision of the size of distribution pipe and represented by the amount per hour. In normal times, it is the planned largest amount of supply per hour in the planned service area furnished by the respective distribution pipe system, on the assumption that in the hour of planned maximum supply the whole planned service population in the service area in question consumes the planned maximum supply simultaneously.

At the time of a fire, special consideration is required because it is necessary for us to concentrate large quantities of water in the spot of the disaster simultaneously. If the planned quantity can be applied for a fire which breaks out at the time of the maximum hour supply, it will be an ideal system. However, the reality is that, for meeting such a challenge, the size of distribution pipe must be designed large, which means higher construction cost and in the case of thinly populated communities, proves an extremely uneconomical plan.

For planned amount of distribution, therefore, the delivery per hour of the maximum daily supply plus an adequate amount for fire fighting has been adopted. If a fire has broken out at the maximum supply time in the summer, required amount for fire fighting should be obtained by restricting the consumption to a certain extent.

5.2 Distribution Basin

Principal function of distribution reservoir is regulating the hourly variations in supply quantity, by which acute changes in purified water can be avoided. And in fires, the reservoir functions as fire water storage basin, and if need by, the reservoir works as regulating device for the supply which undergoes weekly or seasonal fluctuation.

When the distribution reservoir is situated near the center of the service area, the length of the pipe reaching the end can be saved and also the head loss, small. Unless the land contour is great, mostly uniform supply can be maintained, which makes the laying of distribution pipe less costly. In addition, the location of gravity style reservoir should be of such height as, the minimum dynamic pressure required can be maintained of the time of maximum supply per hour or at the time of a fire.

In recent years, there is seen an opinion or view that the capacity of a distribution reservoir shall be enlarged so as to balance the load on filtration or intake facilities over a long period by enabling the reservoir to shoulder the regulating function to weekly or seasonal variations in demand. However, what should be borne in mind is that the staying of water in the reservoir in the period of light demand results in shortage of residual Cl and referring necessitated.

Since distribution reservoir holds great quantities of water in storage, it must be water-tight, safe from outside pollution and of structural endurability, too. Also, if needed, adequate measures for temperature and lifting action by the ground water should be contrived. Further the reservoir should recommendably be divided into two sections at least for convenience of inspection, cleaning and repairs.

In case the reservoir should break, there would naturally be caused great damages due to flooded leak, which presupposes non-construction of the reservoir at the top or toe of slope and near the fault. If such construction is inevitable, full and perfect preventing steps must be employed such as piled foundation, pillar foundation, slope protection, rain water draining, etc. Also, the reservoir is, in many cases, built close to the residential quarters, therefore, special care required for prevention of the noise occasioned by flow controlling work and refilling activities of disinfectent.

5.3 Distribution Tower and Tank

Water tower is filled with water down to the body of it, while a water tank is supported by bearing body. Either structure is built when there is no elevated site adequate for constructing a distribution reservoir in the service area, for principal purposes of water pressure regulation along with controlling quantity of supply. Because it is a lofty structure for storage of water, the cost of building per unit capacity if naturally higher than with the reservoir construction.

In water utility of small scale, however, even if the resource volume is ample enough for variable hourly demand, these are, in some cases, built for pressure control needed in operation of the pump.

In case the service area commands a large range with a long extension of distribution pipeline, because of hourly variations in consumption between the day time and night hours, there appears a considerable difference in the pressure of water served. For these conditions, water tower or elevated tank is provided about the end of the distribution pipe, which is filled in the night hours of high pressure, and during the day hours when consumption is high or at the time of fires, water is furnished either by source or from the tower or elevated tank for balancing the difference in pressure.

Since distribution tower and elevated tank are always built high aboveground, the structure must be not only strong but, at the same time, consideration should be required of the wind pressure when empty and earthquake shocks when filled, endurability of the foundation, thunderbolt protection, electric wave interference, aesthetic appearance. etc.

In addition, in small scale waterworks, such style of pressure tank as appears atmospheric pressure tank are sometimes used for control of volume of water.

5.4 Distribution Pipe

Distribution pipe is such a pipe as is laid starting from distribution reservoir, distribution tower or distribution pump for supplying potable water to the area concerned. It consists of distribution main which is the trunk pipeline and of distribution submain branching from the trunk line and connecting with the service pipe. Distribution pipe should desirably be laid out in a well-balanced network for uniform, stagnation-free service to the customers.

Since the cost of distribution pipe laying occupies more than the half of water facilities construction and at the same time accidents caused by defective distribution pipe invite grave results such as water suspension or reduction. In designing and laying of these, therefore, in consideration of future demand, decision of pipe diameter and selection of the type of pipe should be made together with adequate installing of sluice valve, air valve, hydrant, reducer valve, safety valve, flow gauge, pressure gauge, drainage equipment, manhole, expansion pipe, etc. to contribute to facile management and maintenance of the service system.

The type of distribution pipe range over cast iron, ductile cast iron, steel, cement-asbestos and PVC pipes. In selection of pipes, safety from inner and outer pressures, adaptability to pipeline conditions, or pipe laying techniques, non-influences upon water quality, etc. along with economy, should be considered. Further, according to the condition of laying ground, for prevention of leakage and accidents, care must be taken of protection of the pipe, fittings, and of electric corrosion and other erosions. As for laying of the pipe under the railways, sheath pipe driving technique are employed, but in recent years, instances of shield technique are frequently used.

With an increase in underground installations, there have been many instances of accidents resulting from other underground works, along with frequent pipe branching works performed by water utility itself, and it has become necessary to indicate clearly waterpipe by special signs and marks to prevent misconception by workmen. In addition, non-water-cut project, that is, execution of work of T-pipe fitting or joining a check valve of the same size with the existing distribution pipe is for saving the troublesome business accompanying water suspension and for preventing annoyance on the part of the customers. Further, rejuvenation of pipe intended to increase the serviceability is significant measure from improvement of the reticulation.

CHAPTER 6 MECHANICAL AND ELECTRICAL FACILITY

6.1 General Principles

The prerequisites for mechanical and electrical facilities in waterworks are as follows:

(1) The facilities shall perfectly perform the essential functions required, with high degree of safety.

(2) Systems of the mechanical and electrical facilities shall be determined in view of the merits and demerits in the system of water facilities as a whole.

(3) Pump facilities shall be of such capacity as satisfying the planned supply, and with the appurtenant equipment or supplementary devices, be adequate for operation of high effeciency with high degree of serviceability as well.

(4) Electric facilities shall have sufficient capacity as power source for waterworks facilities with high stability.

(5) Protective and safety devices shall be mutually coordinative, and in times of failure and accidents, shall work to prevent expansion and propagation to other parts by separating the affected part without danger.

(6) Vibrations or noises produced by mechanical and electrical facilities in operation, shall be curbed as much as possible.

6.2 Pumping Facility

Supply of drinking water is desirable to be supplied by means of gravity, but, in reality there are many cases where it must be serviced by pumping system because of the topological conditions of structure and piping, construction cost, etc. Therefore, pumping installations perform an important function in intaking, conveyance, transmission and distribution of water. In general, four types of pump, namely, centrifugal, diagonal flow, axial flow, submerged-motor are used.

It is needless to say, for the pump facilities, to satisfy planned quantity and pressure, the pumping facilities should fully display their functions. In addition to the capacity of the pump itself, the power of primary motor appurtenant equipment or supplementary installations must be adequately planned, designed and provided. Furthermore, coordination with structures such as pump chamber, foundation, pipe route, etc. and building must be considered.

Planned water quantity and number of pump units shall be determined according to the followings:

(1) As regards intake pump and transmission pump, planned maximal daily intaking quantity and planned maximal daily delivery shall be the criteria of the respective pumps.

(2) As for distribution pump, planned distribution quantity should be the basis.

(3) As for booster pump, planned maximal capacity of the pipe-line concerned shall be the basis.

6.3 Control of Pump

The object of controlling pump consists in securing the adequate quantity respectively of transmission and distribution water and maintaining the pressure of respective piping systems or the levels of the distribution water and maintaining the pressure of respective piping systems or the levels of the destinations, ie. Regulation and distribution reservoirs, etc. at proper standards.

Control of pump operations had been performed manually at present. In future, starting, suspension, control of delivery, etc. will, by degrees, be relegated to automatic control.

For control of pumping operation, there are two methods in practice, ie. One where direction for starting or suspension of pump operation or quantity control is done manually (remote control or one man operation) and the other where directions for the above actions are given automatically by instruments installed in the plant (full automation system). Choice of them is determined in view of the scale and operational plan of the facilities concerned.

For controlling the delivery amount of pump in operation, there are several methods, ie. – control of the number of pumps in operation, - control of the opening degree on the delivery valve, - control of the rotation speed, etc. In determining control system, the features of pumps to be installed and their operational effect must be carefully checked.

In addition, as for protective devices for failures and accidents that might result from pumps, motors and appurtenant facilities, adequate means should be mapped out as a link of control equipment.

6.4 Electric Motor

The electric motor has been in a wide range of use, less than 1 kW to thousands kW in out-put as a prime source of power to drive pumps and various types of machine. These classified into the induction motor, synchronous motor, DC motor and AC commutator motor.

(1) simplicity in construction

(2) easy handling

(3) inexpensiveness in comparison with other motors;

The small capacity induction motor mostly used is of cage rotor type; and for great capacity, wound-rotor type is used. And in particular cases, the synchronous motor, DC motor and AC commutator motor are used.

The electric motor including the starting system and the protective system should be selected in consideration of;

(1) load of the pump and characteristics of the motor,

(2) reliability and durability,

(3) difficulty or facility in maintenance,

(4) costs of the equipment and operation costs.

6.5 Electric Facility

The electric facilities are such as efficiently and safely use electricity or a basic energy and are composed of power receiving facilities to be furnished by the electric company, the electric load system, substation facilities in response to the voltage, the distribution device to distribute the load and the load device efficiently utilizing the power according to our purpose.

As electricity can easily be transmitted and can be converted to energy rather simply, it is widely used as dynamic power, lighting, heat, communication, measuring instruments and energy source of other facilities; if it is misused, not only stoppage of the facilities operation, but dreadful danger comes to man and living stock, inviting leaks and fires, and causing induction troubles in communications; therefore various kinds of legal regulations are enforced and particularly, satisfactory consideration for public welfare shall be used.

Planning of electric facilities shall be based on the following:

(1) The electric facilities shall be installed in accordance with the technical standards of power facilities.

(2) The electric facilities are required to be installed in view of the future program for utility development.

(3) The electric facilities shall be installed in consideration of facility in operation, maintenance and management and safety from accidents.

(4) The electric facilities shall be such as have sufficient strength and safety against earthquake shocks and natural disasters.

6.6 Reserved Power

The reserved power is a poser source installed in order to lessen the shortage or lack of water supply caused by the interruption of power source (commercial power source) furnished by electric power company and confusions involved in the management of the facilities.

In waterworks facilities, for security power source, reserved power (space line) is generally included in the supply contact with a power company, but no interruption of service can be included therein. Therefore, reserved power source must be provided so as to be able to switch over the source. In a small scale pump station, standby power can be provided by connecting on internal combusion engine to the load without resorting to any electric generator.

In general, power generator claims expensive equipment, and in deciding its capacity, studies required in the operational conditions of the equipment for emergent use in the above-mentioned circumstances.

6.7 Room for Machinery and Electrical Devices

For planning of building to be furnished with primary machines, electric facilities or monitoring and controlling equipment such locations as are safe from sinking of the ground and flooding must be adopted.

In recent years with the increased water demand and amalgamation of waterworks utilities, the machinery site has become enlarged and the operation system remarkably complicated. The work of staff engaged in daily duty in there building has also been to grown more and more complicated in quality.

Therefore, the need to improve their working surroundings will naturally augment hereafter, which accompanies the requirement for improvement in building style and layout of the machines and operators.

The monitoring rooms and operation rooms are places where the persons in charge work and their location and environment greatly influences the work efficiently, so the monitoring board and operation board should be in the best possible conditions in the sight of the facilities as a whole.

As to the source of noise in the machinery room the noise regulations have been widely in the public interests, which needs sufficient attention when planning and designing of these advanced utility.

CHAPTER 7 SERVICING FACILITY

7.1 General Principles

Service installations shall be defined as such devices as furnish water suitable for drinking to the consumers by service pipes branching from the distribution main and service appliances connected to the service pipes.

Service installations are such as branch from distribution pipes laid by water utilities and faucets (or taps) connected direct to the service rips to furnish water. Therefore, the devices beyond the receiving tank, apart from the hydraulic pressure of distribution pipes are not service installations. The special installations and unitized facilities may be used as service installations when authorized by waterworks enterprises.

What service installations are little different from other facilities of waterworks in that a major part of the installing cost is shouldered by the consumer and in proportion to the advancement or progress in our life style and diversification, new types of service appliances are developed and appear on the market.

In this connection, in each community, new and different materials are utilized in the manufacture of new products according either to their financial situations or to their traditions and customs. Therefore, waterworks enterprises and agencies should establish criteria of designs and execution of the service work. In addition, prior to actual service, sufficient cleaning and disinfection of the pipe required for protection of water quality.

7.2 Service Pipe

The essential component of service installations is service pipe, and the requisites for service pipe are: adequate strength super endurability and freedom from undesirable impact upon water quality. Even when the choice of pipe type is adequate, if the pipe size, piping technique or protective means lack adequacy, function of service devices is no doubt interrupted. In designing and installing of these, therefore, sufficient attention is required to follow the criteria introduced by the legal authority.

7.3 Water Meter

Water meter is such an instrument for integrally measuring the consumption of water by the customer, fixed on the service installation. Since the result of its computation forms the basis of water charge calculation, the meters to be installed must be those which have passed the test as stipulated in "Law of measurement" by the country.

7.4 Other Appliances

Water appliances are devices for service, which constitute water service installations as a unit of service pipe. According to their functions and styles, these are classified as corporation cock, curb cock, service cock (or faucet, tap), special appliances and unified devices.

Appliances for service installations must meet the following requirements in basic principle:

(1) Safety in the respect of sanitation

(2) Resistance to a definite pressure (17.5 kg/cm^2)

(3) Difficult of breakage and corrosion

(4) Small head loss and free from excessive water hammering

(5) No backflow and easy discharge of stagnant water

(6) Convenience in use and fine outer appearance

As regards the appliances for service installations, specifications for their quality and maintenance should be given by the country.

As for such as no specifications are found in the standards, those the main components and materials of which are up to these standards, must be employed.

CHAPTER 8 INSTRUMENTATION

8.1 General Principles

In the waterworks field, instrumentation started with measuring and surveillance of the facilities in which technical meters predominated, and then, through the stage of concentrated management of facilities, ie. gathering measurement instruments in a special place for efficient and economical management of the facilities, sequential control, feedback control, etc. have developed. Since, in instrumentation, it is essential, not only to have thorough knowledge of the composition, theory and functions of meters, controllers and other instruments, but to be wellversed in the technique in efficient use of them, further still, in waterworks, "instrumentation" has come to be used to express the whole scope or gamut of techniques and equipment for surveillance and control of the facilities.

In the years hereafter, it is absolutely required for the waterworks men to maintain an organic relations among the respective facilities in the whole picture of waterworks industry ranging from intake to distribution to achieve the most effective and adequate management of waterworks in response to the progress of instrumentation technique, expansion of service are, and enlargement and complexity attending facilities, all of which indicate to us the mere surveillance and control of an individual plant is no longer an answer for the question now.

For water facilities to operate smoothly, it is necessary that there are constant communications between man and the facilities, in particular, the metering equipment; there is an absolute requirement for grasping the factors relating to the operation and management of the facilities as pieces of information rapidly and precisely so that these can be utilized for operation of the facilities.

Therefore, in here, the term instrumentation is used, as a term of broad sense, including the technique and equipment for "treating information".

8.2 Necessary Instrument

Instrumentation machinery must be adequate for the processes of water facilities, control system and information treatment and, at the same time., the safest and of high reliability.

Instrumentation machinery is generally classified into 5 units, ie. reading, expressing, adjusting operation and transmitting units. Reading unit works to detect the water level, pressure, amount and the like in the respective parts of facilities and convert them to signs. Expressing unit works to indicate, record, represent the converted signs and, if needed, issue warnings.

Adjusting unit emits such signs as for maintaining the amount and conditions at a specified level or varying them up to definite standards.

Operation unit, receiving the operational signs from adjusting unit, works to attain the object of control.

Transmitting unit is for transmission of signs between each of the above four units, ie. Reading, expressing adjusting and operation units.

In deciding composition and scale of instrumentation system, the following should be noted:

(1) The subject and unit number of measurement and surveillance vary over a wide range and this fact requests us to be positive and meticulous in deciding our attitude to the instrumentation system, that is, clarification of our object and need for each subject for instrumentation. Simplification of subject matters and unit number is recommended.

(2) As for control, the composition of machinery should be determined in accordance with its method and importance in waterworks field, that is to say, whether the controlling operation is to be performed by human hand or by control loop formed based on variations in amount by means of adjusting unit. The decision must be made in consideration of need for frequent performance, performance in emergency alone or little need for such controlling, etc.

8.3 Places to be Instrumented

Instrumentation in various water facilities should aim to operate and control the facilities in the respective stages from intake to distribution with safety and reliability, and at the same time, to make the management of water facilities as a whole adequate and rational.

In the plan of instrumentation, therefore, through thorough knowledge of the structure, functions, theory and features of unit facilities, the adopted system should meet them perfectly, and be highly dependable not only in ordinary service day to day, but in times of emergency, also. At the same time, simplification of water facilities must be contrived from standpoint of economy and facility of management and maintenance, without being concerned merely in instrumentation in each individual facilities, but in mutual relations of these as a total system.

The field of application of instrumentation system in waterworks includes unit-plant control of such as intake station, filter plant, distribution plant (reservoir) and unified, comprehensive control of the entire water facilities from source to distribution network, termed "serial, operation control".

In the plant control system in waterworks, reading, expressing, adjusting, operation and transmission by means of industrial meters are combined into an instrumentation system and in common use in water plants. And for control in filter plants of some of the medium and large-scaled filtration plants, dataloggers and computers have now been introduced.

From the standpoint of facilities scale, the main consideration is only directed to the number of each unit facilities and equipment, but in the case of facilities where the number of pumps, the kind of chemicals used, feeding points, or the number of filters are extremely small, automation system or concentrated operation can be saved.

In deciding the scale and setup of instrumentation system, consideration should be focused upon clarification of the object and effect of the system; at the same time, along with sufficient survey and study on the fundamental conditions involved in the system, the extent of protection devices for upkeep of safety for the instruments should also be determined.

CHAPTER 9 SUSTAINABLE FINANCIAL MANAGEMENT

In this manual general concept on the sustainable financial management of a WSA is explained. If a group of competent personnel faithfully sticks to the steps and rules written hereunder, a financially sustainable and successful management of the WSA will be warranted.

Financial management can be said to be an endless cycle of "plan-do-see". In the below, "plan" covers demand projection, budget formulation and projection of financial statements, "do" is financial transactions and recording, and "see" is analysis of financial performances.

9.1 Demand Projection

What is to be required before anything else is to project the volume of water to be demanded by the clients in future. To project water demand, the number of clients and unit water demand must be projected. To project the number of clients, population and the economy of the town must be forecast.

The clients are divided into two major groups: domestic and non-domestic. Domestic clients are further divided into house connection, yard connection and communal water point users. Non-domestic clients are also further divided into industrial, commercial (hotels, restaurants, bars, shops, etc.) and institutional (government offices,.schools, hospitals, churches, mosques, etc.) customers.

There are three projections, namely long-term, medium-term and short-term. The periods of the respective projections are 10, 5 and 1 years.

1) Projection of Population

If there is an official projection of population, it can be used. At the same time, however, the following procedure is necessary to make it more accurate. Because an accurate projection of population forms the the first step or the very basis of a good financial management.

The increase/decrease of the population of a town depends on two factors: social and natural. The social factor consists of immigrations and emigrations, while the natural factor is comprized of births and deaths. These four components are projected based on the past time-series data. When they are projected, the population in a future year is easily calculated by adding immgrations and births to the population in the previous year, and subtracting emigrations and deaths from that population.

If such information is not available, annual growth rates can be applied based on the past time-series data or a sheer, but reasonble guess. Such a guess hinges on the capacity and calibre of the person in charge.

2) Projection of Clients

(a) Division of households by Mode/Income Group

The current households consist of house connection, yard connection and communal water point users. Each group of households fits into a certain range of income, having a certain average income.

The information on income for the three types of users can be obtained from official documents formulated based on sampling questionnaire surveys.

It would be fine if the three types of users could fit into high, middle and low income groups respectively. As a convenience, let us assume that they can.

The growth of household income in future is projected based on the growth in the past several years. If there is no such information, you have to rely on your own guess, supported by your knowledge on the business and economy of the town and the nation. Such a growth should be in real terms, as well as in current terms.

(b) Projection of Domestic Clients

Projected population will be converted into the number of households through the average family size. Then, households wil be divided into three groups, the high, middle and low income groups, corresponding to house connection, yard connection and communal water point users respectively.

In doing so, such factors as the growth rate of the respective groups in the past, the projected growth rate of household income in future and the projected price escalation in future will be taken into consideration.

(c) Projection of Establishments/Institutions

The growth of the number of afore-mentioned industrial/commercial establishments and institutions in a town depends on the master plan as well as the economic growth of the town.

The economic growth rate consists of the population growth rate and the per capita economic growth rate. The former has already been projected. As the latter, the national average in the past several years can be adopted. If it is not available, one has to rely on one's own guess, turning one's mind to the growth of household economy in recent years in the town.

The future number of non-domestic house connection users will be projected in accordance with the town development plan as well as on the assumptions that it grows in parallel with the growth of the town economy.

3) Projection of Unit Water Demand

lcd in future will be projected for the three types of domestic users based on the official projection and the growth of lcd in the past.

Water demand for each type of establishments/institutions will be projected based on the official and other data sources.

4) Projection of Water Demand

From the projected number of domestic clients by service mode, the average family size and the projected lcd by service mode, future demand for domestic water will be projected.

In the same way, from the projected number of various non-domestic clients by type and unit water demand by type, future demand for non-domestic water will be projected.

This way, future water demand will be determined.

9.2 Budget Formulation

1) Formulation of Expenditure Budget

By adding water to be lost through leakage to the future water demand projected above, future water production will be calculated.

Then, capital cost and O & M cost to be required to realize such water production will be estimated. Such cost will be esimated annually for the coming 10 years. The short-term cost estimation will be made on the monthly or bi-monthly basis.

(a) Estimation of Capital Cost

To secure a production of such and such volume of water in such and such a year in future, rehabilitation/replacement of existing equipment/facilities and/or installation/construction of new equipment/ facilities will be required. The capital cost to meet such requirements will be estimated.

(b) Estimation of O & M Cost

To regularly produce such and such volume of water in such and such a year in future, personnel, electricity, fuel, chemicals, materials & parts, etc. will be required. The O & M cost to meet such requirments will be estimated.

(c) Needs for Experts

WSA must be organizationally strengthened to cope with the multiple and diversified O & M requirements in the future. Especially, it is essential that it be sufficiently staffed with qualified and competent technical/engineering, financial and legal experts based on personnel plan.

2) Formulation of Revenue Budget

(a) Analysis of Water Tariff

Under the existing water tariff, water tank clients pay by far more than communal water point users for a fixed volume of water. In turn, communal water point users pay by far more for a fixed volume of water than house connection users. This is not only unwise and counter-productive in terms of financial management of WSA, but also it squarely runs counter social justice.

Against such background, a new water tariff must be introduced, under which water price for the domestic and non-domestic house connection users is higher than that for the yard connection users. In turn, water price for the yard connection users is higher than that for communal water point users.

This is to fufill the concept of cross-subsidy and social justice.

Water prices will be determined in such a way that WSA can maintain a financially sustainable management. But, at the same time, they must be so determined that the payment for water of a household will be within 4% of its income.

(b) Estimation of Revenue

By multiplying future domestic water demand for a service mode by the water price of that service mode, and by applying a water charge collection rate, future revenue from domestic users will be calculated.

Similarly, by multiplying future non-domestic water demand by the non-domestic water price, and by applying a water charge collection rate, future revenue from non-domestic users will be calculated.

This way, future revenue from water charge will be determined.

Future revenue from technical service charge, meter rental, etc. will also be projected.

9.3 Projection of Financial Statements

The present WSS in Debarwa is financially doing surprisingly well. However, one thing to be noticed is that accounting is done under the single entry book-keeping system. The time will come sooner or later that the system will not be able to cope with the growing volume of financial transactions to be expected in future when the Project is implemented.

To cope with the growing volume of financial transactions and to grasp a true picture of financial accomplishments, WSA must adopt the double entry book-keeping system, in which there will be three types of financial statements, that is, income statement, fund statement and balance sheet.

Those statements will be annually projected for 10 years. Regarding the short-term projection, monthly or bi-monthly estimation will be made.

1) Projection of Income Statement

Income statement is composed of revenue, expenditure and profit. Revenue equals expenditure plus profit. Therefore, profit equals revenue minus expenditure.

The revenue derives from water charge, technical service charge, meter rental, etc.

The expenditure consists of O & M cost, depreciation, payment of interest, etc. Let us now suppose that there is no borrowing of money. Then, depreciation is the only new item appearing in the double entry book-keeping system. Equipment and facilities have their own durable life. For instance, the life of vehicles, pumps and pipes will be 10, 15 and 50 years respectively.

Supposing the capital cost and the life of an equipment/facility is Nfa A and n years respectively, then the annual depreciation of the equipment/facility is A/n. It has to be regarded as an expenditure, although there is actual disbursement of the equivalent amount.

Accumulation of annual depreciation works as the reserve for rehabilitation/replacement/new construction of equipment/ facilities.

Future income statement must be projected in such a way that a reasonable extent of profir or surplus will be expected under the statement.

2) Projection of Fund Statement

This statement clarifies the sources and applications of fund. The sources of fund always equal the applications of fund.

The sources of fund for capital transactions cover such items as profit, depreciation, subsidy and loan. Supposing there is no subsidy, nor loan, then they basically consist of profit and depreciation.

The applications of fund cover capital works, payment of principal, working capital, etc. If there is no loan, there will be no payment of principal. In such a case, they basically consist of capital works and working capital.

In a simple case as cited above, working capital equals profit plus depreciation minus capital works. It is very important to maintain a reasonable extent of working capital. Otherwise, WSA will run into the solvency problem. Therefore, future fund statement must be projected in such a way that such a problem may not happen.

It is to be reminded that as the above explanation shows, capital cost is not entered as an expenditure item in the income statement.

3) Projection of Balance Sheet

Balance sheet shows the current financial status of a business grasped as a stock accumulated since its establishment.

The balance sheet consists of liabilities, capital and total assets. Total assets always equal liabilities plus capital. Liabilities and capital (or total capital including both items) show where the money comes from, while total assets show where the money is. Total assets are comprized of current and fixed assets.

Liabilities consist of current and fixed liabilities. Fixed liabilities are cumulative long-term loan minus cumulative repayment of principal. Capital is cumulative capital stock, subsidy and profit.

Current assets are cumulative profit and depreciation minus cumulative repayment of loan and capital expenditure by own fund. Fixed assets are cumulative capital stock, subsidy, loan and capital expenditure by own fund minus cumulative depreciation.

To make matters simple, let us suppose that there is no capital stock and no loan. Then, there are no liabilities. Total capital consists of cumulative subsidy and profit. On the assets side, current assets are cumulative profit and depreciation minus cumulative capital expenditure by own fund, while fixed assets are cumulative subsidy and capital expenditure by own fund minus cumulative depreciation.

It must be checked especially whether long-term liabilities are rising and whether current assets are declining. If they happen, it may mean that WSA is financially taking a wrong path.

Various management indices can be gotten from the three statements such as, current assets to fixed assets ratio, profit to total capital ratio, revenue to total capital ratio, turnover of total capital, current assets to current liabilities ratio, capital to fixed assets ratio and capital to total capital ratio. The values of these indices must be normal to assure that the WSA is financially sustainable

9.4 Financial Transactions and Recording

1) Financial Transactions

Water charge is collected from clients by bill collectors and water sellers. Technical service charge is taken from customers when connections are installed for them. Meter rental is regularly collected from them. Fine is imposed on violators of rules and regulations related to water supply.

Salaries are paid to the staff of WSA. Electricity charge is paid to the power authority. Chemicals are bought from shops to disinfect raw water. Materials and parts are bought from suppliers and repairmen are mobilized to repair equipment and facilities. There are many other expenditures such as those related to telecommunications, transport, light & heat, stationery and furniture.

Works for rehabilitation, replacement and/or new construction of equipment and facilities are implemented, and the related cost is incurred.

These activities are called financial transactions and every person in WSA is involved in them directly or indirectly.

2) Recording of Financial Transactions

The accounting technique in accordance with the double entry book-keeping rules is necessary to accurately record financial transactions. However, one does not delve into it here, because it is complicated, taking many pages to explain it. Instead, only the final forms of such recording will be described.

Final forms mean financial statements, that is, income statement, fund statement and balance sheet. They will be prepared on monthly or bi-monthly basis and finally on yearly basis.

(a) Preparation of Income Statement

Revenue collected from clients as water charge, technical service charge, meter rental and others will be recorded.

O & M cost, that is, personnel, electricity, chemicals, repairing and other cost that were incurred will be entered.

If interest was paid, it will be entered.

Depreciation of capital works completed in the current period will be entered.

O & M cost, payment of interest and depreciation will be added together, and shown as expenditure.

Lastly, expenditure is subtracted from revenue, being presented as profit.

(b) Fund Statement

Firstly, profit in the income statement will be entered.

Then, depreciation in the same statement will be entered.

If loan and/or subsidy were obtained, they will be entered.

Profit, depreciation, loan and subsidy will be added together, and entered as the sources of fund.

If any capital works were done, the cost invested will be entered.

If any loan were made, and a certain amount of principal was repaid, it will be entered.

Capital works and repayment of principal will be subtracted from the sources of fund, and entered as working capital.

Capital works, repayment of principal and working capital will be added together, and entered as the applications of fund.

(c) Balance Sheet

If any loan is made, cumulative loan up to the present is entered, then cumulative repayment of principal up to the present is entered, and thirdly the latter is subtracted from the former, and shown under liabilities.

Cumulative capital stock, subsidy and profit up to the present are shown under capital.

Cumulative profit and depreciation up to the present are entered, then cumulative repayment of principal and capital expenditure by own fund up to the present are entered, and thirdly the latter are subtracted from the former, being shown under current assets.

Cumulative capital stock, subsidy, loan, and capital expenditure by own fund up to the present are entered, then cumulative depreciation up to the present is entered, and thirdly the latter is subtracted from the former, and presented as fixed assets.

9.5 Analysis of Financial Performances

1) Comparison of Projections and Accomplishments

Comparison will be made between projections and accomplishments regarding income statement, fund statement and balance sheet. It will be done on monthly/bi-monthly as well as yearly basis.

It will be done by item. If any noticeable differences are found for some items, the causes and reasons for them will be looked for and identified.

This operation is quite important, requiring a high level of expertise. If the differences culminate in lower profit, lower working capital, lower current assets, etc., then it means that there are problems in the financial management of WSA. The results, and ways and means to narrow and overcome the differences will be discussed at high level meetings, and subsequently appropriate measures will be taken.

2) Revision of Demand Projection and Budget

The results of the analysis of financial statements as explained in the preceding section will be fed back in the form of revision of demand projection and budget.

The revision of demand projection and budget will be carried out by analyzing such items as listed below.

a. Population projection.

b. Number of clients.

c. Unit water demand.

d. Water tariff.

e. Water charge collection efficiency.

f. Number of WSA personnel.

g. Number and level of technical, financial and legal experts in WSA.

h. Water leakage.

i. O & M of water supply facilities.

j. O & M cost.

k. Capital cost.

The analysis must show how revisions/corrections will be made as well as how they will be implemented on the respective above items.

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