# CHRISTIAN RELIEF AND DEVELOPMENT ASSOCIATION

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# Training Programme
# On
# Community Based Water Supply and Sanitation

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## *CHAPTER ELEVEN – CHAPTER SEVENTEEN*

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# CHAPTER ELEVEN

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# WATER TREATMENT

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# CRDA - TRAINING ON COMMUNITY BASED WATER SUPPLY AND SANITATION

## COURSE TITLE - WATER TREATMENT

## 1. INTRODUCTION

### 1.1 Why water needs treatment

The primary function of water treatment is to provide a continuous supply of safe, palatable drinking water - safe water that is free from contaminants that can cause diseases or toxic to a consumer; and palatable water that is free, or practically free, of unpleasant characteristics such as color, turbidity, taste and odor.

Few raw-water sources can supply water of this quality without some treatment. Ground water, for example, generally requires at least disinfecting for complete public health protection.

Some ground water needs additional treatment to reduce hardness, remove excess fluoride, iron and manganese and other constituents that cause staining, color, tastes and odors.

Surface water should never be used for drinking without complete treatment. In addition to disease-causing organisms, surface water often contains turbidity and aquatic life (such as algae), as well as domestic and industrial wastes.

### 1.2 Water treatment process

There are various treatment methods available for making water safe and appealing to consumers.

The methods used depend primarily on the characteristics of the raw water. Table 1 summarizes the water treatment processes commonly used today and identifies the main purpose of each.

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**Table 1. Complete water treatment process**

| PROCESS | PURPOSE |
|---|---|
| *PRELIMINARY TREATMENT PROCESS* | |
| Screening | Removes large debris that can foul or damage plant equipment |
| Chemical pretreatment | Conditions the water for eventual removal of algae and other aquatic nuisances that can cause taste, odor and color. |
| Pre sedimentation | Removes gravel, sand, silt, and other gritty materials |
| Horizontal flow roughing filtration | Turbidity reduction for eventual preparation of raw water for treatment by slow sand filtration |
| Microstraining | Removes algae, aquatic plants and small debris. |
| *MAIN PLANT PROCESS* | |
| Aeration | Removes odorous, oxidizes iron and manganese, adds oxygen to improve taste. |
| Coagulation/flocculation | Converts nonsettlable particles to settlable particles |
| Sedimentation | Removes settlable particles |
| Filtration | Removes finely divided particles, suspended flocs and most micro organisms |
| Disinfection | Kills disease-causing organisms |
| Fluoridation/defluoridation | Adds fluoride when needed and removes fluoride when it is in excess |
| Softening | Removes hardness-causing chemicals |
| Adsorption | Removes organic and colors |
| Stabilization | Prevents scaling and corrosion |
| Desalination | Converts saline water to fresh water |

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## 2. PRELIMINARY TREATMENT PROCESS

Water supplies, whether from surface or ground water sources, often contain impurities or objectionable characteristics. The main or conventional treatment processes, such as coagulation, flocculation, sedimentation, filtration and disinfection, are used to treat water at the plant. The load on these processes may be reduced by removing some impurities from the water or altering some of the objectionable characteristics of the water, before it reaches the treatment plant. This is the purpose of pretreatment, also known as preliminary treatment.

## 2.1 Screening

Screening is often the first pretreatment that water receives; screening facilities should always be provided at points where surface water is withdrawn from the source.

Coarse screens located on intake structure prevent clogging and protect the rest of the water system by removing sticks, limbs, logs and other large debris found in rivers, lakes and reservoirs.

Finer screens are often located within head works of treatment plants to remove smaller debris.

**Types of screens**

There are two types of screens:

- Bar screen
- Wire-mesh screen

Each type is available in both manually and automatically cleaned models.

Bar screens consists of straight steel bars welded at their ends to two horizontal steel members. The screens are ranked as fine, medium or coarse depending on the spacing between bars.

***Fine*** : a spacing of 1.5 to 13 mm between bars
***Medium*** : a spacing of 13 to 25 mm between bars
***Coarse*** : a spacing of 25 to 100 mm between bars

Wire-mesh screen are made of fabric woven from stainless steel or other corrosive resistant, wire-like material. The fabrics have square openings ranging from 0.4mm to 100mm.

## 2.2 Aquatic plant control

Surface waters contain algae and other microscopic organisms that can foul pipe lines, cause taste and odor problems, clog filters and create potentially dangerous, slimy growths on treatment plant structures. There are about 30,000 species of algae. Algae can also cause additional problems including:

- Slime
- Color
- Corrosion

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- Toxicity
- Interference with other treatment process

Rooted aquatic plants or water weeds also cause the same problem as algae.

**Algae Control**:

Algae can be controlled by using:

- Chemicals such as copper sulfate and powdered activated carbon.
- Pond covering - to reduce the amount of sunlight available to the algae for photosynthesis.

## 2.3 Horizontal-flow roughing filtration

Reasonable slow sand filtration operation is only possible at turbidity levels of less than 10 to 20 NTU. Since periods of higher turbidities are very common in surface waters in Ethiopia, pretreatment of the raw water is often necessary. Plain sedimentation commonly fails to separate the fine solid matter, chemical pretreatment (flocculation) can be difficult or unreliable, and prolonged storage may not be feasible due to local (topography, geology, climate) and financial circumstances.

Horizontal-flow roughing filtration (HRF) technique has been found as the appropriate pretreatment method.

**Filter composition**:

HRF basically comprises three main parts. (Fig.1) the inlet structure, the filter bed and the outlet structure.

The inlet structure is composed of a weir which leads the raw water into the inlet chamber. The outlet structure consists of a chamber located upstream of the outlet weir.

The inlet and outlet structures are flow-control installations required to maintain a certain water level and flow along the filter as well as to establish an even flow distribution across the filter.

The filter bed is composed of three or four sections filled with filter media of different sizes arranged from coarse to fine in the direction of the water flow.

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The coarsest filter media (gravel) should be around 15 to 25 mm and the finest gravel not smaller than 4 mm.

Each fraction is usually separated by perforated vertical elements, or an open-jointed masonry wall to avoid mixing during cleaning. The filter bed is usually provided with an under-drainage system to enable hydraulic sludge extraction to be carried after a certain running period.

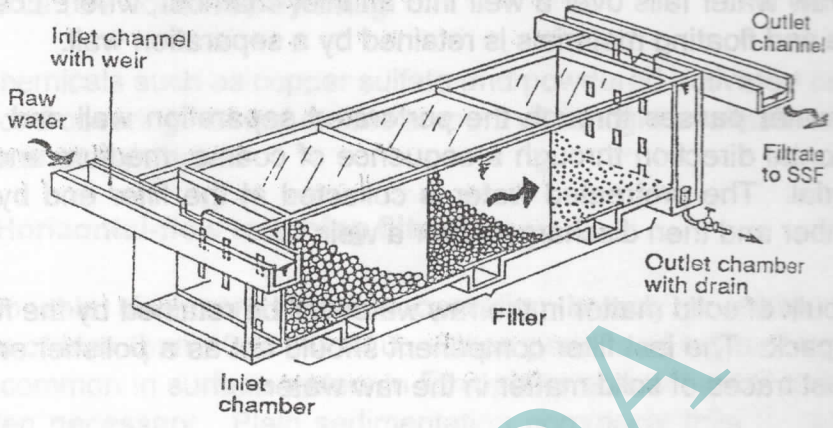
The raw water falls over a weir into an inlet chamber, where coarse solids settle and floating materials is retained by a separation wall.

The water passes through the perforated separation wall and flows in a horizontal direction through a sequence of coarse, medium and fine filter material. The pretreated water is collected at the filter end by an outlet chamber and then discharged over a weir.

The bulk of solid matter in the raw water will be retained by the first coarse filter pack. The last filter component should act as a polisher and remove the last traces of solid matter in the raw water.

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*Figure 1. Main features of a horizontal-flow roughing filter*




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HRF



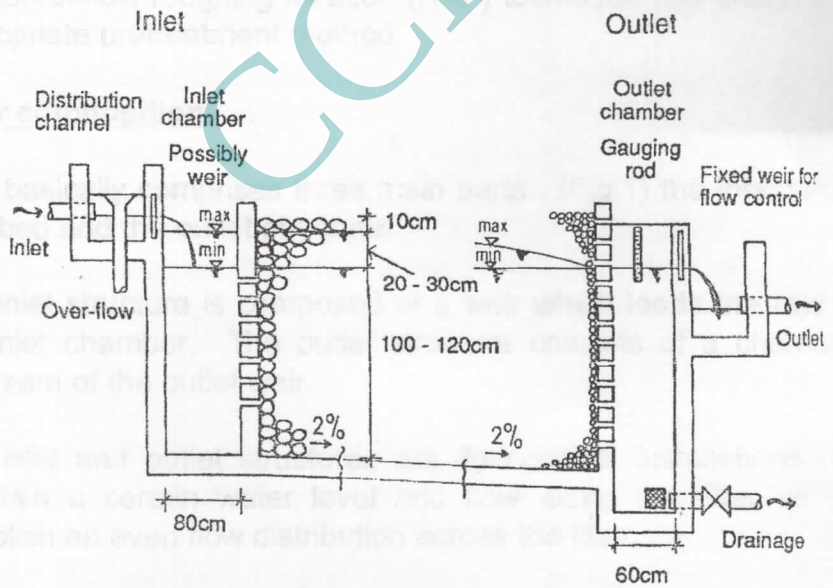



*Figure 3. Inlet and outlet structures of horizontal roughing fileters.*

Fig. 1. Main features of a horizontal-flow roughing filter.

### 2.4 Presedimentation

Pre sedimentation is a pre-treatment process used to remove gravel, sand, silt and other gritty material from raw water before it enters the main treatment facility. This material is potentially damaging to treatment plant machinery such as pump impellers, drive shafts and bearings.

There are three types of pre sedimentation system.

- Pre sedimentation impoundment
- Sand traps
- Mechanical sand and grit removal.

A pre sedimentation impoundment can be a simple earthen reservoir providing 24 hours storage capacity.

### 2.5 Pre Chlorination

Pre-chlorination refers to the practice of injecting chlorine into the raw water soon after it is abstracted from the rivers. The purpose is to (1)oxide iron and manganese (2) improve taste and odor. Fairly high dose of chlorine (2-5 mg/l) are commonly used.

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## 3. MAIN TESTAMENT PLANT PROCESS

### 3.1 Aeration

Aeration is the process of brining water and air into close contact in order to remove dissolved gases such as $CO_2$ and to oxidize metals such as iron.

#### 3.1.1 Description of aeration process

In water treatment the aeration process brings water and air into close contact by exposing drops or thin sheets of water to the air (water into air), or by introducing a small bubbles of air and letting them rise through the water (air into water). For both procedures, the process by which aeration accomplish the desired result are the same.

- Sweeping or scrubbing action caused by the turbulence of water and air mixing together.
- Oxidizing certain metals and gases.

### 3.2 Constituents Affected by Aeration

The constituents commonly affected by aeration are:

1. Carbon dioxide ($CO_2$) which has a problem of :

- increasing the acidity of the water
- tending to keep iron in solution
- reacting with lime added to soften water

2. Hydrogen sulfide ($H_2S$): which as a problem of

- toxicity
- producing rotten - egg odor
- corrosivity to metals

3. Methane ($CH_4$) which as a problem of :

- explosion
- garlic - like taste

4. Iron and Manganese: which as a problem of

- staining
- color
- metallic or medicinal taste
- turbidity

5. Dissolved oxygen (DO): which has a problem in palatability due to lack of sufficient oxygen in water.

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### 3.3 Types of Aerators

The general categories are based on the two main aeration methods : water into air and air into water

Water-into-air aerators are Cascade aerators, Cone aerator, Salt and coke tray aerators, Draft aerators and Spray aerators.

Air-into-water aerators are Diffusers aerator and Draft tube aerators. In addition to the two main aeration process, there are also mechanical and pressure aerators.

# 4. COAGULATION/FLOCCULATION

## 4.1 Description of Coagulation/Flocculation

The coagulation/flocculation process helps remove non settlable solids. The process utilizes chemicals to convert the non settlable particles to form larger, heavier, more settlable floc particles.

Coagulation is associated with rapid mixing to disperse the chemicals added to water so that the chemicals come into close contact with the impurities in water.

Flocculation follows rapid mixing facilities for the agglomeration of minute flocs into larger flocs by gradually bringing the minute flocs together. The velocity gradient plays an important role in flocculation.

## 4.2 Basic principles

Particles in water resist settling for two basic reason.

1. particle size: untreated, natural water continuous three types of non settlable solids, these particles are:

- Suspended - are particle carried along (held in suspension)
- Colloidal - include fine silt, bacteria, color - causing particles and viruses
- Dissolved solids: organic or inorganic matter such as salt, chemicals of plants and animal origin

2. Natural force

Particles in water usually carry a negative electrical charge. There are two kinds of forces associated with the charge. Zeta potential is natural repelling force. Vander Walls force is natural force of attraction. Whenever the Zeta potential is greater than the Vander walls force, particles will stay in suspension.

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**Effect of coagulation/flocculation**

The coagulation/flocculation process neutralizes or reduces the Zeta potential of non settlable solids so that the Vander walls force of attraction can begin pulling particles together.

## 4.3 Coagulation/flocculation facilities

The coagulation/flocculation process require facilities for:

- Chemical storage
- Solution preparation
- Dosing
- Rapid mixing
- Flocculation

**Coagulants**

The most commonly used coagulants in water are: aluminum sulfate (usually called alum), ferrous sulfate, ferric sulfate and sodium alluminates.

The relocation of chemicals used as coagulants are quoted in many text books and can be referred to.

**Seeds as coagulants**

There is a well known species of plant seeds known as Moringa Olifera whose powder is effective in coagulation. This plant is found in Arbaminch area. One powdered seed in one litter of water has a capacity of coagulating and lifting solids fall to the bottom of the container.

**Coagulant aids**

A coagulant aid is a chemical added during coagulation to improve coagulation. There are three general type of coagulant aids:

- activated silica - will increase the rate of coagulation, reduce the coagulant dose needed, and widen the pH range.

- weighting agents and absorbents - enhance floc formation. Bentonite, powered silica, ash are weighting agents.

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Rapid mixer



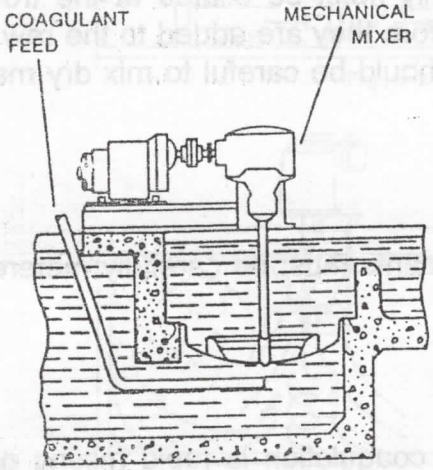



Figure 3-9. Mechanical Mixing Chamber

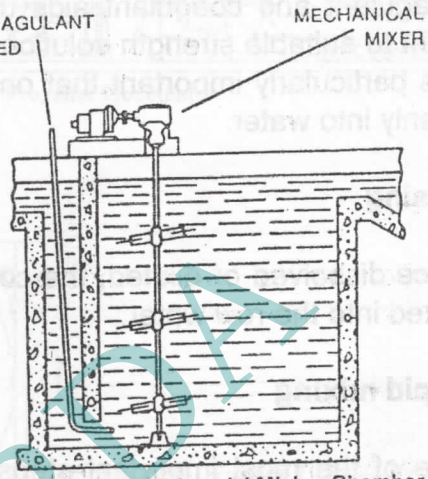



Figure 3-10. Mechancial Mixing Chamber

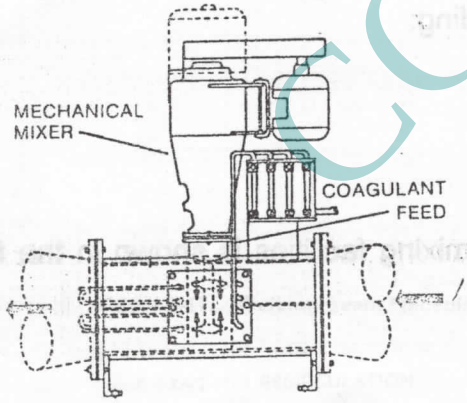



Figure 3-11. In-Line Mixer

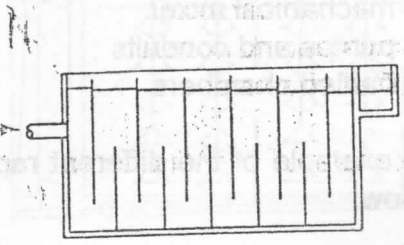


Figure 3-12. Baffled Chamber

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- Polly electrolyte - are extremely large molecules that, when dissolved in water, prudence highly charged irons.

**Chemical storage**

Coagulants and coagulant aid chemicals should always be stored in a dry area at a moderate and fairly uniform temperature.

**Solution preparation**

Coagulant and coagulant aids usually must be diluted at the treatment plant to suitable strength solution before they are added to the raw water. It is particularly important that one should be careful to mix dry materials evenly into water.

**Dosing**

Once dissolved or diluted, the coagulants must be carefully metered and mixed into the row water.

**Rapid mixing**

One of the most important steps in coagulation is rapid mixing or flush mixing. Rapid agitation is essential to distribute the coagulation evenly through out the water. There are different types of facilities that can be used to provide rapid mixing, including:

- mechanical mixer
- pumps and conduits
- baffled chambers

An example of the different rapid mixing facilities is shown in the figures below.

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## Flocculation

The flocculation facility consist of a basin or tank and a means of slow, genre mixing. Examples are shown in the figures below

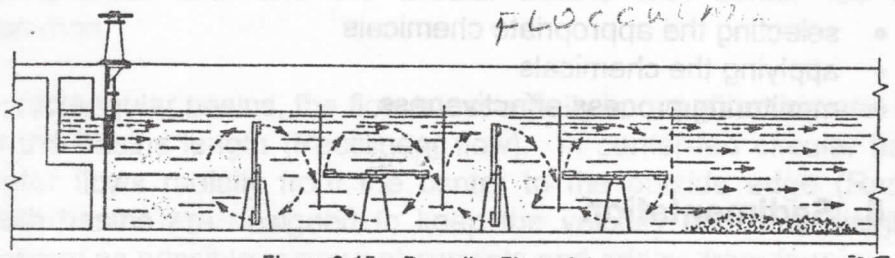


Figure 3-15. Propeller Flocculator

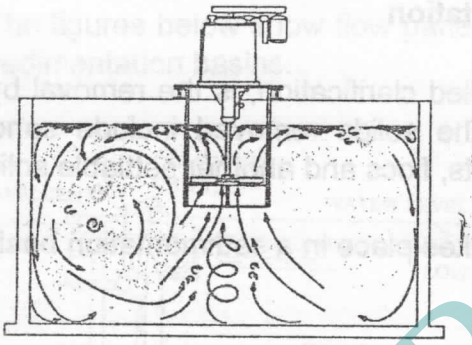


Figure 3-16. Turbine Flocculator

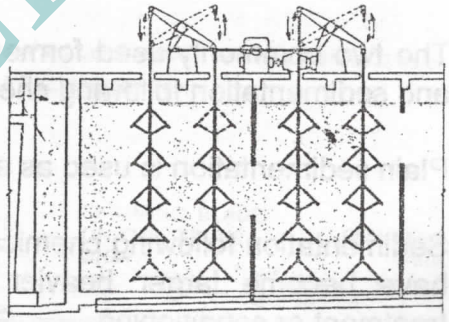
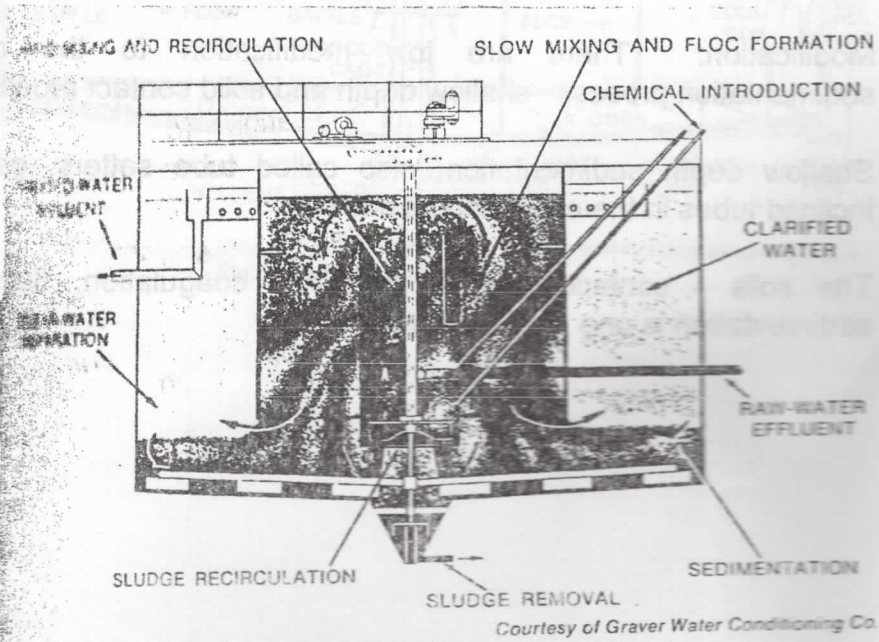


Figure 3-17. Walking Beam Flocculator




Courtesy of Graver Water Conditioning Co.

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**Operation of the Coagulation/Flocculation Process**

There are three fundamental steps in operating the coagulation/flocculation process

- selecting the appropriate chemicals
- applying the chemicals
- monitoring process effectiveness,

## 5. Sedimentation

### 5.1 Description of Sedimentation

Sedimentation sometimes called clarification, is the removal by gravity of settlable soils in water. The solids removed include sand, silt, grit. Chemical precipitate, pollutants, flocs and another settlable solids.

The sedimentation process takes place in a sedimentation basis or setting basis.

### 5.2 Forms of sedimentation

The two commonly used forms of sedimentation are plain sedimentation and sedimentation following chemical addition.

Plain sedimentation is used as a preliminary treatment process.

Sedimentation following chemical addition: removes by gravity solids that have become larger heavier and more settlables due to chemical treatment or conditioning.

Modification: There are tow modification to the conventional sedimentation process: shallow depth and solid contact process.

Shallow depth sedimentation, also called tube setters, generally use inclined tubes in the conventional basins.

The soils - contact process combines coagulation, fluctuation and sedimentation is one treatment unit.

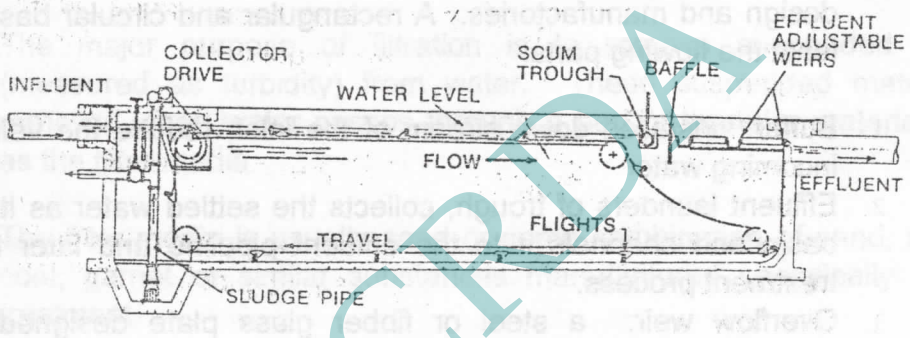
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## 5.3 Sedimentation facilities

Sedimentation takes place in specially disjoined basins. These basins are known as setting tanks, setting basins, sedimentation tank, sedimentation basin, or clarifies. They can be rectangular, square, or circular. Rectangular tank and the circular basins with center fed are most common.

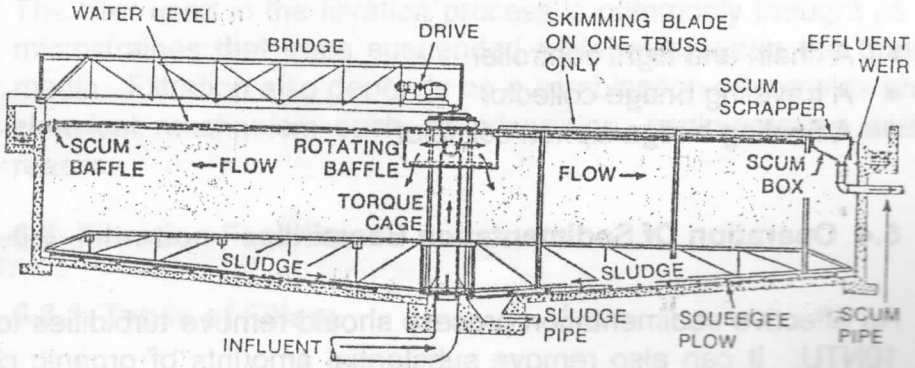
In rectangular basins, the flow is essentially in one direction and is parallel to the basins length (Rectilinear flow). In center-fed circular basins, the water flows radially from the center to the outside edge (Radial flow). Both basins are designed to keep the velocity and flow distribution as uniform as possible to prevent currents and eddies from farming.

The figures below show flow pattern in sedimentation basins and parts of sedimentation basins.




*Courtesy of the FMC Corp., Material Handling Systems Division*

**Figure 4-5. Parts of a Rectangular Basin**




*Courtesy of the FMC Corp., Material Handling Systems Division*

**Figure 4-6. Parts of a Circular Basin**

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### Zones in sedimentation basins

Regardless of the type of basins used, four zones exist, each with its own function. These zones are:

1. Inlet zone: decreases the velocity of the incoming water and distributes the flow evenly across the basin
2. Settling zone: provides the clam area necessary for the suspended materials to settle.
3. Outlet zone: provides a smooth transition form the settling zone to the effluent flow area.
4. Sludge zone: receives the settled solids and keeps them separate from other particles in the settling zone.

### Parts of a sedimentation basin

Equipment sued in conventional setting basin varies depending on the design and manufactories. A rectangular and circular basins have at least the flowing parts:

1. Buffer: installed down stream of the inlet, reduce the velocity of the incoming water
2. Effluent launders of trough, collects the settled water as it leaves the basin and channels it to the effluent pipeline and later to the next treatment process.
3. Overflow weir: a steel or fibber glass plate designed to evenly distribute the overflow to all points of the basin.
4. Sludge removal equipment: removes sludge which can carried out the mainly or automatically operated sludge removal equipment. The removal equipment is usually one of the following.

- A chain and flight controller
- A traveling bridge collector
- A floating bridge siphon collector.

## 5.4 Operation Of Sedimentation Basin

An effective sedimentation process should remove turbidities to less than 10NTU. It can also remove substantial amounts of organic compounds that cause color and other objectionable substances.

Since effective sedimentation is linked with proper coagulation/flocculation, the operation must ensure that the best possible floc is being formed.

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### 5.4.1 Operating Problems

Poorly formed floc and short circuiting are the two most common problems in sedimentation.

## 6. FILTRATION

The removal of suspended solids by filtration plays an important role in both the naturally occurring purification of ground water and the artificial purification of water in treatment plants.

### 6.1 Description of Filtration

The major purpose of filtration is to remove suspended materials (measured as turbidity) from water. These suspended materials are removed when water passes through a bed of granular materials known as the filter media.

The filter media is usually sand or some combination of sand, anthracite coal, garnet or similar substances manufactured specifically for water treatment.

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### 6.2 Filtration Process

The filter used in the filtration process is commonly thought as a sieve or microstraines that traps suspended material between the grains of filter media. Filtration also depends on a combination of complex physical and chemical mechanism such as adsorption, sedimentation and chemical reaction.

### 6.3 Filtration Facilities

#### 6.3.1 Types of Filters

Filters can be classified by the filtration rate, type of filter media, or type of operation. For purpose of this note, the following classification. Which combines the above factors will be used.

1. Gravity filters: the force of gravity moves the water through the filter media. It includes:

- Slow sand
- Rapid sand
- High rate which consist of dust-media and multimedia

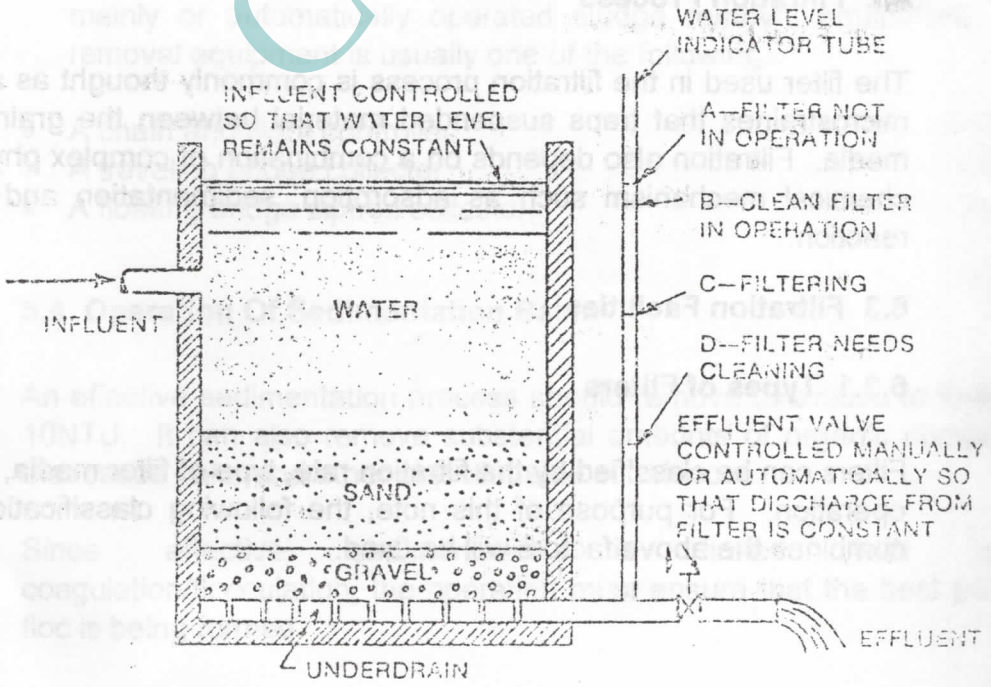
2. Pressure filters: operate on the same principle as gravity filters but flow through the filter media is under pressure.

**Slow sand filters**: are the oldest type of municipal water filtration. Slow sand filtration is the appropriate filtration system used in conditions of rural area in Ethiopia. Because the filter media (sand) is readily available, and it is generally less costly. The disadvantages are:

1) it requires large area,
2) can not effectively work for turbidities more than 30 NTU,
3) it has very slow filtration rate.

Because of these disadvantages, slow sand filtration systems are being neglected in treatment systems in industrialized countries.

However, coupled with horizontal flow roughing filtration as primary treatment, it is the most economical and appropriate filtration system for developing countries. The figure below shows the general layout of slow sand filtration.




*Courtesy of the New York State Department of Health*

Figure 6-3. A Slow Sand Filter

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**Rapid Sand Filter:** Rapid sand filters can accommodate filtration rates 40 times of the slow sand filters. Its design features differ from the slow sand filters in that it has a back washing facility. The components include:

- Filter tank
- Filter media
- Gravel support bed
- Under drain system
- Wash water troughs
- Filter bed apitaters
- Control equipment

Air binding and media loss are the most common operational problems

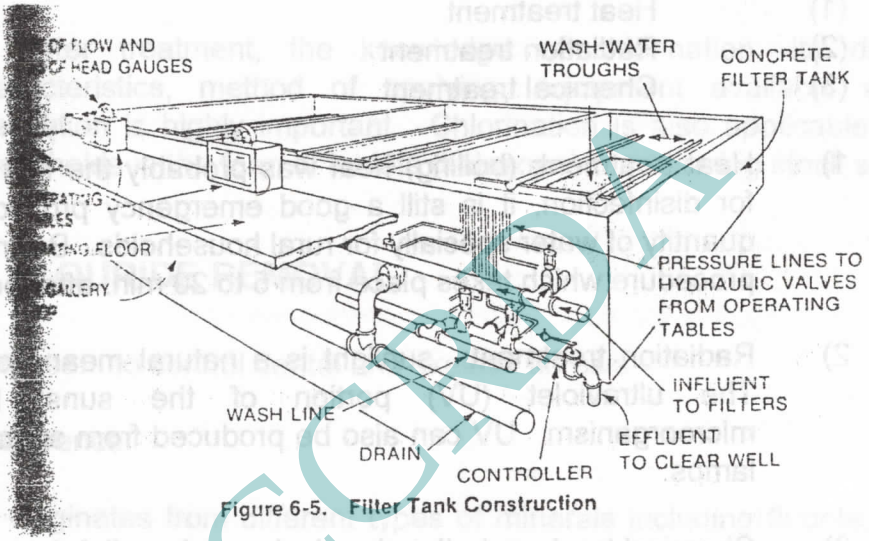



Figure 6-5. Filter Tank Construction

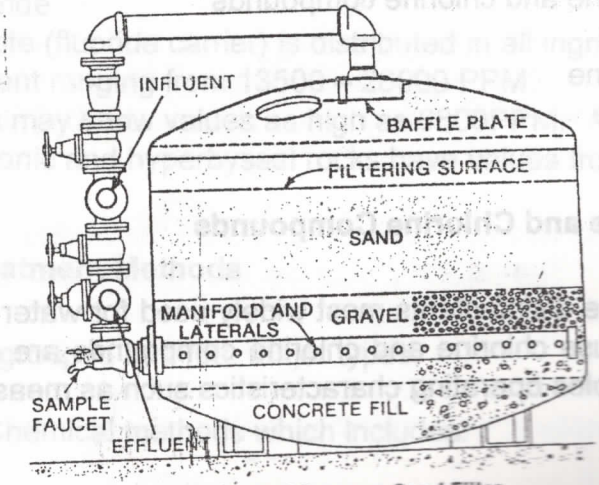



Figure 6-15. Vertical Pressure Sand Filter

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# 7. DISINFECTION

Disinfection is the treatment process used to destroy disease causing organisms, usually through the addition of chlorine to the water. Diseases caused by pathogenic organisms in water are called water borne diseases. The more common ones are: gastroenteritis, typhoid, dysentery, cholera, infections hepatitis, amebic dysentery and giardiasis.

## 7.1 Methods of Disinfection

The three general types of disinfection are:

(1) Heat treatment
(2) Radiation treatment
(3) Chemical treatment

1) Heat treatment: (boiling) heat was probably the first method used for disinfection, it is still a good emergency procedure for small quantity of water specially for rural households. Boiling water is the procedure which takes place from 5 to 20 min. after boiling.

2) Radiation treatment: sunlight is a natural means of disinfection. The ultraviolet (UV) portion of the suns' light destroy microorganism. UV can also be produced from specially designed lamps.

3) Chemical treatment: the chemicals used as disinfectants are:

- Chlorine and chlorine compounds
- Iodine
- Bromine
- Ozone

## 7.2 Chlorine and Chlorine Compounds

These are the disinfectants most widely used for water treatment. This is simply because chlorine and chlorine compounds are cheaper, common, and has simples operating characteristics such as measuring the residual.

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### 7.2.1 Chlorine Chemicals

Hypochlorous acid (HOU)and Hypochlorous (Ocl) are the most common residuals. They can be delivered as:

- Chlorine ($cl_2$)
- Calcium hypochlorite (ca $(Ocl)_2$)
- Sodium hypochlorite (Na Ocl)

### 7.2.2 Handling, Storing and Dosing Chlorine

In water treatment, the knowledge of chlorination, its disinfection characteristics, method of applying, equipment available and softy precaution is highly important. Chlorination is also applicable for small households in the form of tablets (halazone) or preparing stock solutions.

## 8. FLOURIDE REMOVAL

Purpose: to control dental and skeletal florosis

Occurrence:

- Originates from different types of minerals including fluorite, appetite, micas, hornblende, tourmaline and cryolite.
- In most cases it occurs as fluorite or flourospan (Ca $F_2$).Apetite (fluoride
- Apatite (fluoride carrier) is distributed in all ingnesns rocks with fluoride content ranging from 13500 – 26000 PPM.
- Mica may show values as high as 6800PPM.
- Volcanic and hyperbyssal rocks have values from 80 – 2500 PPM.

### 8.1 Treatment Methods

Can be grouped into four major types:

1) Chemical methods which includes:

- Filtration through activated aluminum
- Treatment with bone char

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- Treatment with aluminum sulphate
- Softening with lime
- Treatment with tricalcium sulphate
- Filtration through granular activated carbon
- Treatment with hydroxyl – apatite

2) Electrical method

- Electrodialysis

3) Physical method

- Single stage distillation
- Multiple stape distillation
- Vapour compression process
- Solar evaporation still
- Reverse osmosis

4) Biochemical methods

- Vyredox method (Oxidation – reduction) method

## 9. IRON

Most water supplies contain some iron, because iron is common in many ingenious rocks and is found in trace amounts in practically all sediments and sedimentary rocks.

Small amounts of iron seriously affect waters usefulness for some domestic and industrial purpose. Concentrations of 2 to 5 mg/l in ground waters are common. Iron concentration in drinking water should not be greater than 0.3 mg/l.

Water may dissolve iron upon contract with metal well casings, pump parts and piping. The more corrosine the water (low $p^H$ or high oxygen content), the more metal it will dissolve. Iron bearing waters favour the growth of iron bacteria such as Crenothrix, Gallionella and Leptothrix. These growths farm so abundantly in water mains, recirculating systems, and occasionally in wells that they have a marked clogging effect.

Iron removal is based on oxidation principle. Aeration and prechlorination are the principal methods.

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The "Vyredox" method which was developed in Finland, for example, makes use of aeration wells and iron – oxidizing bacteria in the ground. In this method, numerous aeration wells are constructed in ring around the production well. Water is withdrawn from a nearby supply well, degassed ($CO_2$ and $CH_4$ are removed), aerated with oxygen and then injected into the ground water system through the aeration wells.

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# *CHAPTER TWELVE*

# *DISTRIBUTION NETWORK DESIGN*

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# CRDA - TRAINING ON COMMUNITY BASED WATER SUPPLY AND SANITATION

## COURSE TITLE - DISTRIBUTION SYSTEM

### 1. INTRODUCTION

#### 1.1 Background

Water is supplied to consumers based on the type of source and the size of the communities. Water from a shallow well can be supplied to the consumers on the spot by hand pumps. On the other hand water can also be supplied from a shallow bore hole with a motorized pump at the spot at the service reservoir. Such kind of supply system can be called as spot supply.

On the other hand water can be transported to the supply area where it will be distributed to the consumers by public taps or yard and house connections. The conveyance of the water to the supply points can be accomplished by installing pipe lines. The water demand can also be balanced by a balancing reservoir or a service reservoir. The conveyance of the water from the source to the supply point through the pipe line and balancing reservoir is called distribution system. For a pipe line to be called as a distribution system it has to have at least pipes branching in two or more directions to the delivery points. Booster pumps can be also considered as part of a distribution network if available in the system.

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#### 1.2 Layout of Distribution Network

The layout of the distribution network can be in most cases governed by the lay out of the supply areas. If the supply area is elongated and only follows one route then the distribution network could as well follow the road lay out and could also be elongated one. Such lay out may have only pipes leading to one direction with out forming a connection at the end. On the other hand pipe lines could be laid inter connected at the ends forming a grid or loop system.

Primary mains or feeders are pipe lines of larger size which are connected to the main transmission line or from a main reservoir that supply the water for the distribution. Primary lines has to be laid in parallel and cross connected at certain intervals with valves for isolation of sections in case of break down.

Accordingly the water supply distribution network is classified based on the lay out shape and the connecting system as described below:

- Like a tree or dead end system
- Like a circular or ring system
- In grid iron system
- In radial system

The grid iron system is the best arrangement for distributing water. All primary and secondary mains are looped and interconnected, eliminating dead ends and permitting water circulation such that a heavy discharge from one main allows drawing water from other pipes. When piping repairs are necessary, the area removed from service can be reduced to one block if valves are properly installed.

## 2. DESIGN OF DISTRIBUTION NETWORK

### 2.1 General

The design of distribution network will be started when the layout is first defined on a master plan of the supply area. If there is no master plan topographic map survey work has to be done in order to determine the elevation along the pipe line route and the length of the pipe to be laid.

Once the topographic map is prepared the pipe line route will be selected and pipe nodes will be defined. The lay out of the pipe has to be done in such a way that the main distribution pipe will not be used as connection lines while secondary and tertiary lines will be used for connections. The secondary and tertiary lines have to be close to the consumers so that long distance laying of pipe will not be required to the individual connections.

Ones the lay out of the distribution network is done then the water demand at each node has to be determined. This includes domestic demand, public demand, losses and other demands. The analysis of the distribution network will then be carried out either manually or using computer software. The manual method of calculating the distribution network is very tiresome and takes a long time compared to the computer software now in use and is therefore not practiced particularly for large size distribution network system.

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## 2.2 Piping Layout

The piping layout of a distribution network has to be done prior to the start of the design of the system. The layout has to be made based on the master plan of the area to be served and the present and future population settlement pattern and density and land use plan. Distance between parallel tertiary or secondary lines may not have to be more 200 meters based on the settlement condition of the area.

Ones the layout is done the piping has to be divided in to segments which will help in the design. The connections has to be given node numbers while the segments has to be given pipe number which will help in the design. The length of each pipe segment has to be measured from the map or from the survey and each node elevation has to be also determined from the contour of the map or survey work.

The laying of the pipe can be done in two phases depending on the design horizon to be established in the design criteria. Areas which are not occupied now or will not be occupied during the first phase will be covered during the second phase design period.

## 2.3 Network Analysis

Ones the pipe layout is done the analysis has to follow to determine the different conditions of the pipe line in order to supply the required water to the consumers. The network analysis will be made for the first and second phase demands based on the design horizon to be established in the design criteria.

**Determination of Node Demand**: Nodal water demand has to be determined in order to determine the size of the pipe line between two nodes and the pressure at the nodes. The water demand at the node includes domestic demand, losses, public demand and fire fighting requirement if any. The sum of all the demands will be the demand at the node.

Demand at the node can be determined by taking the population that can be served from that particular node based on the density of the settlement in that area using the map in use. Ones the population to be served is known then the domestic demand at the node can be obtained by multiplying it with the average per capita water demand. The public demand can also be allocated to the node if such consumers are available to the proximity of the node. Losses can be divided among the number of nodes depending on the length of the pipe between the nodes.

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**Estimation of Pipe Diameter**: Ones the nodal water demand is estimated then the next step is to determine the pipe diameter for each segment based on the nodal water demands. Where the node demand is big then larger pipe diameter could be estimated and so on. The estimated pipe diameter will be revised after the simulation by computer soft ware until all the required conditions are fulfilled.

**Selection of Pipe Material**: Ones the nodal water demand is estimated and the pipe diameter for each segment based on the nodal water demands is determined then the pipe roughness coefficient has to be determined. This can be done ones the type of pipe material to be used is defined. For a distribution network it is most of the time economical to use PVC pipes if the soil condition is not rocky and not exposed to heavy traffic loads. Other type of pipe materials can also be used depending the water quality, the physical condition of the area, soil condition and traffic loads, etc. The roughness coefficient of the selected pipe material will be used in the analysis of the network for determination of friction in the pipes. Pipe roughness coefficient for PVC is normally taken as 130, for Ductile cast iron 110 and for Galvanized steel pipe 120.

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The types of pipe used for distributing water under pressure include ductile cast iron, gray cast iron, galvanized steel, asbestos cement, concrete, plastic and copper. Small diameter plastic, copper and galvanized steel pipes are mostly used for house connections. The most commonly used pipes for distribution mains are ductile cast iron, plastic and galvanized steel. In general for use in transmission and distribution system the pipe materials must have the following:

- Adequate tensile and bending strength to withstand external loads that will result from trench back fill, unstable soil conditions, earth movements, etc.
- High bursting strength to withstand internal water pressures.
- Ability to resist impact loads encountered in transportation, handling and installation.
- Smooth, none corrosive interior surface for minimum resistance to water flow. The exterior unaffected by aggressive soils and ground water.
- A pipe material that can be provided with tight joints and easy to tap for making connections.

**Length of Pipe and Node Elevations**: The length of each pipe segment and the ground elevation at each node are also very important for the simulation work. The length of each pipe segment has to be measured from the layout plan based on the scale of the map. The node elevation has to be also determined from the contour of the map crossing the node. Reservoir location elevation, booster station elevation has to be also determined if available in the system.

## 2.4 Design Criteria for Network Analysis

The network analysis will be based on established design criteria which has to be fulfilled after the analysis. The simulation of the network will continue until all or most of the conditions set in the network design criteria are fulfilled. The criteria for the network analysis are:

- Velocity in the pipe should not be below 0.3 m/s
- Head loss per kilometer of pipe should not exceed 5 m/1000 m (some times this can be up to 7 m/1000 m).
- Pressure at each node should not be below 15 meters and above 70 meters of water column. In some cases the pressure can be as low as 7 meters and as high as 90 meters depending on the terrain condition and the location of the node.
- If it is a very big distribution network then the size of the main and secondary lines should not be below 50 mm.
- The simulation has to be done both for peak hour demand and night flows. The peak hour factor will be determined in the design criteria for the scheme and the night flow factor usually should not be more than 0.3.

## 2.5 System Appurtenances

The distribution network has to be provided with the necessary valves and other appurtenances for proper operations.

**Fire Hydrants**: Fire hydrants has to be installed at public places, commercial areas, densely populated residential areas, communal places and institutions. Fire hydrants can be located at low points of the distribution network to get pressure. This can be determined based on the master plan and physical observations of the area. Fire hydrants should not be installed on primary and sometimes secondary lines.

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**Valves**: Valves will be installed at all nodes in order to isolate a segment or block of pipes in case the pipe requires maintenance or cleaning. The number of valves to be installed at one inter cross connection depends on the number of pipe inter connected at that point and is normally equals N - 1 where N is the number of pips connected at that node.

**Flushing Devices**: Flushing devices are used to flush main lines when there is need and has to be installed at low points in the network where there is no fire hydrant.

**Air Release Valves**: Air release valves may not be required in a distribution network as the air in the system can be released through the taps of the yard and house connections in the system. However, it might be important to install air release valve at high points where water flow might be blocked with the air logged in the pipe.

## 2.6 Software

Network analysis is the process of using computer model of water distribution system to analyze performance capabilities and to define the system requirements necessary to meet system design standards for pressure and flow. A computer model is composed of two parts; a network-data file that defines the system in terms of pipes and nodes a computer program that solves series of hydraulic equations for pressure and flow.

Network analysis of water systems has evolved during the past 40 years from a time consuming process done infrequently on small systems to a quick and easy process done regularly on systems of all sizes.

There are at present a number of computer software which can be used for the distribution network analysis. LoopV5 developed by the UNDP/World Bank can be used for small and medium towns distribution network analysis. There are also other software like Watnet, Water, Extended period Simulation, etc. LoopV5 for instance can be obtained free of charge while the others can be purchased from the software companies.

## 2.7 Pipe Laying

Laying of pipes depend also on the design of the trench depth and the type of pipe material. Distribution network is usually laid in towns where traffic load exists and the pipe line to be laid has to be therefore buried to a sufficient depth so that it can resist the vehicle load and the back fill pressure.

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The depth of the trench can be calculated using known formula or can be determined from manufacturer's catalogue showing the type of pipe, pressure class and depth of trench for different soil and traffic loading conditions. Trench depth for road crossings normally has to be not less than 1 meter and in none traffic areas not less than 0.60 meters. This is just an indication and has to be considered for each specific site.

Laying of pipe line requires bedding materials to avoid any extruding surface from bursting the pipe material. Such bedding material normally has to be granular material of uniform size and should not contain rocks or boulders. The bedding material has to be about 15 cm below the pipe and about 10 cm above the pipe. Back fill material from the excavated material can then be used to cover the rest of the depth.

Anchor blocks has to be constructed from concrete structure at bends where there is high pressure in the pipe line. The anchor blocks can also be designed using standard formula or from manufacturer's catalogue.

Manholes has to be provided for gate valves, flushing devices, fire hydrants and air release valves as necessary to protect them from external damages and interference. River crossings will be done using bridges for big rivers and concrete casing for small ones as necessary.

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(i) The consumers are required to store water in cisterns

## 10.4. LAYOUT OF DISTRIBUTION SYSTEM

The water supply distribution systems are laid in the following forms.

### 10.4.1. Tree or dead end system

There is a simple main which goes on diminishing in size. The small pipes take off from the main as shown in Fig 10.6. This system is suitable for irregularly growing towns. The pipes can be added as the town develops. There are many dead ends in the system which cause the stagnation of water. Also in case any repair is to be done the area beyond this point will go without water. However, the advantages are that this method will have lesser number of valves and pipe sizes are easy to calculate.

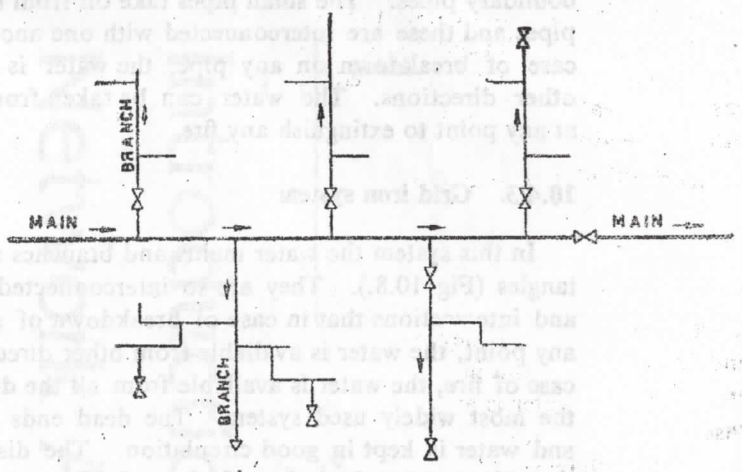



Fig 10.6. Tree or dead end system

### 10.4.2. Circle or ring system

In this case the supply main is laid round the district and the discharge is divided into two portions. Each portion goes along the boundary as indicated by arrows in Fig 10.7 and

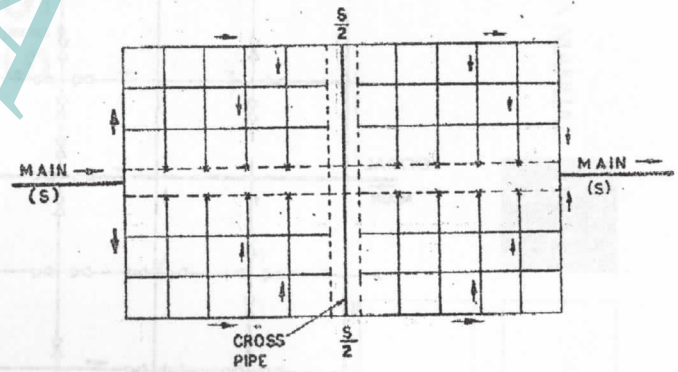



Fig 10.7. Circle or ring system

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reaches a point from both the sides. The water reaches every point very quickly with minimum loss of head. A pipe is provided in the middle of the area to cross connect the boundary pipes. The small pipes take off from these boundary pipes and these are interconnected with one another so that in case of breakdown on any pipe, the water is available from other directions. The water can be taken from several pipes at any point to extinguish any fire.

### 10.4.3. Grid iron system

In this system the water mains and branches are laid in rectangles (Fig 10.8.). They are so interconnected at the streets and intersections that in case of breakdown of service main at any point, the water is available from other directions. Also in case of fire, the water is available from all the directions. It is the most widely used system. The dead ends are eliminated and water is kept in good circulation. The disadvantages are that the exact calculation of sizes of pipes are not possible. The system involves the provision of valves on all branches. It is best suited for towns with roads of rectangular pattern (grid iron) like that in Chandigarh.

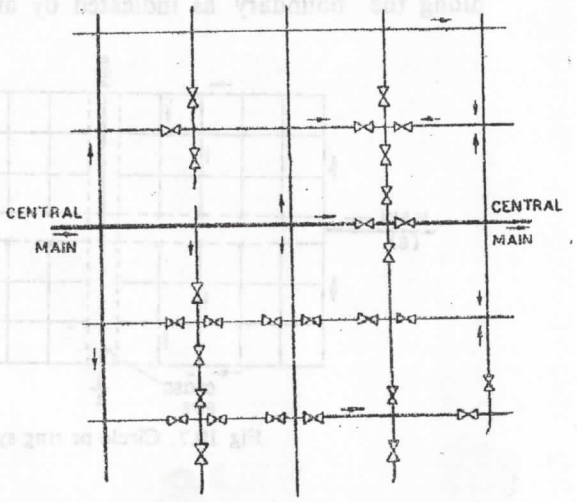



Fig 10.8. Grid iron system



### 10.4.4. Radial system

This system is the reverse of the ring system. The water i pumped into the distribution reservoirs kept in the middle o each zone as shown in Fig 10.9 and the supply pipes are lai

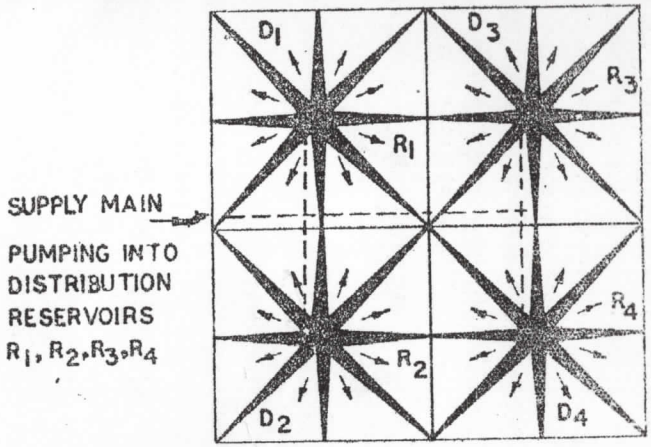



Fig 10.9. Radial system

radially ending towards the boundary of the area to be serve It gives quick service. The calculation of pipe sizes is eas This system is suitable when the town has a radial layout roads.

In States, the grid iron system is popular while the ring sy tem is popular in the Continent. As a matter of fact, no c follows one system alone. A combination of several systems often employed depending upon the local conditions.

## 10.5. NECESSITY OF BOOSTING

The distribution system should be such that sufficient pr sures are maintained throughout. Very high pressures increa the cost for safety and maintenance. If in any part or parts the city the pressure is not good and the capacity of mains a falls short of requirements, booster pumps should be instal

Chapter 1

# Introduction to Network Analysis

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Network analysis is the process of using a computer model of a water distribution system to analyze performance capabilities and to define the system requirements necessary to meet system design standards for pressure and flow. A computer model is composed of two parts: a network-data file that defines the system in terms of pipes and nodes and a computer program that solves a series of hydraulic equations for pressure and flow.

Network data include physical characteristics for pipes, such as length, roughness coefficient, diameter, and node data, which describe elevation and water demand or water supply. Nodes, or junctions, define the end points of pipes or pipe segments. Operational parameters, which indicate the actual value of system facilities, such as pump-station flow rate or reservoir elevation, are also included in the model.

Calculating pressure and flow in pressurized pipe systems is a time-consuming process that requires several iterations to arrive at a solution. A solution is a set of pressures and flows that simultaneously satisfies the energy and continuity equations for every link and node in the network. Calculations for a system containing a few loops can be done manually, but this becomes impractical when more than a few loops are involved. Computer programs to solve energy and continuity equations have been in use for many years, but only during the last several years, with the advent of the microcomputer, has computerized network analysis become widely used.

## HISTORICAL DEVELOPMENT

Network analysis of water systems has evolved during the past 30 years from a time-consuming process done infrequently on small systems to a quick and easy process done regularly on systems of all sizes. Because network analysis requires solutions to mathematical formulas and calculations that are more easily done by computer than by hand calculations, the growth in the use of network analysis parallels the growth of the computer industry. Several events in the history of network analysis resulted from advancements in computer technology.

### Cost

The cost of computer hardware and software is relatively small compared to the amount of money that can be saved by designing a water system efficiently and accurately. Water facilities are expensive, and the cost savings achieved through proper sizing and installation can range from thousands of dollars to millions of dollars. Efficient operating strategies developed through use of network analysis can also be used to minimize energy costs, thus increasing cost savings.

### Socioeconomic/Environmental Impacts

Several socioeconomic and environmental considerations make network analysis a standard utility tool. Increasing construction costs, combined with increasing population and consumption, make systematic analysis necessary to efficiently design, plan, and operate a system. Water-consumption-management plans can be used to save water and to redefine consumption patterns that lead to more efficient use of facilities.

### Familiarity

A final advantage of network analysis is that it enables the user to gain a feel for system capabilities and limitations. This is required to meet industry trends. Emphasis on water quality in distribution systems, fire-flow capabilities, and advanced system-operation techniques and tools make understanding a system increasingly important.

## SOFTWARE

There is an abundance of network-analysis software. The AWWA Computer Assisted Design of Water Systems (CADWS) Committee has attempted to compile information about programs and their use. Several surveys and questionnaires by the CADWS Committee and other groups have been distributed during recent years (see Table 1-1).[12]

Table 1-1 Computer Questionnaires Distributed by AWWA CADWS Committee

| Questionnaire Title | Date |
|---|---|
| Computer Assistance Group of Water Utilities of America (CAGWUA)—Questionnaire 1 | July 1980 |
| Engineering/Scientific Computer Usage Questionnaire (AWWA) | December 1980 |
| Computer Assistance Group of Water Utilities of America (CAGWUA)—Questionnaire 2 | February 1981 |
| Network Analysis Survey (Denver Water Department, Denver, Colo.) | September 1981 |
| Network Analysis Survey 1984 (AWWA–CADWS) | June 1984 |
| Microcomputer Software Usage in Water Utilities (AWWA) | November 1984 |

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## Network Analysis Survey 1984

In an effort to learn recent national trends in the development and usage of network-analysis software, the Network Analysis Survey 1984 was conducted. The survey, which was designed, distributed, and compiled by the CADWS Committee, was mailed to 396 US water utilities. The questionnaire contained questions in three primary categories: general information, computer usage, and *C* factors. All responses are compiled in the Network Analysis Survey 1984 Report.[13] These results represent the most current information available at the time this manual was written.

There were 172 respondents to the survey. Of these, 109 used network-analysis programs. Responses to the survey indicated that many programs are in use and more programs were implemented in 1983 than any preceding year. Other significant results include the following:[12]

- 5 percent developed their programs in-house,
- 52 percent modified their models,
- 88 percent planned to improve their models,
- 40 percent plan to establish models in the next two years, and
- 92 percent felt their models were suitable in complexity.

Current uses of network analysis, beginning with the highest percentage, were: long-range planning (95%), fire-flow assessment (78%), operational strategy (52%), infrastructure rehabilitation (40%), emergency-response plan (25%), and energy management (17%).[14] Several papers written by committee members discussing survey responses have been presented and published at AWWA conferences.[14,15,16]

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## Trends in Network Analysis

Two key trends emerged from the Network Analysis Survey 1984. First, a parallel was noted between the increased use of network analysis and the introduction and use of microcomputers. This was determined by observing the brand names of the computers being used as listed in the results.

A second trend was the use of computer programs that perform more than the basic network-analysis functions of calculating pressure and flow. Comparison of responses of the 1981 and 1984 network analysis surveys indicate that many users have moved beyond basic network analysis to more sophisticated capabilities, such as energy calculations, network loading, and network building. (It should be noted that the 1981 and 1984 network analysis surveys were constructed and conducted by committee members without the aid of professional pollsters; nevertheless, the trends are quite clear and can be easily recognized.)

## Software Capabilities

Many of the steps involved in network analysis can be performed by a computer with the proper software. Following is a brief discussion of network-analysis-program and support-software capabilities as identified in the Network Analysis Survey 1984.

*Automatic hydrant use:* The ability to automatically select the hydrants required to meet a specified fire-flow requirement in a given vicinity. The program determines the number of hydrants and their flow capabilities based on flow requirements and the number of hydrants to be used.

*Demand forecasting:* The process of using consumption values based on land use and consumption ratios to arrive at a consumption projection for a geographical area under given conditions, such as peak hour.

*Design optimization:* The process of determining pipe sizes and least operational cost based on selected sizes, cost per foot for selected pipe sizes, and power costs.

*Energy-use calculations:* The use of energy-cost factors to calculate energy requirements and pumping cost.

*Flow:* The calculation of flow in pipes in the network.

*Graphics:* The graphic display of network data and network solution output, such as pressures, flows, pressure contours, and other similar items.

*Hydraulic grade line (HGL):* The calculation of hydraulic-grade-line values at nodes. The HGL is equal to the pressure, in feet, plus the elevation.

*Hydrograph generation:* The creation of hydrographs for various conditions, such as demand and reservoir elevation. A hydrograph is a graph having a horizontal axis defined in units of time and a vertical axis defined in units of the item being measured, such as feet for reservoir elevation or gallons for consumption.

*Network-data generation:* The process of extracting selected network data from a data base and automatically formatting this data for input into the network-analysis program. This capability can be used to combine network-data files for different areas or to extract a network for a selected area from a larger area.

*Network loading:* The process of calculating and distributing loads or demands to the nodes in the network-data file. Sometimes also called load allocation or load distribution.

*Network plotting:* The ability to plot a network-data file using computer techniques; it is also called automatic plotting.

*Optimization of operations:* The process of determining the least-cost operation strategy based on operating costs, incorporating energy-use calculations.

*Output comparison:* The comparison of network-analysis output values for various cases. For example, a program with this capability can create a table that lists pressures at selected nodes for various demand conditions, such as peak hour or minimum hour, or with or without specified facilities. These computer-generated values can then be compared to actual values.

*Ability to change parameters:* The ability to change parameters and factors that are used in solving and defining the network. Parameters and factors include, among others, roughness coefficient, demand factors, units of flow, tolerance factor, and number of iterations for solving the network. Specific variables may include, for example, use of Hazen–Williams and/or the Manning formula for pipe-flow characteristics, use of a multiplicative factor to change all loads, and use of million gallons per day (mgd) and/or gallons per minute (gpm) for units of flow.

*Pressure:* The calculation of pressure at nodes.

*Pressure contour plotting:* The plotting of pressure contour lines (similar to ground contour lines).

*Pressure/flow plotting:* The ability to plot network-solution output (pressure and flow) automatically.

*Simulation of standard water-system components:* The ability to simulate standard components of a water system, such as pumps, pressure-regulating valves, check valves, closed valves, and reservoirs.

*Time simulation:* The calculation of pressure and flow in the network for varying demand conditions over a period of time; 24 time periods at 1-hour intervals is common.

One should keep in mind that there are numerous programs with a variety of capabilities currently available. An individual might consider developing simple data-manipulation and analysis programs, if such software is not accessible.

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## Sources of Software

Network-analysis programs are available from a variety of sources. Four sources are engineering consulting firms, software vendors or publishers, universities, and utilities and government agencies.

**Consulting firms.** Engineering consulting firms have provided network-analysis services for many years. Consulting firms frequently perform capital-improvement studies that require the use of computerized network-solution programs. After the network data base is created, the analysis performed, and the improvement plan provided, the consulting firm usually offers the utility a number of options for continued use of the network-solution program. The consultant might lease a copy of the program to the utility for in-house use. The consultant might also make the program available on a time-share basis, which allows the utility to perform its own analysis while sharing hardware. Another option is to have the consulting firm perform all analyses, in which case the utility has no control of or access to the analysis program. In all cases, the consultant maintains and upgrades the software.

**Software vendors and publishers.** Software vendors and publishers develop, maintain, and sell network-analysis software. Generally, these companies are primarily concerned with selling programs and providing software support, rather than setting up the data base and doing analysis.

**Universities.** Several universities have developed network-analysis programs that have been widely used and, in some cases, modified by utilities, consultants, and vendors. University programs are perhaps the most widely used programs, because they were, and still are, relatively inexpensive and are frequently updated. Seminars in the fundamentals of hydraulics and network analysis are held periodically by several universities.

**Utilities and government agencies.** A number of utilities and government agencies share their software with other utilities. In some instances, a nominal fee is charged to cover copying and mailing expenses. Some utilities also require an agreement that their software not be released to a company that might use it for profit. Programs in this category were generally created and placed in the public domain (such as WATSIM) or were developed by a utility. The latter programs were developed to meet the needs of a particular utility and, therefore, might require modification to meet the needs of another utility. While such programs appear to be free, some require a great deal of work to modify and implement; they may be poorly documented as well. However, other utility-developed programs may be both easy to use and well documented.

In choosing a software program, the potential user must evaluate the utility's needs and resources in order to select the most suitable program. User needs include program capabilities and the amount of customizing required; resources refer to hardware, number of people, and skills.

# HARDWARE

Computer hardware requirements for network-analysis programs vary according to individual programs; however, certain computer hardware components are required by enough programs to warrant general discussion here.

Network-analysis programs are available for mainframes, mini-, and microcomputers. Mainframe computers are large computers with extensive capabilities. Mainframes perform many functions; network analysis is simply one of them. Minicomputers are similar to mainframes in that they have extensive capabilities;

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however, they are generally used for specific types of applications, such as computer-assisted design, process control, or computerized mapping. Microcomputers are also used for many applications, but these applications are generally handled one at a time.

## Standard Components

**System unit.** Standard hardware components for a microcomputer system include the system unit, a monitor or cathode-ray tube (CRT), a keyboard, at least one disk drive, and a printer. The system unit contains the central processing unit (CPU), which commonly has at least 640K bytes of random-access memory (RAM). Memory requirements of network-analysis software vary widely. The memory required by a program is some indication of the capabilities of the program. A program that requires 128K bytes is probably more limited than a program that requires 640K bytes. The 640K-byte program probably can handle a larger network, as determined by the number of pipes and nodes. The larger memory may also allow for use of a numeric coprocessor, which can greatly decrease the time required for mathematical calculations.

**Monitor.** Some programs make use of various colors, and a color monitor is required to make use of this feature. However, many programs written for monochrome, or one-color, monitors will also run on color monitors. Use of various colors can be extremely helpful in the analysis process but is not essential.

**Keyboard.** A keyboard is a standard component that provides a method of communication between the user, the system unit, the printer, and the monitor.

**Disk drives.** At least one disk drive is required to store the program and data. Generally, two disk drives are better and a hard disk is better yet. The use of two disk drives or a hard disk minimizes disk swapping and thus lengthens the life of drives and disks. Hard disks are also capable of handling large data files.

**Printer.** A printer is required to obtain a printout of network data and results. Two types of printers are available. Impact printers include the original dot matrix and daisy wheel. Nonimpact printers are known as ink jet and laser, although they might also use a dot-matrix technique. The quality of print varies among printers; dot matrix and letter quality are two common types of print. Dot matrix is generally of lesser quality than letter-quality print.

The graphics capability of a network-analysis program might require a printer with graphic capabilities. For example, if the program produces screen graphics, then a graphics printer that will perform a graphics screen dump is required.

**Other hardware.** Other hardware that can be used with some network-analysis programs includes a mouse (or puck), a digitizing tablet, a plotter, and a graphics board. A mouse or puck may be used to communicate spatial information to the system unit. Generally, a mouse is used with menus to select commands for execution. It can also be used with a digitizing tablet to establish coordinates and create network drawings. A plotter is used to create high-quality, accurate drawings. A graphics board for insertion in the system unit is required for programs with graphics capabilities; in some cases, the graphics board is included with the CPU when it is purchased.

Minicomputer systems have components similar to those of a microcomputer system. A digitizing table having a much larger surface area than a tablet is available. Dual-screen work stations and tape drives are also common.

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## Summary

Hardware requirements vary depending on the requirements of the network-analysis software. Many programs operate using standard equipment; however, some programs with extensive capabilities require additional hardware. In short, hardware and software must be evaluated jointly to ensure that the system can perform the desired capabilities.

## References


1. CROSS, H. Analysis of Flow in Networks of Conduits or Conductors. Bull. 2 and 6. Univ. of Illinois, Engrg. Exper. Stn., Urbana, Ill. (1936).
2. CESARIO, A.L. *Network Analysis Survey 1981*. Denver Water Dept., Denver, Colo. (1981).
3. SHAMIR, URI & HOWARD, C.D.D. Water Distribution System Analysis. *Jour. Hydraulics Div.—ASCE*, 94:HY1:219 (Jan. 1968).
4. EPP, ROBERT & FOWLER, A.G. Efficient Code for Steady-State Flows in Networks. *Jour. Hydraulics Div.—ASCE*, 96:HY1:43 (Jan. 1970).
5. WOOD, D.J. & CHARLES, C. Hydraulic Network Analysis Using Linear Theory. *Jour. Hydraulics Div.—ASCE*, 98:HY7:1157 (July 1972).
6. DAVIS, A.L. & JEPPSON, R.W. Developing a Computer Program for Distribution System Analysis. *Jour. AWWA*, 71:5:236 (1979).
7. RAO, H.S. ET AL. *Extended Period Simulation of Water Distribution Networks*. Ofce. Water Res. and Tech., US Dept. Int., Contract 14-31-0001-0927 (Feb. 1974).
8. CESARIO, A.L. & LEE, T.K. A Computer Method for Loading Model Networks. *Jour. AWWA*, 72:4:208 (1980).
9. CESARIO, A.L. Computer Modelling Programs: Tools for Model Development. *Jour. AWWA*, 72:9:508 (1980).
10. FLASCO, R.D. Use of Computer Plotting in Hydraulic Analyses. Proc. AWWA Ann. Conf., Las Vegas, Nev. (June 1983).
11. GESSLER, JOHANNES & WALSKI, T.M. *Water Distribution System Optimization*. Dept. of Army, US Army Corps of Engineers, Washington, D.C. (Oct. 1985).
12. CESARIO, A.L. *Microcomputers for Water Utilities*, 79–83. AWWA, Denver, Colo. (1986).
13. Network Analysis Survey 1984. CADWS Committee, AWWA, Denver, Colo. (June 1984).
14. CESARIO, A.L.; MOREY, E.F.; & BRASHER, P.T. Computer Assisted Design of Water Systems. Proc. AWWA Ann. Conf., Dallas, Texas (June 1984).
15. VELON, J.P.; CESARIO, A.L.; & SHAMIR, URI. Network Analysis of Treated Water Systems. AWWA DSS Proc., Syracuse, N.Y. (Sept. 1984).
16. SARIKELLE, SIMSEK & CESARIO, A.L. Developments in Water Distribution System Analysis and Graphics Programs. AWWA DSS Proc., Seattle, Wash. (Sept. 1985).


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## Fundamentals of Fluid Flow

In order to understand the historical development of computerized network analysis, one must first understand the fundamental laws of physics on which it is based. Two laws of physics that apply to water-system networks define flow continuity and head loss around a loop. Flow continuity means that flow entering a node must be equal to the flow leaving the node plus the water use at the node; in other words, the total flow must be accounted for. Head loss around a loop refers to the law stating that the sum of head loss in each pipe is equal to the total head loss in the loop, which is equal to zero. A loop is a series of pipes connected in such a way that the beginning of the first pipe is the end of the last pipe and no pipe is traced twice. These fundamentals of fluid flow are used in all network-solution methods. The Hardy Cross method of calculation, which uses a systematic numerical scheme to calculate flows that satisfy these physical laws, has been used since 1936.[1]

Manual network calculations were time-consuming and susceptible to error; this made them candidates for solutions using computer techniques. As computers made their way into the business world, engineers and other professionals began to recognize the possibility of using computers to solve network calculations.

## 1940s

The McElroy Analyzer was developed and used in the 1940s to analyze water distribution networks. The analyzer, using an analog computer rather than the now-common digital computer, used wires, resistors, and light bulbs to simulate a water network. Resistors simulated flow restrictions. The method was crude by current standards, but it did provide a physical model.

## 1950s

Network analysis was done on large mainframe computers in the 1950s. A few network-analysis programs were available, but their use was relatively limited. Some utilities developed their own network-analysis programs, as did the City of Dallas, Texas, in the late 1950s.[2] However, use of computers was limited by their expense, physical size, and the extensive programming efforts required to implement applications.

## 1960s

Several computer programs for network analysis were developed and implemented in the 1960s. Two programs that became widely used are the Shamir–Howard program,[3] developed in 1965, and the Epp–Fowler program, developed in 1969.[4] Both programs made use of the Newton–Raphson technique for calculations. However, there were two notable differences in the programs. First, the Shamir–Howard program was based on a node-continuity formula, while the Epp–Fowler program was loop oriented. Second, the Shamir–Howard program solved for a mix of unknowns, including pressure, consumption, and pipe and node characteristics, while the Epp–Fowler program solved for pressure and flow.

Other network-analysis programs were available on a time-sharing basis. Utilities and consultants accessed a mainframe computer through a teletype terminal. Files containing water-distribution-system data were created, the program executed, and the output printed immediately. Thus, computer calculations for large systems became possible. Using these programs, several cases could be analyzed relatively quickly and easily.

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Some network-analysis programs developed in the 1960s used solutions (pressures, tank levels, and flows) for one point in time as input to the program for a second point in time, and then made calculations to result in a second solution. This set of multiple solutions represented the operation of a system over a series of time periods. It became known as multiple-solution simulation, continuous simulation, time simulation, or extended-period simulation.

With new technology came new problems and limitations. Two of the problems were the cost of processing time and the length of turnaround time. Users were concerned about the number of cases analyzed and the size and components of the system analyzed, because the costs of analyses were based on the number of runs and the amount of computer-processing time used.

Two solutions to the problems were available: running interactively or running in a batch mode. Running interactively was expensive because it required immediate use of the computer's resources. Interactive execution produced results quickly, but the expense could seldom be justified. Running in a batch mode, which allowed use of the computer during off-peak times (generally at night), was less expensive. However, when running in a batch mode, the user had to wait for results—sometimes for hours and sometimes until the next day, depending on the demands placed on the computer. Thus, errors in data files could not be detected immediately and analysis that depended on previous results was delayed.

Whatever method was used to run the programs, certain limitations were inherent in the programs themselves. For example, analysis was generally limited to single pressure zones and/or multiple pressure zones if pumps were used and pressure-regulating valves were not used. Analysis of more complex systems required execution of the program for each zone. Downstream pressures at pressure-regulating valves were used as input for analysis of another zone.

## 1970s

The 1970s brought enhancements to popular programs and development of new programs. This generation of programs had expanded capabilities based on improved mathematical and computer-programming techniques as well as advances in computer hardware. Three such programs are the University of Kentucky, Lexington, Ky., program, developed by Wood in 1972;[5] the Utah State University, Logan, Utah, program, developed by Jeppson in 1978;[6] and WATSIM, developed by Systems Control, Inc., Palo Alto, Calif., under a federal government contract in 1974.[7]

During this decade, universities began to offer network-analysis seminars that covered the fundamentals of fluid mechanics and provided hands-on use of programs. In most cases, participants were urged to bring network data to use in analyzing a real problem.

Significant improvements in the capabilities of network analysis began to appear in the 1970s. Programs could simulate all of the components of a water system, including pump stations, pressure-regulating valves, check valves, and reservoirs. Continuous-simulation capabilities were improved and more readily available.

Problems of cost, interactive versus batch processing, and turnaround time became less significant. More powerful computers resulted in faster processing, which made interactive processing cost-effective. Interactive processing eliminated problems with slow turnaround time, because results could be seen within seconds.

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Support programs to aid analysis began to appear in the late 1970s. The Denver Water Department, Denver, Colo., developed programs for load allocation, network building, and output comparison in 1979.[8,9]

Also in the 1970s, computer-processing power expanded and the cost of hardware decreased. With less expensive computer costs, increased awareness of computers and their capabilities, and good software, computerized network analysis began to play a major role in the design of water systems of all sizes.

### 1980s

The microcomputer began to have a significant impact on network analysis in the early 1980s. Microcomputers of the mid-1980s were more powerful than large mainframe computers of the 1950s and 1960s and, therefore, were capable of solving complex mathematical problems. In addition, microcomputers were low enough in price that their use could be easily justified based on their potential to save money.

Popular network-analysis programs of the 1960s and 1970s were converted to run on microcomputers, and many new programs were introduced by software vendors and consultants. The Shamir–Howard, Epp–Fowler, Wood, and Jeppson programs were converted, and hundreds of programs became available through vendors, software publishers, and consultants.

Capabilities of network-analysis programs of the 1980s were greater than those of the 1970s. Simulation of all water-system components in static state and continuous period became routine. Attention began to shift to expanded capabilities, such as data-base management, network graphics, pumping-energy cost calculations, network building, data manipulation, and sizing-optimization routines. Data-input methods were made easier and output was easily manipulated.

A program introduced by Sarikelle of the University of Akron, Akron, Ohio, in 1979[10] combined computer mapping and data base with network analysis. The Akron program was developed on a mainframe computer, was converted to a minicomputer with supporting computer-graphics hardware and software, and in 1986 was converted to run on a microcomputer. Pressure contour plotting, improved fire-flow calculation techniques, and the ability to report on information in the data base were key features of this program. These features were not previously available in most other programs.

A water-distribution simulation and optimization program (WADISO) was developed in 1985 by Gessler and Walski.[11] This program, which is in the public domain, focused on pipe sizing and rehabilitation optimization for use by the US Army Corps of Engineers.

During this decade, several utilities began to look for methods of combining various engineering computer applications with network analysis, because much of the data for each is common. Mapping information management systems (MIMS), computer-assisted design systems (CAD), automated mapping/facility management systems (AM/FM), and similar systems using computer graphics and a facility data base were used to generate maps, drawings, and reports. These types of systems also provided capabilities to plot networks, pressures, flows, and other network-solution outputs. The Denver Water Department, City of Bellevue (Wash.) Water Department, and other utilities began to implement these types of systems.

## APPLICATIONS OVERVIEW

Applications of network-analysis software generally fall into three categories: planning, design, and operations.

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### Planning

A primary planning application of network-analysis software is the development of long-range capital-improvement plans, which include scheduling, staging, sizing, and the preliminary routing and locating of future facilities. Other applications include the development of a main-rehabilitation plan and system-improvement plan. Rehabilitation plans call for cleaning and/or cement-mortar lining of mains. System-improvement plans call for installing new mains to keep up with growth or to upgrade the distribution system to utility standards. Network analysis and modeling can also be used to develop main-sizing guidelines or a standard grid to provide the desired pressures.

### Design

Network-analysis design applications include the sizing of various types of facilities. Pipelines, pump stations, pressure-regulating valves, tanks, and reservoirs can be sized using pressure and flow calculations resulting from network analysis. In addition, system-performance capabilities can be analyzed to determine fire-flow capabilities and the improvements necessary to meet fire-demand requirements.

### Operations

Applications to system operations include the development of operating strategies, operator training, and system troubleshooting. Operating strategies may be based on emergency conditions, energy-management restrictions, water availability, or other conditions of particular concern. For example, contingency plans for an outage of a key facility, such as a pump station, can be developed. Computer modeling and network analysis can also be used to develop operational strategies based on energy-management guidelines and restrictions for more efficient system operations. Strategies for shifting loads among treatment plants can be developed to maximize use of available water.

Modeling and network analysis are also good means of training personnel involved in the operation of distribution systems. Distribution-system operators can experiment with the model to determine how the system will perform under specified operating conditions.

System troubleshooting, based on modeling and network analysis, can be used to determine the cause of various problems, such as low pressure and unexplained events.

Network-analysis software is widely used in a variety of applications. The user must decide what applications, or uses, are most important in his or her situation. It should be noted that network analysis is a tool used to analyze situations; the user must exercise a great deal of judgment and interpretation to make use of the results.

## ADVANTAGES OF COMPUTERIZED NETWORK ANALYSIS

### Feasibility

The most important advantage of computer modeling is that it makes network analysis feasible. Without computerized techniques, analysis is slow and impractical, except for very simple systems. Before computerized network analysis, overdesign was the common reaction to uncertainty caused by the inability to accurately predict flows and pressures in a system. By providing reliable information, network analysis enables the user to more efficiently analyze, design, and plan water systems.

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# chapter 4
# Hydraulics and Hydrology

The following sections present the basic principles of hydraulics applicable to water distribution and waste-water collection systems. Low-flow characteristics of streams and stratification of lakes provide background for the study of water pollution.

## 4-1 WATER PRESSURE

Mass per unit volume is referred to as density of a fluid. The density of water is 998 kg/m$^3$ at a temperature of 20° C and pressure of 101.3 kPa. (Under standard conditions of 4° C and 101.3 kPa, the value is 1 000 kg/m$^3$.) The force exerted by gravity on one cubic metre (specific weight) of water is 9.79 kN/m$^3$, which is equal to the density multiplied by standard acceleration of gravity which is 9.807 m/s$^2$.

Pressure is force exerted per unit area. Referring to Figure 4-1a, the pressure exerted on the bottom of a one cubic metre container filled with water is equal to 9.79 kPa. (Force in kilonewtons per square metre is numerically equal to pressure in kilopascals.) In engineering hydraulics, water pressure is frequently expressed in terms of metres of head, as well as kilopascals. The relationship between these units is visually shown in Figure 4-1a where a height of 1.0 metre of water head exerts a pressure of 9.79 kPa. Water pressure increases with depth below the surface linearly such that the pressure in kilopascals is equal to 9.79 times the depth in metres. The sketch in Figure 4-1b shows the pressure acting only horizontally for ease of illustration. In fact, water pressure is exerted equally in all directions.

A simple piezometer, illustrated in Figure 4-2*a*, consists of a small tube rising from a container of water under pressure. The height of the water in the piezometer tube denotes the pressure of the confined water. Water piezometers are rarely practical for pressure measurements, since values generally exceed the height of water columns that are convenient to read. A mercury column can be used to measure relatively high pressure values within a limited head range, since mercury is approximately 13.6 times heavier than water, that is, a 1-m

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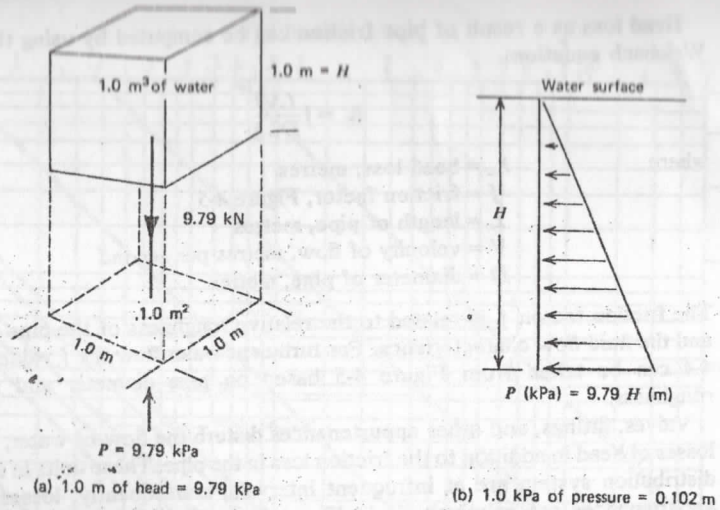



**Figure 4-1** Basic relationships between water pressure in kilopascals and metres of water head.

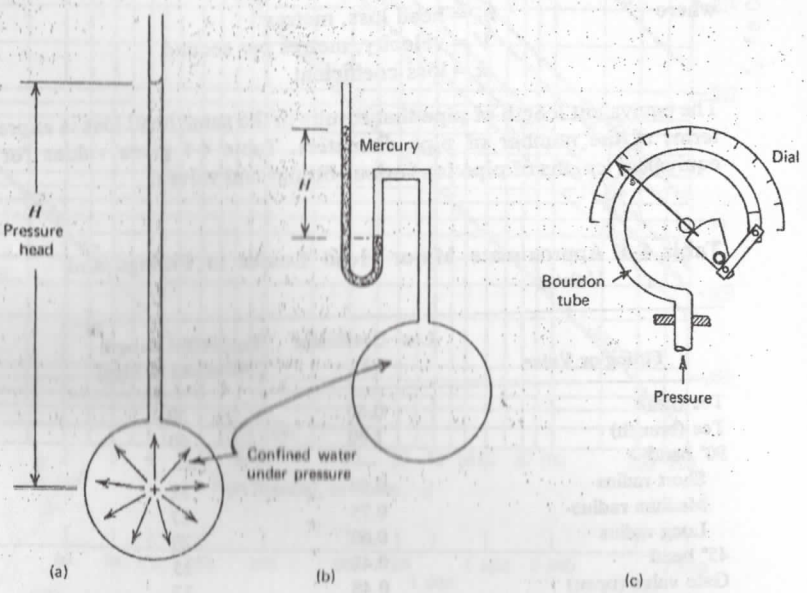



**Figure 4-2** Water pressure measuring devices. (*a*) Piezometer. (*b*) Manometer. (*c*) Pressure gage.



head of mercury is equivalent to a pressure of 133 kPa. Figure 4-2*b* is a sketch of a mercury manometer. The pressure reading is equal to the difference of the fluid pressures in the two legs of the U-shaped tube. The use of manometers is generally restricted to indoor applications where the unit is in a fixed location.

Water pressure is most commonly measured by a Bourdon gage (Figure 4-2*c*). A hollow metal tube of elliptical cross section is bent in the form of a circle with a pointer attached to the end through a suitable linkage. As pressure inside the tube increases, the elliptical cross section tends to become circular, and the free end of the Bourdon tube moves outward. The dial of the instrument can be calibrated to read gage pressure in kPa. Bourdon tubes and manometers actually measure pressure relative to the atmosphere pressure. (Atmospheric or barometric pressure is caused by the weight of the thick mass of air above the earth's surface. Under standard atmospheric conditions, the barometric pressure at sea level is 101.3 kPa.) If the pressure measured is greater than atmospheric, this value is sometimes called gage pressure. If the pressure measured is less than atmospheric, it is referred to as a vacuum. Absolute pressure is the term used for a reading that includes atmospheric pressure, that is, the pressure relative to absolute zero.

## 4-2 PRESSURE-VELOCITY-HEAD RELATIONSHIPS

The association between quantity of water flow, average velocity, and cross-sectional area of flow is given by the equation:

$$Q = VA \tag{4-1}$$

where $Q$ = quantity, cubic metres per second
$V$ = velocity, metres per second
$A$ = cross-sectional area of flow, square metres

This formula is known as the continuity equation. For an incompressible fluid such as water, if the cross-sectional area decreases (the water main becomes smaller), the velocity of flow must increase; conversely, if the area increases, the velocity decreases (Figure 4-3).

The total energy at any point in a hydraulics system is equal to the sum of the elevation head, pressure head, and velocity head.

$$\text{Total Energy} = \text{Elevation Head} + \text{Pressure Head} + \text{Velocity Head} \tag{4-2}$$

$$E = Z + \frac{P}{\gamma} + \frac{V^2}{2g}$$

where $E$ = total energy head
$Z$ = elevation above datum
$P$ = pressure
$V$ = velocity of flow
$\gamma$ = specific weight of liquid
$g$ = acceleration of gravity

The vertical line at point 1 on the left-hand side of Figure 4-4 graphically illustrates the total energy equation. The pressure head is equal to the height to which the water would rise in a piezometer tube inserted in the pipe. The elevation head is equal to the vertical distance $Z$ from an assumed datum plane

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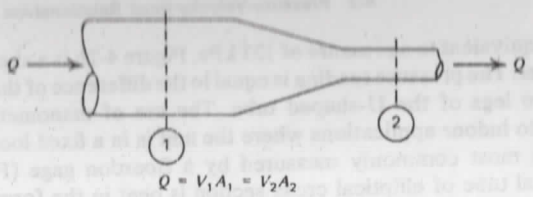



Figure 4-3 Flow equation for incompressible liquids.

to the pipe. The sum of these two heads is the hydraulic head. The velocity head is equal to the kinetic energy in the water flow, and when added to the hydraulic head yields total energy. If SI units are used in Eq. 4-2, each of the separate head calculations will be in metres.

If the energy is compared at two different points in a piping system (Figure 4-4) Eq. 4-3 results. The term $h_L$ represents the energy losses that occur in any real system. The major loss of energy is due to friction between the moving water and pipe wall; however, energy losses also occur from flow disturbance caused by valves, bends in the pipeline, and changes in diameter. The imaginary line connecting all points of total energy is called the energy gradient or grade line. This line must always slope in the direction of flow showing a decrease in energy, unless external energy is added to the system, for example, by a pump. The hydraulic gradient is defined as the line connecting the level of elevation plus pressure energies, this being defined by the water surfaces in imaginary piezometer tubes inserted in the piping.

$$Z_1 + \frac{P_1}{9.79} + \frac{V_1^2}{19.6} = Z_2 + \frac{P_2}{9.79} + \frac{V_2^2}{19.6} + h_L \qquad (4\text{-}3)$$

$Z$ = elevation, metres
$P$ = pressure, kilopascals
$V$ = velocity, metres per second
$h_L$ = head loss, metres
9.79 = specific weight of water at 20° C
19.6 = 2 × standard acceleration of gravity

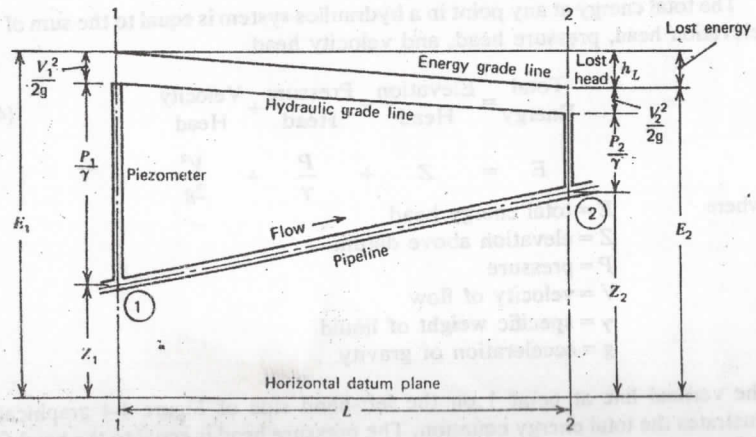



Figure 4-4 Energy equation parameters as related to water flow in a pipe.



Head loss as a result of pipe friction can be computed by using the Da Weisbach equation:

$$h_L = f\frac{LV^2}{D2g}$$

where
$h_L$ = head loss, metres
$f$ = friction factor, Figure 4-5
$L$ = length of pipe, metres
$V$ = velocity of flow, metres per second
$D$ = diameter of pipe, metres

The friction factor, $f$, is related to the relative roughness of the pipe mate and the fluid flow characteristics. For turbulent water flow the $f$ value for 4-4 can be taken from Figure 4-5 based on pipe diameter and mate roughness.

Valves, fittings, and other appurtenances disturb the flow of water, caus losses of head in addition to the friction loss in the pipe. These units in a typi distribution system are at infrequent intervals; consequently, losses due appurtenances are relatively insignificant in comparison with pipe frict losses. In the case of pumping stations and treatment plant piping, the mi losses in valves and fittings are significant and constitute a major part of total losses. Unit head losses may be expressed as being equivalent to the l through a certain length of pipe or by the formula:

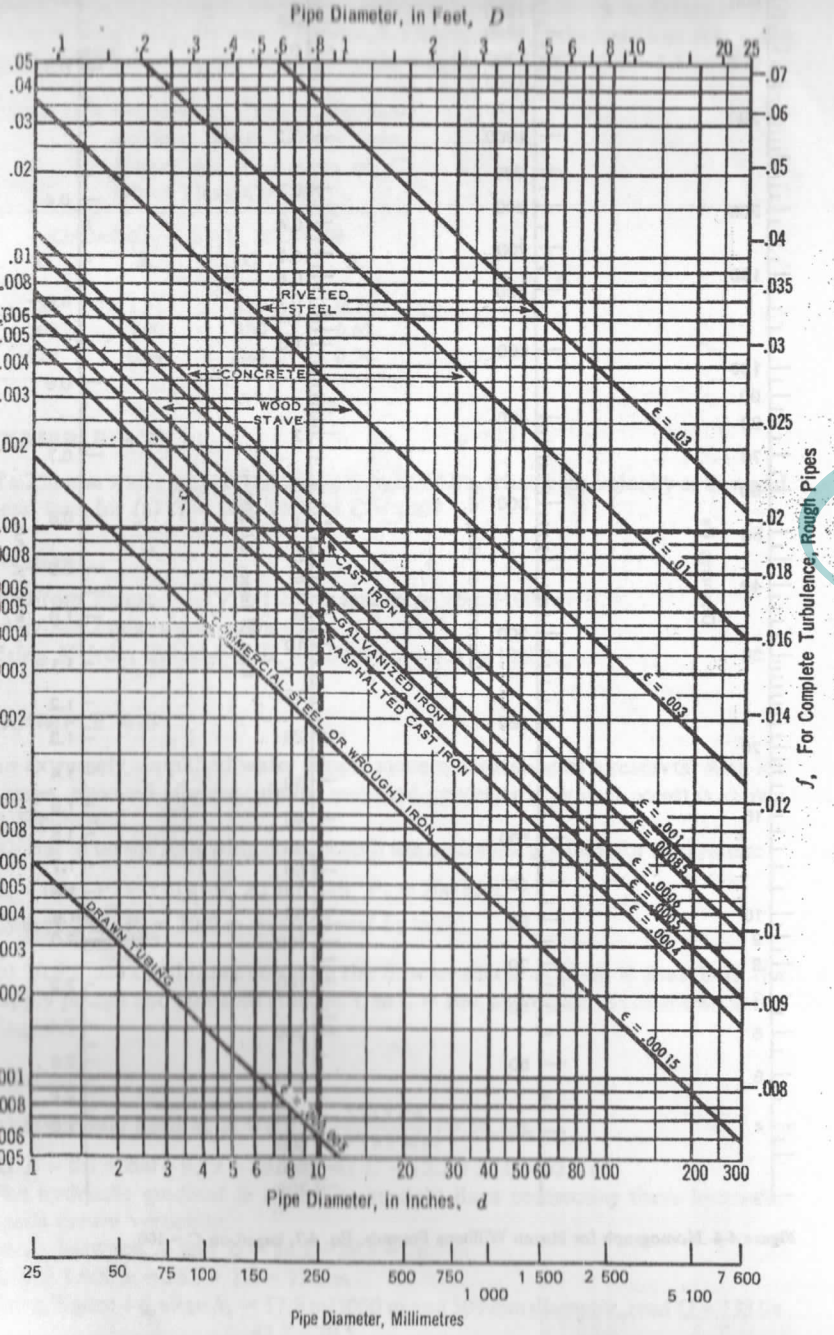
$$h_L = \frac{kV^2}{2g}$$

where
$h_L$ = head loss, metres
$V$ = velocity, metres per second
$k$ = loss coefficient

The equivalent length of pipe that results in the same head loss is expressed terms of the number of pipe diameters. Table 4-1 gives values for $k$ a equivalent lengths of pipe for various fittings and valves.

**Table 4-1.** Approximate Minor Head Losses in Fittings and Valves

| Fitting or Valve | Loss Coefficient $k$ | Equivalent Length (Diameters of Pipe) |
|---|---|---|
| Tee (run) | 0.60 | 20 |
| Tee (branch) | 1.80 | 60 |
| 90° bend- | — | — |
| Short radius | 0.90 | 32 |
| Medium radius | 0.75 | 27 |
| Long radius | 0.60 | 20 |
| 45° bend | 0.42 | 15 |
| Gate valve (open) | 0.48 | 17 |
| Swing check valve (open) | 3.7 | 135 |
| Butterfly valve (open) | 1.2 | 40 |




4-5 Relative roughness of pipe materials and friction factors for turbulent pipe flow. (From *Flow of* , Crane Co.)



**EXAMPLE 4-1**

Calculate the head loss in a 600 mm diameter, 1 500 m long, smooth-walled concrete ($\varepsilon = 0.001$) pipeline carrying a water flow of 0.30 m³/s.

*Solution*

Using Eq. 4-1,

$$V = \frac{Q}{A} = \frac{0.30\ \text{m}^3/\text{s}}{3.14 \times 0.3\ \text{m} \times 0.3\ \text{m}} = 1.06\ \text{m/s}$$

From Fig. 4-5 entering with $d = 600$ mm and $\varepsilon = 0.001$, $f = 0.017$. Then substituting into Eq. 4-4,

$$h_L = 0.017 \frac{1\,500}{0.60} \frac{(1.06)^2}{2 \times 9.81} = 2.4\ \text{m}$$

**EXAMPLE 4-2**

A pump discharge line consists of 60 m of 300 mm new cast-iron pipe, three 90° medium-radius bends, two gate valves, and one swing check valve. Compute the head loss through the line at a velocity of 1.0 m/s.

*Solution*

Using equivalent lengths for the fittings and valves as given in Table 4-1, the total equivalent pipe length is:

$$60 + 3 \times 27 \times 0.3 + 2 \times 17 \times 0.3 + 1 \times 135 \times 0.3 = 135$$

From Figure 4.5, $f = 0.019$, then using Eq. 4-4,

$$h_L = 0.019 \frac{135}{0.30} \frac{(1.0)^2}{2 \times 9.81} = 0.44\ \text{m}$$

**EXAMPLE 4-3**

Calculate the head loss in the pipeline illustrated in Figure 4-4 based on the following: $Z_1 = 4.5$ m, $P_1 = 280$ kPa, $V_1 = 1.2$ m/s, $Z_2 = 9.3$ m, $P_2 = 200$ kPa, $V_2 = 1.2$ m/s.

*Solution*

Substituting into Eq. 4-3,

$$4.5 + \frac{280}{9.79} + \frac{(1.2)^2}{19.6} = 9.3 + \frac{200}{9.79} + \frac{(1.2)^2}{19.6} + h_L$$

$$4.5 + 28.6 + 0.07 = 9.3 + 20.4 + 0.07 + h_L$$

$$h_L = 3.4\ \text{m} = 33\ \text{kPa}$$

## 4-3 FLOW IN PIPES UNDER PRESSURE

The Darcy Weisbach equation for computing head loss is cumbersome and not widely used in waterworks design and evaluation. A trial-and-error solution is required to determine pipe size for a given flow and head loss, since the friction factor is based on the relative roughness which involves the pipe

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diameter. Because of this practical shortcoming, exponential equations are commonly used for flow calculations.

The most common pipe flow formula used in the design and evaluation of a water distribution system is the Hazen Williams, Eq. 4-6. This equation relates the velocity of turbulent water flow with hydraulic radius, slope of the hydraulic gradient, and a coefficient of friction depending on roughness of the pipe. Coefficient values for different pipe materials are given in Table 4-2.

$$V = 0.849CR^{0.63}S^{0.54} \tag{4-6}$$

where $V$ = velocity, metres per second
$C$ = coefficient that depends on the material and age of the conduit, Table 4-2
$R$ = hydraulic radius, metres (cross-sectional area divided by the wetted perimeter)
$S$ = slope of the hydraulic gradient, metres per metre

By combining the Hazen Williams formula with Eq. 4-1 and substituting the value of $D/4$ for $R$, the formula for quantity of flow in circular pipes flowing full is

$$Q = 0.278CD^{2.63}S^{0.54} \tag{4-7}$$

where $Q$ = quantity of flow, cubic metres per second
$C$ = coefficient, Table 4-2
$D$ = diameter of pipe, metres
$S$ = hydraulic gradient, metres per metre

The nomograph shown in Figure 4-6 solves the above equation for a coefficient equal to 100, represents 15 to 20-year-old cast-iron pipe. Given any two of the parameters (discharge, diameter of pipe, loss of head, or velocity) the remaining two can be determined from the intersections along a straight line drawn across the nomograph. For example, the flow of 30 l/s in a 200 mm diameter pipe has a velocity of 0.96 m/s with a head loss of 8.1 m/1000 m (0.008 1 m/m).

**Table 4-2.** Values of Coefficient $C$ for the Hazen Williams Formula, Equations 4-6 and 4-7

| Pipe Material | $C$ |
|---|---|
| Asbestos cement | 140 |
| Cast iron | |
| Cement lined | 130 to 150 |
| New, unlined | 130 |
| 5-year-old, unlined | 120 |
| 20-year-old, unlined | 100 |
| Concrete | 130 |
| Copper | 130 to 140 |
| Plastic | 140 to 150 |
| New welded steel | 120 |
| New riveted steel | 110 |

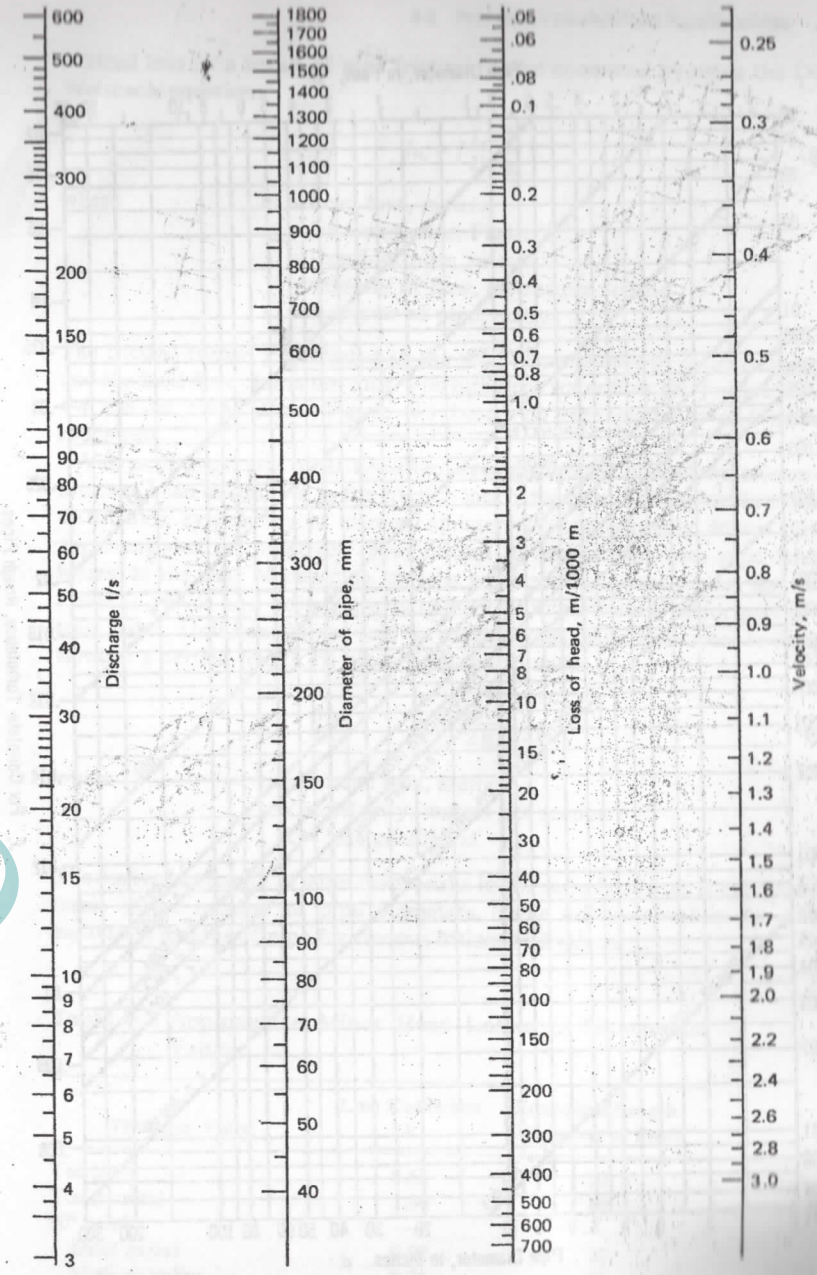



**Figure 4-6** Nomograph for Hazen Williams Formula, Eq. 4-7, based on $C = 100$.

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Head losses in pipes with coefficient values other than 100 can be determined by using the correction factors in Table 4-3. For example, if the head loss at $C = 100$ is 8.1 m/1000 m, the head loss at $C = 130$ would equal $0.62 \times 8.1 = 5.0$ m/1000 m.

Table 4-3. Correction Factors To Determine Head Losses from Figure 4-6 at Values of $C$ Other Than $C = 100$

| Corrected $h_L = K \times h_L$ at $C = 100$ | | | |
|---|---|---|---|
| $C$ | $K$ | $C$ | $K$ |
| 80 | 1.51 | 120 | 0.71 |
| 100 | 1.00 | 130 | 0.62 |
| 110 | 0.84 | 140 | 0.54 |

## EXAMPLE 4-4

If a 250 mm water main is carrying a flow of 60 l/s, what is the velocity of flow and head loss for (a) $C = 100$, and (b) $C = 140$?

*Solution*

a) From Figure 4-6, $V = 1.2$ m/s and $h_L = 9.9$ m/1000 m

b) $V = 1.2$ m/s (same as part a)

Using $K$ from Table 4-3, $h_L = 0.54 \times 9.9 = 5.3$ m/1000 m

## EXAMPLE 4-5

An extremely simplified water supply system consisting of a reservoir with lift pumps, elevated storage, piping, and load center (withdrawal point) is shown in Figure 4-7.

a) Based on the following data, sketch the hydraulic gradient for the system:

$Z_A = 0$ m, $P_A = 550$ kPa, $Z_B = 9.1$ m, $P_B = 200$ kPa,

$Z_C = 12.2$ m, $P_C = 30.0$ m (water level in tank).

b) For these conditions compute the flow available at point $B$ from both the supply pumps and elevated storage. Use $C = 100$, and pipe sizes as shown in the diagram.

*Solution*

a) Hydraulic head at $A = 0 \text{ m} + \dfrac{550 \text{ kPa}}{9.79 \text{ kPa/m}} = 56.2$ m

At $B = 9.1 + 200 \div 9.79 = 29.5$ m. At $C = 12.2 + 30.0 = 42.2$ m

The hydraulic gradient is shown as straight lines connecting these hydraulic heads drawn vertically.

b) $h_L$ between $A$ and $B = 56.2 - 29.5 = 26.7$ m

$h_L$ per 1 000 m $= 26.7 \div 1.5 = 17.8$ m

Using Figure 4-6, align $h_L = 17.8$ m/1000 m and 300 mm diameter, read $Q = 133$ l/s

$h_L$ per 1 000 m $B$ to $C = \dfrac{42.2 - 29.5}{0.9} = 14.1$ m



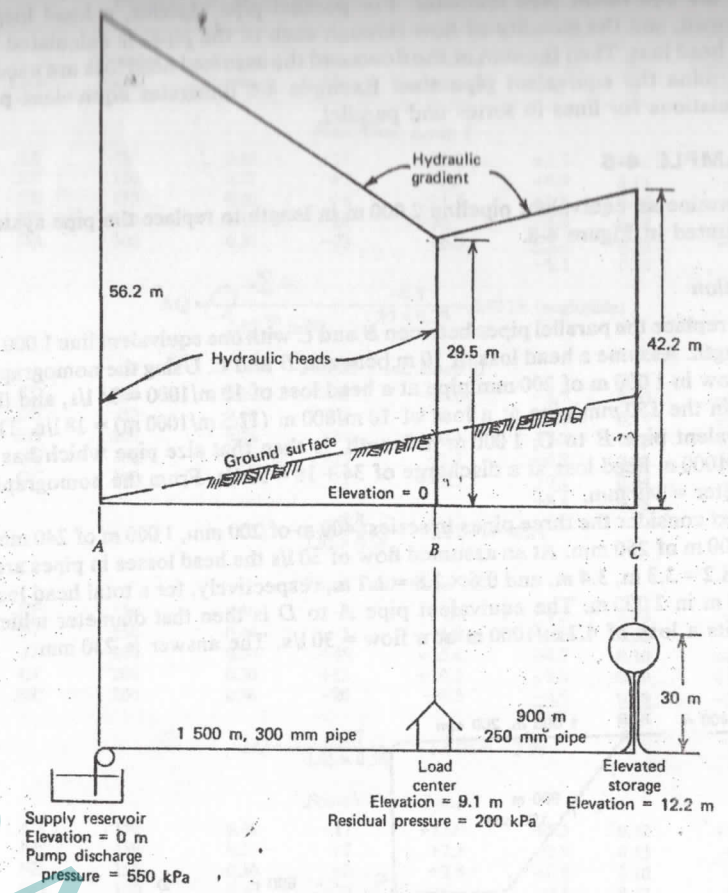



Figure 4-7 Simplified water system for Example 4-5.

For $h_L = 14.1$ m/1000 m and 250 mm, $Q = 73$ l/s

Total $Q$ available at $B = 133 + 73 = 206$ l/s

## 4-4 FLOW IN PIPE NETWORKS

Analysis of a water distribution system includes determining quantities of flow and head losses in the various pipelines, and resulting residual pressures. Computations for a large network can often be made easier if a series of pipes of varying diameter are replaced with equivalent pipes. An equivalent pipe is an imaginary conduit that replaces a section of a real system such that the head losses in the two systems are identical for the quantity of flow. For example, pipes of differing diameters connected in series can be replaced by an equivalent pipe of one diameter as follows: assume a quantity of flow and determine the head loss in each section of the line for this flow, then using the sum of the sectional head losses and the assumed flow, enter the nomogram to

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find the equivalent pipe diameter. For parallel pipe systems, a head loss is assumed, and the quantity of flow through each of the pipes is calculated for that head loss. Then the sum of the flows and the assumed head loss are used to determine the equivalent pipe size. Example 4-6 illustrates equivalent pipe calculations for lines in series and parallel.

## EXAMPLE 4-6

Determine an equivalent pipeline 2 000 m in length to replace the pipe system illustrated in Figure 4-8.

*Solution*

First replace the parallel pipes between $B$ and $C$ with one equivalent line 1 000 m in length. Assume a head loss of 10 m between $B$ and $C$. Using the nomograph, the flow in 1 000 m of 200 mm pipe at a head loss of 10 m/1000 = 34 l/s, and the flow in the 150 mm pipe at a loss of 10 m/800 m (12.5 m/1000 m) = 18 l/s. The equivalent pipe $B$ to $C$, 1 000 m in length, is then that size pipe which has a 10 m/1000 m head loss at a discharge of 34 + 18 = 52 l/s. From the nomograph, diameter = 240 mm.

Next consider the three pipes in series: 400 m of 200 mm, 1 000 m of 240 mm, and 600 m of 250 mm. At an assumed flow of 30 l/s the head losses in pipes are: $0.4 \times 8.2 = 3.3$ m, 3.4 m, and $0.6 \times 2.8 = 1.7$ m, respectively, for a total head loss of 8.4 m in 2 000 m. The equivalent pipe $A$ to $D$ is then that diameter which exhibits a loss of 4.2 m/1000 m at a flow = 30 l/s. The answer is 230 mm.

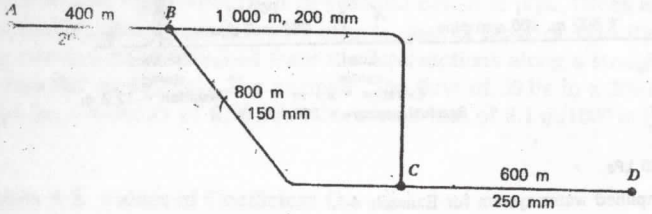



**Figure 4-8** Pipe system for Example 4-6.

The method of equivalent pipes cannot be applied to complex systems, since crossovers result in pipes being included in more than one loop and because there are normally a number of withdrawal points throughout the system. Network analysis can be performed using the Hardy Cross technique. Assumed flows are assigned to each of the pipelines and then corrections are applied, based on hydraulic calculations, until the computed flows and resultant head losses are in acceptable balance.

The derivation of the expression for flow corrections follows. The Hazen Williams equation (4-7) can be rewritten as

$$Q = KS^{0.54} \tag{4-8}$$

where $K$ is a constant when dealing with a single pipe of specific size and roughness. Rearranging and substituting head loss, $h_L$, for the hydraulic gradient, $S$, results in an equation relating lead loss as a function of flow to the 1.85 power for the Hazen-Williams formula.

$$h_L = KQ^{1.85} \tag{4-9}$$

In balancing a given loop within a network the actual quantity of flow, $Q$, is determined by applying a correction $\Delta Q$ to the assumed flow, $Q_1$.

$$Q = Q_1 + \Delta Q \tag{4-10}$$

Inserting this term in Eq. 4-9 and expanding the binominal, it becomes

$$KQ^{1.85} = K(Q_1 + \Delta Q)^{1.85} = K(Q_1^{1.85} + 1.85Q_1^{0.85}\,\Delta Q + \cdots) \tag{4-11}$$

Then, the sum of the head losses must equal zero for balanced flow,

$$\sum h_L = \sum KQ^{1.85} = \sum KQ_1^{1.85} + \sum 1.85KQ_1^{0.85}\,\Delta Q = 0 \tag{4-12}$$

And finally, solving for $\Delta Q$ and substituting $h_L$ for the $KQ^{1.85}$ from Eq. 4-9, the term for flow correction is Eq. 4-13.

$$\Delta Q = -\frac{\sum h_L}{1.85\sum (h_L/Q)} \tag{4-13}$$

The procedure for solving a pipe network using the Hardy Cross method is illustrated in Example 4-7 and involves the following steps:

1. Assume a direction and quantity of flow for each pipe in the system such that the amount entering each pipe junction, or discharge point, equals the quantity flowing out.
2. Select one pipe loop in the system and compute the net head loss for that circuit based on the assumed flows. (The nomograph in Figure 4-6 is normally used for these calculations.)
3. Without regard to sign, calculate the sum of the $h_L/Q$ values.
4. Compute the flow correction using Eq. 4-13 and correct each of the flows in the loop by this amount.
5. Apply this procedure to each pipe loop in the system, repeating earlier circuits as necessary, to arrive at answers within the desired accuracy. (Computational accuracy depends on the precision in reading the nomograph. In general, an error of 5 to 10 percent in calculating the head losses around a loop is satisfactory.)

## EXAMPLE 4-7

Using the Hardy Cross method, compute the quantities of flow for the pipe network shown in Figure 4-9. Water enters the distribution system from the well supply, 90 l/s at point $A$, and storage reservoir, 50 l/s at point $J$.

*Solution*

The assumed direction and quantities of flow are shown for each line on Figure 4-9. These estimates are not entirely arbitrary but are based on careful assessment of the network, thus providing the most probable flow pattern. For example, at junction $A$ a significantly greater flow is assumed for the 300 mm diameter pipe $AD$ than the 150 mm line $AB$, and the quantity entering at $J$

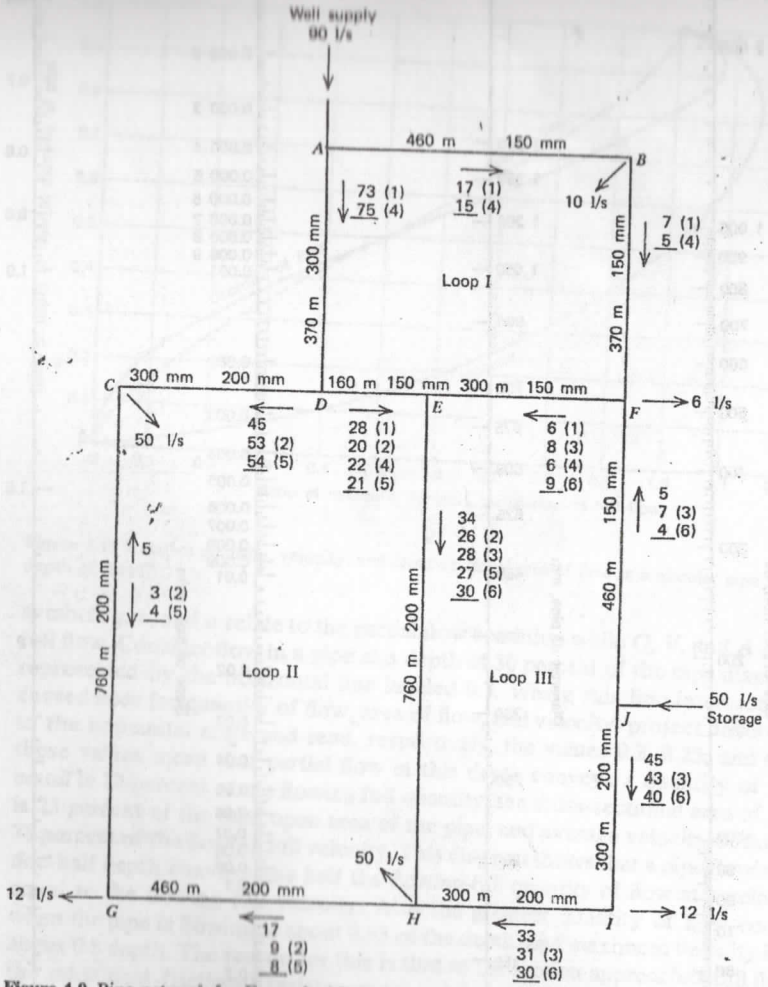



**Figure 4-9** Pipe network for Example 4-7. The numbers along each pipeline are quantities of flow from several trial calculations given in Table 4-4. For example, 15(4) on line *AB* means 15 l/s computed during trial 4.

directed primarily into pipe *JI* heading to the heavy discharge at point *H*.

The trial computations are given in Table 4-4. After listing the information on pipe diameter and length for each line in the loop, head losses are determined from the nomograph (Figure 4-6), using the assumed flows. All clockwise flows are positive, and all counterclockwise flows are negative. Head loss resulting from positive flow is considered positive, and negative flows yield negative losses. The head loss is determined with respect to sign for each line, and then is summed to provide total $h_L$. Values of $h_L/Q$ are computed by dividing the head loss in each line by the assumed flow. The sum of $h_L/Q$ is performed without regard to sign. The flow correction is then calculated using Eq. 4-13. The correction values in this problem are rounded to the nearest 1.0 l/s, which is consistent with the accuracy of reading the nomograph.

**Table 4-4. Computations for the Hardy Cross Analysis of the Pipe Network in Figure 4-9, Example 4-7**

| Line | Diameter (mm) | Length (1 000 m) | Flow (l/s) | Head Loss (m/1000 m) | Total $h_L$ (m) | $\frac{h_L}{Q}$ | Corrected Flow |
|---|---|---|---|---|---|---|---|
| | | | *First Trial, Loop I* | | | | |
| *AB* | 150 | 0.46 | +17 | +12.0 | +5.5 | 0.32 | +17 |
| *BF* | 150 | 0.37 | +7 | +2.3 | +0.9 | 0.13 | +7 |
| *FE* | 150 | 0.30 | +6 | +1.7 | +0.5 | 0.08 | +6 |
| *ED* | 150 | 0.16 | −28 | −30 | −4.8 | 0.17 | −28 |
| *DA* | 300 | 0.37 | −73 | −6.0 | −2.2 | 0.03 | −73 |
| | | | | | −0.1 | 0.73 | |

$$\Delta Q = -\frac{\sum h_L}{1.85 \sum h_L/Q} = -\frac{-0.1}{1.85 \times 0.73} = 0.07 \text{ l/s (negligible)}$$

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | *Second Trial, Loop II* | | | | |
| *CD* | 200 | 0.30 | −45 | −15.6 | −4.7 | 0.10 | −53 |
| *DE* | 150 | 0.16 | +28 | +30 | +4.8 | 0.17 | +20 |
| *EH* | 200 | 0.76 | +34 | +10.1 | +7.7 | 0.22 | +26 |
| *HG* | 200 | 0.46 | +17 | +1.7 | +0.8 | 0.05 | +9 |
| *GC* | 200 | 0.76 | +5 | +0.3 | +0.2 | 0.04 | −3 |
| | | | | | +8.8 | 0.58 | |

$$\Delta Q = -\frac{+8.8}{1.85 \times 0.58} = -8.2 \text{ l/s} = -8 \text{ l/s}$$

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | *Third Trial, Loop III* | | | | |
| *EF* | 150 | 0.30 | −6 | −1.7 | −0.5 | 0.08 | −8 |
| *FJ* | 150 | 0.46 | −5 | −1.2 | −0.6 | 0.12 | −7 |
| *JI* | 200 | 0.30 | +45 | +15.6 | +4.7 | 0.10 | +43 |
| *IH* | 200 | 0.30 | +33 | +10.0 | +3.0 | 0.09 | +31 |
| *HE* | 200 | 0.76 | −26 | −6.5 | −4.9 | 0.19 | −28 |
| | | | | | +1.7 | 0.58 | |

$$\Delta Q = -\frac{+1.7}{1.85 \times 0.58} = -1.6 \text{ l/s} = -2 \text{ l/s}$$

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | *Fourth Trial, Loop I* | | | | |
| *AB* | 150 | 0.46 | +17 | +12.0 | +5.5 | 0.32 | +15 |
| *BF* | 150 | 0.37 | +7 | +2.3 | +0.9 | 0.13 | +5 |
| *FE* | 150 | 0.30 | +8 | +2.8 | +0.8 | 0.10 | +6 |
| *ED* | 150 | 0.16 | −20 | −16 | −2.6 | 0.13 | −22 |
| *DA* | 300 | 0.37 | −73 | −6.0 | −2.2 | 0.03 | −75 |
| | | | | | +2.4 | 0.71 | |

$$\Delta Q = -\frac{+2.4}{1.85 \times 0.71} = -1.8 \text{ l/s} = -2 \text{ l/s}$$

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | *Fifth Trial, Loop II* | | | | |
| *CD* | 200 | 0.30 | −53 | −25 | −7.5 | 0.14 | −54 |
| *DE* | 150 | 0.16 | +22 | +15.8 | +2.5 | 0.11 | +21 |
| *EH* | 200 | 0.76 | +28 | +7.2 | +5.5 | 0.20 | +27 |
| *HG* | 200 | 0.46 | +9 | +0.9 | +0.4 | 0.04 | +8 |
| *GC* | 200 | 0.76 | −3 | −0.1 | −0.1 | 0.03 | −4 |
| | | | | | +0.8 | 0.52 | |

$$\Delta Q = -\frac{+0.8}{1.85 \times 0.52} = -0.8 \text{ l/s} = -1 \text{ l/s}$$

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | *Sixth Trial, Loop III* | | | | |
| *EF* | 150 | 0.30 | −6 | −1.7 | −0.5 | 0.08 | −9 |
| *FJ* | 150 | 0.46 | +7 | +2.2 | +1.0 | 0.14 | +4 |
| *JI* | 200 | 0.30 | +43 | +15.4 | +4.6 | 0.11 | +40 |
| *IH* | 200 | 0.30 | +33 | +10.0 | +3.0 | 0.09 | +30 |
| *HE* | 200 | 0.76 | −27 | −6.7 | −5.1 | 0.19 | −30 |
| | | | | | +3.0 | 0.61 | |

$$\Delta Q = -\frac{3.0}{1.85 \times 0.61} = -2.7 \text{ l/s} = -3 \text{ l/s}$$

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The first trial—loop I resulted in a negligible value for $\Delta Q$ indicating a balance of the head losses for the assumed flows. As is shown in trial four, this does not mean that these flows are correct, since two of the lines (*DE* and *EF*) are common with other loops. The trial number was placed in parentheses after the assumed flows in loop I, for example, line *AB* 17 (1).

The second trial—loop II reversed the assumed flow in line *GC*, and reduced the flow in line *DE*, common with loop I, from 28 to 20 l/s. Trials three to six were sufficient to provide the required balancing of flows in the network. Final quantities for flow for each pipe are underlined.

## 4-5 GRAVITY FLOW IN CIRCULAR PIPES

Sanitary and storm sewers are designed to flow as open channels, not under pressure, although storm sewers may occasionally be overloaded when water rises in the manholds surcharging the sewer. The waste water flows downstream in the pipe moved by the force of gravity. Velocity of flow depends on steepness of the pipe slope and frictional resistance. The Manning formula, Eq. 4-14, is used for uniform, steady, open channel flow. The coefficient of roughness $n$ depends on the condition of the pipe surface, alignment of pipe sections, and method of jointing. The common sewer pipe materials of asbestos cement, vitrified clay, and smooth concrete have $n$ values in the range of 0.011 to 0.015. The lower value is applicable to clear water and smooth joints, while the greater roughness is for waste water and poor joint construction. Corrugated steel pipe used for culverts has considerably greater roughness in the range of 0.021 to 0.026. The common value of $n$ adopted for sewer design is 0.013. Even though certain pipe materials in a new condition may exhibit a lower $n$, such as plastic or asbestos cement, after they are placed in use pipes accumulate grease and other solids that modify the interior and disturb waste-water flow.

$$Q = \frac{1.00}{n} AR^{2/3}S^{1/2} \qquad (4\text{-}14)$$

where $Q$ = quantity of flow, cubic metres per second
$n$ = coefficient of roughness depending on material
$A$ = cross-sectional area of flow, square metres
$R$ = hydraulic radius, metres (cross-sectional area divided by the wetted perimeter)
$S$ = slope of the hydraulic gradient, metres per metre

The nomograph shown in Figure 4-10 solves the Manning equation for circular pipes flowing full based on a coefficient of roughness of 0.013. Given any two of the parameters (quantity of flow, diameter of pipe, slope of pipe, or velocity) the remaining two can be determined from the intersections along a straight line drawn across the nomograph. For example, a 200 mm diameter pipe set on a slope of 0.02 m/m (2.0%) conveys a quantity of flow of 46 l/s flowing full with an average velocity of 1.5 m/s. Quantity of flows at $n$ values other than 0.013 can be calculated by multiplying the nomograph value by 0.013 and dividing the resultant by the desired $n$ factor.

Hydraulic problems of circular pipes flowing partly full are solved by using Figure 4-11. To plot these curves, ratios of hydraulic elements were calculated at various depths of flow in a circular pipe using the Manning equation. The

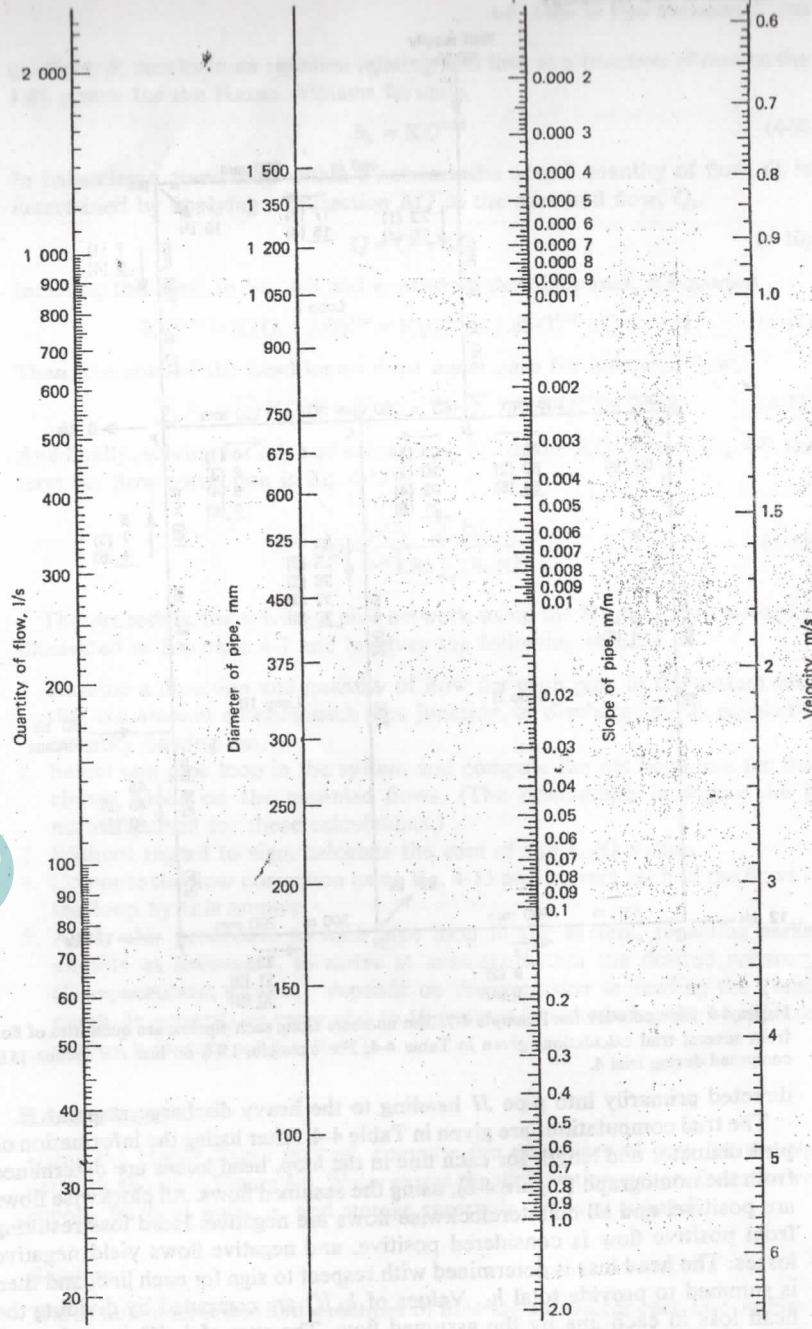



**Figure 4-10** Nomograph for Manning formula, Eq. 4-14, for circular pipes flowing full based o $n = 0.013$.

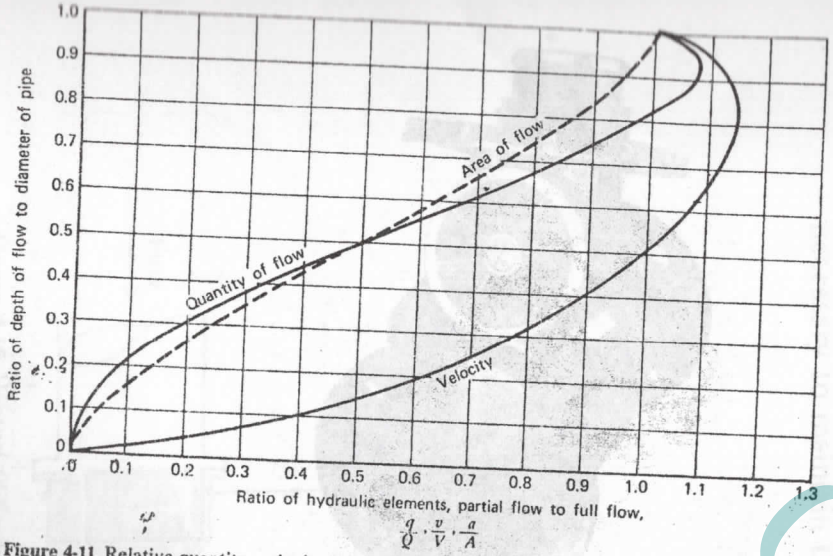



**Figure 4-11** Relative quantity, velocity, and cross-sectional area of flow in a circular pipe for any depth of flow.

symbols $q$, $v$, and $a$ relate to the partial flow condition while $Q$, $V$, and $A$ are at full flow. Consider flow in a pipe at a depth of 30 percent of the pipe diameter, represented by the horizontal line labeled 0.3. Where this line intersects the curved lines for quantity of flow, area of flow, and velocity, project downward to the horizontal scale and read, respectively, the values 0.2, 0.25, and 0.78; these values mean that partial flow at this depth conveys a quantity of flow equal to 20 percent of the flowing full quantity, the cross-sectional area of flow is 25 percent of the total open area of the pipe, and average velocity of flow is 78 percent of the flowing full velocity. This diagram shows that a pipe flowing at one-half depth conveys one half the flowing-full quantity of flow at a velocity equal to the flowing full velocity. Also the greatest quantity of flow occurs when the pipe is flowing at about 0.93 of the depth, and maximum velocity is at about 0.8 depth. The reason for this is that as the section approaches full flow, the additional frictional resistance caused by the crown of the pipe has a greater affect than the added cross-sectional area. For practical application, Figure 4-11 yields only approximate results, since the theoretical curves are based on steady, uniform flow which does not precisely characterize the nature of actual flow in sewers. Examples 4-8, 4-9, and 4-10 illustrate the use of the nomograms and partial flow diagram.

### EXAMPLE 4-8

If a 250 mm sewer is placed on a slope of 0.010, what is the flowing full quantity and velocity for (a) $n = 0.013$, and (b) $n = 0.015$?

*Solution*

(a) Project across Figure 4-10 through slope = 0.010 and diameter = 250 mm, read $Q = 59$ l/s and $V = 1.2$ m/s.



(b) From Eq. 4-14, $Q$ and $V$ are both inversely proportional to $n$; therefore,

$$Q \text{ at } n \text{ of } 0.015 = \frac{0.013 \times 59}{0.015} = 51 \text{ l/s}$$

$$V \text{ at } n \text{ of } 0.015 = \frac{0.013 \times 1.2}{0.015} = 1.0 \text{ m/s}$$

### EXAMPLE 4-9

The measured depth of flow in a 1 200 mm concrete storm sewer on a grade of 0.0015 m/m is 740 mm. What is the calculated quantity and velocity of flow?

*Solution*

From Figure 4-10 the flowing full $Q$ and $V$ are 1 500 l/s and 1.34 m/s, respectively.
The depth of flow to diameter of pipe ratio is

$$\frac{d}{D} = \frac{740}{1\,200} = 0.62$$

Entering Figure 4-11 with a horizontal line at this ratio, read $q/Q$ and $v/V$ by projecting downward at the intersections with the flow and velocity curves.
Read $q/Q = 0.72$ and $v/V = 1.08$.
Then, flow at a depth of 740 mm = $0.72 \times 1\,500 = 1\,100$ l/s and $v = 1.08 \times 1.34 = 1.45$ m/s.

### EXAMPLE 4-10

An 450 mm sewer pipe, $n = 0.013$, is placed on a slope of 0.0025. At what depth of flow does the velocity of flow equal 0.60 m/s?

*Solution*

Velocity flowing full = 0.90 m/s (Figure 4-10)
Calculate $v/V = 0.60/0.90 = 0.67$
Enter Figure 4-11 vertically at 0.67, intersect the velocity line, and project horizontally to read $d/D = 0.23$.
Depth at a velocity of 0.60 m/s = $0.23 \times 450 = 100$ mm.

## 4-6 FLOW MEASUREMENT IN PIPES

The common positive displacement water meter has a measuring chamber of known volume containing a disk that goes through a certain cycle of motion as water passes through (Figure 4-12). The rotation resulting from filling and emptying of the chamber is transmitted to a recording register. The advantages of this meter are: simplicity of construction, high sensitivity and accuracy, small loss of head, and low maintenance costs. Also the accuracy of registration is not materially affected by position. This nutating disk meter is commonly used for small customer services, such as, individual households and apartments.

Several meter manufacturing firms have developed remote registration systems. The simplest is a remotely mounted digital register which is placed so

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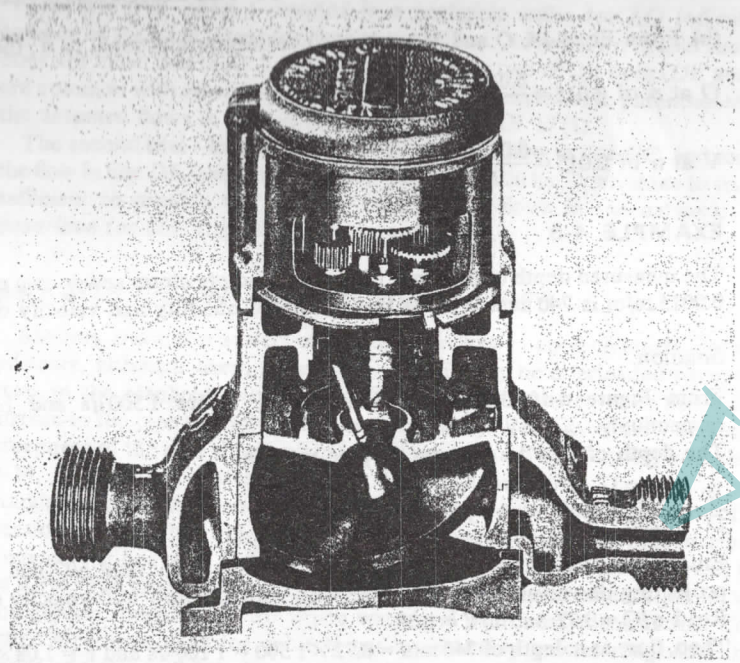


Figure 4-12 Cutaway section of a household water meter with a nutating disk geared to a recording register. (Courtesy of Neptune Water Meter Co., Division of Neptune International Corp.)

that the person reading the register can do so from outside the house. A more sophisticated system consists of an outdoor receptacle read by plugging in a small portable recording device. The recorder punch card, or magnetic tape, is later used in data processing equipment at the central office for billing and recording in the memory system. Automatic remote meter reading, and billing by computer processing, reduces costs for reading of meters and preparation of water bills.

The measuring device in a current (velocity) meter is a bladed wheel that rotates at a speed in proportion to the quantity of water passing through the blades (Figure 4-13). A recording register is geared to the turbine wheel. The shortcoming of a current meter is poor accuracy at low flow rates when the water is not moving at sufficient velocity to rotate the blades. Consequently, they are of limited value in water systems and are used only in restricted applications, for instance, on sprinkler carts that draw water from hydrants or on water towers. Current meters are unsuitable for customer services because of their inability to register low flow rates.

A general-service compound meter consists of a current meter, a positive displacement meter, and an automatic valve arrangement that directs the water to the current meter during high rates of flow and to the displacement meter at low rates (Figure 4-14). The advantages are high accuracy at all flow rates and relatively wide operating range. The switchover from low- to high-flow operation is controlled by head loss through the disk meter; when it exceeds a certain amount, a valve automatically opens and the current meter in the main

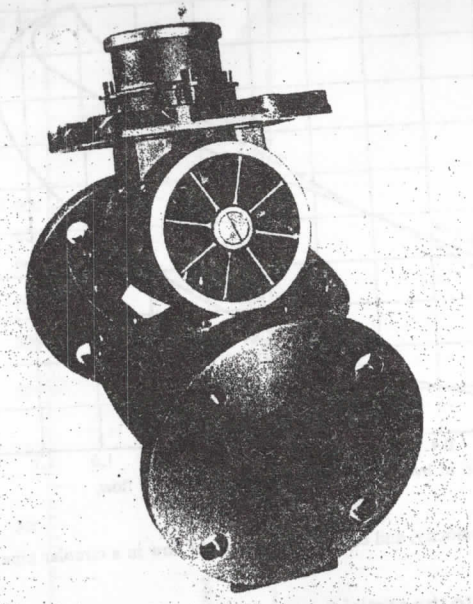


Figure 4-13 Turbine-type water meter used for measuring continuous high rates of flow. (Courtesy of Hersey Products Inc.)

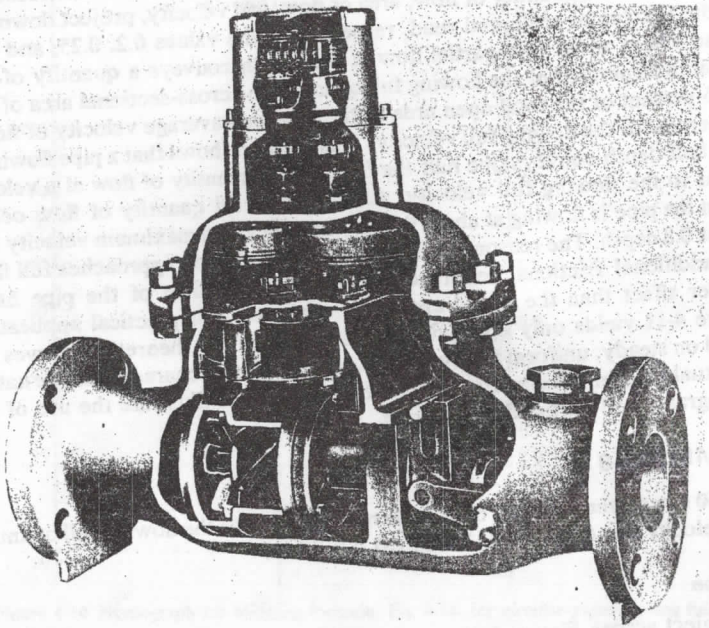


Figure 4-14 Compound water meter designed for services requiring accurate measurements of bot large and small flows. (Courtesy of Rockwell International Corporation)

line begins to measure the higher flow. Compound meters are used on larger services where widely varying flow rates are typical, such as motels, office buildings, factories, and commercial properties.

Proportional meters are sometimes referred to as "compound meters." The name is derived from the fact that only a portion of the total flow through the meter passes through a by-pass measuring chamber, which is the actual measuring device. The by-pass meter, either positive displacement or current type, is adjusted to register the total flow through the meter. Different methods of by-passing the water are utilized, such as an orifice in the main throat or a diverging tube. The proportional meter is capable of measuring large volumes of flow at comparatively low head loss and unrestricted flow, as well as accuracy of measurement.

Differential pressure meters, including venturi tubes, orifices, and nozzles, placed in a pipe section are the primary flow measuring devices in water systems. The meter shown in Figure 4-15 consists of a venturi tube with a converging portion, throat, and diverging portion and differential pressure gauge. As water flows through the tube, velocity is increased in the constricted portion and temporarily lowers the static pressure, in accordance with the energy Eq. 4-2. The pressure difference between inlet and throat is measured and correlated to the rate of flow. A flow recorder with a rotating chart and ink pen plots variation of flow with respect to time, and a digital totalizer registers total flow. Venturi meters are shaped to maintain streamline flow for minimum head loss. In addition to mainline flow metering, venturi tubes are used in rate of flow controllers, for example, on the discharge side of water filters. The pressure sensor transmits a controlling signal to a hydraulically, or electrically operated butterfly valve that is inserted in the pipeline ahead of the venturi. By setting in the desired flow rate, the valve automatically opens or closes as necessary to maintain this rate of flow.

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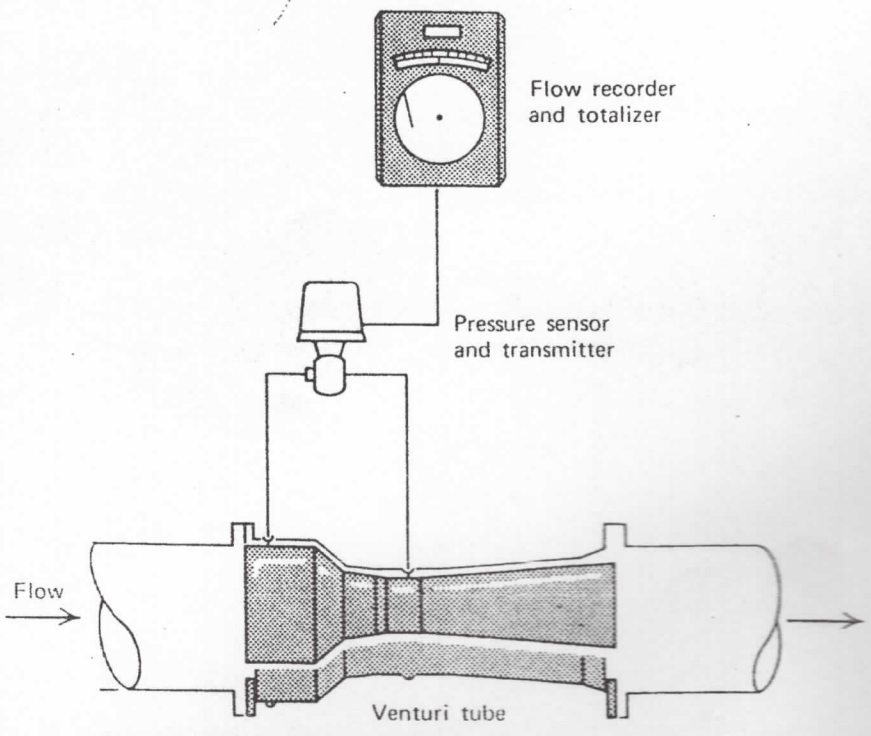



**Figure 4-15** Venturi (differential pressure) meter inserted in a water pipeline, with sensor and recorder.

# *CHAPTER THIRTEEN*

## *NGO INVOLVEMENT*

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# Non-Government Organizations Involvement In the Activities of Water Supply & Sanitation Projects

## 1. Introduction

There are increasingly several indigenous and international Non-Governmental Organizations (NGOs) operating in Ethiopia. Since the world-wide publicity given to the 1973-74 Wollo drought and famine strike. The government encourages NGOs to intervene and supplement the efforts to tackle acute and chronic social hazards through the provision of relief aids in the past. Nowadays, however, NGOs operation have been transformed into broader development activities.

With this context, NGOs are non-profitable ones with the expectation of no privateer returns from what they invest. In other words all of their investment targets social and economic well- being of the marginalized community in which social benefit maximization stands as primary priority. In this aspect NGOs shall adhere to the government general policy guideline, which includes:

- registration
- area assignment
- support to be given to the agencies
- duties and responsibilities and
- other code of conducts that define the relationships between the NGOs and their respective government partners.

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Most NGOs were active in food distribution programs and the provision of other basic services such as:

- Health services
- Water and environmental sanitation from a relief perspective.

While some left after the emergency and many NGOs stayed on and expanded their programs to include:

- rehabilitation, operation and maintenance the existing schemes.
- planning/designing and implementation of new project development activities.

### 1.1 Classification of NGOs

NGOs can be classified in various ways, although it is difficult to make strict distinctions. With this understanding, NGOs in Ethiopia can be grouped into the following classification:

1. **By Origins**

   - Generally NGOs can be grouped into indigenous and international voluntary agencies. Some indigenous NGOs may also have affiliation with international agencies and it may be difficult to treat them in isolation from their parent agencies.

2. **By Geographical Area**

   - Few NGOs operating in Ethiopia have no preference of area. They operate wherever the need exists. Other NGOs prefer to work in selected regions or even in selected zones or districts. The highly localized NGOs are mostly indigenous organized by people from that particular locality.

3. **By Affiliation**

   - Some NGOs are religious affiliated while others are not. These religion oriented are inclined to work in areas where they think there are potentials for disseminating their beliefs.

4. **By Involvement**

   - Most NGOs are implementing while a few are funding. They may need different treatment in the guideline.

5. **By Program Orientation**

   - NGOs are either development and/or relief oriented. Development oriented NGOs are involved in natural and human resource, agricultural, health and infrastructure, development and similar activities, while the relief oriented agencies focus on relief oriented activities.

### 1.2 Areas for NGOs Operations

There is no restriction on NGOs involvement as long as their work is in line with government policy and its directives. The contribution of NGOs can be in one or more of the following areas:

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a) **Program/Project Implement:**

NGOs can initiate or take available projects, and implement them with their own resources. The nature of the projects them with their own resources. The nature of the projects or programs may vary from relief to development.

b) **Funding Projects and Programs**

NGOs can provide fund to implement government agencies, and non-government agencies preferably to the indigenous, the focus of funding NGOs shall be on monitoring, supervising and evaluating the projects which they finance.

c) **Supporting/Supplementing Others Projects**

NGOs can render partial support or supplement others project/ programs. The support could be government and/or NGO agencies (preferably indigenous) and can be interms of man-power, material or financial resources.

### *1.3 Main Activities of NGOs*

There are a lot of activities which NGOs may undertake during normal and disaster period:

a) Funding or implementing development and development oriented projects

This is a priority activity, which NGOs will be encouraged to under take. In such cases their projects should be chosen so as to address one or more of the following:

* Environmental protection and improvement,
* Prevention of land degradation,
* Improvement in land capabilities,
* Improve moisture retention,
* Water harvesting,
* Irrigation,
* Exploitation of ground water,
* Credit
* Community, and women empowerment education
* Advocacy
* Child right
* Education
* Funding and networking
* Improvement in road and other instructor
* Building up of community assets and other productive works

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b) Provision of Rehabilitation Assistance

This would include:

* Provision of seeds
* Supply of agricultural implements, tools and restocking depleted livestock with emphasis on drought oxen and milking cows.

c) Distributions of Relief Items to beneficiaries

d) Provision of health services, veterinary services and distribution of fodder

### 1.4 Mandate for NGOs Registration

Previously Relief and Rehabilitation commission (RRC) and currently National Disaster Prevention and Preparedness Commission (NDPPC) is mandated government agency to register NGOs interested to work in Ethiopia, according to the registration procedures.

Registration entails guaranteeing legal status to NGOs to operate their plan of relief and development projects.

### 1.5 Principles Governing NGOs Relations and Services

NGOs relations, services, and activities are governed by principles. These principles can and may serve as broad code of conducts that NGOs are expected to uphold in their activities/works. These principles are:

- ***Accountability*** - being answerable to beneficiaries target communities, government bodies at National and Regional and donor organizations.

- ***Empowerment*** - i.e. development of self-reliance in the user communities and enhance their capability to decide and act for themselves and eventually to replace the NGO in order to decrease their dependence.

- ***Non-discrimination***- objective, non-selective, and equal application of services and implementation of activities, regardless of gender, class, ethnic group, political opinion, religious belief, national origin, disability etc. ...

- ***Participation*** - free involvement of the users communities, target government sectors and other stake holders in the decision-making process, and in the planning, implementation, O & M as well as monitoring and evaluation.

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- Software aspects
  - * Level of community contributions
  - * Extent of community management
- Future coverage and investment
  - * Water converge
  - * Sanitation coverage
- Integration of water and sanitation
  - * CRDA role
  - * National advisory board should be set up with elected representatives from:
    - ⇒ Government
    - ⇒ NGOs and other professional consultants
- Regular meetings at
  - * National
  - * Regional levels
  - * Magazine, journal and reports published periodically on WATSAN sector by:
    - ⇒ National
    - ⇒ Independent bulletin
  - * NGOs reports at
    - ⇒ National
    - ⇒ Regional
    - ⇒ Zonal and
    - ⇒ District, project sites

## 4. NGOs Working Guidelines

Guidelines or working manual to enhance partnership and determine collaboration between regional governmental agencies and NGOs should be prepared in the pursuit of social and economic development of the region on the basis of general guidelines for the implementation of the National Policy on Disaster Prevention and Management.

The objectives and aims of this guidelines are to :

- clarify uncertainty in accessing entry points for project formulation, appraisal and implementation;

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- ensure efficient utilization of resources to address felt needs of communities,
- institutionalize transparency and accountability between partners through regular exchange of information and feedback.
- strengthen community participation in planning, implementation and evaluation of a project.
- indicate areas of support and encouragement of NGOs from Regional Government and
- recommend the establishment of a joint forum to oversee the progress of the partnership.

## 5. Accessing Entry-Point for Project Designing and Signing

- Entry Point: NGO desiring to formulate a project shall process and possess:

  * A valid certificate of registration from the Federal Ministry of Justice or National Regional Bureau of Justice
  * A valid General Agreement signed between the NGO and DPPC and
  * A project idea or profile indicating:
    - ⇒ area of intervention (district, zone)
    - ⇒ project intervention period (duration
    - ⇒ estimated fund of the intervention

- Review of the application by regional bureau

  * The Bureau shall review NGOs project profile and may instruct to develop the project proposal according to National Regional Guidelines for project formation.
  * Issue a supporting letter and refer to zonal project monitoring and evaluation committee.

- Responsibilities of zonal project monitoring & evaluation committee

  * designate experts, who will jointly design a project with the NGO
  * facilitate community meeting with permission of District Administration, for need identification using participatory methods, and submit the project proposal to the regional bureau with its approval.

- Project appraisal: National Regional state's DPPB shall review and appraise and facilitate signing of a project agreement.

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# I. MONITORING AND EVALUATION

An integration of monitoring and evaluation (M&E) into the whole planning cycle is indispensable. It is a matter of giving emphasis to the process. Other wise, monitoring and evaluation remained part of the implementation processes quite for a long time. An effective use of monitoring and evaluation (M&E) system improves program coordination and management.

The traditional approach of (M&E) focused mainly on keeping track of inputs and outputs. It accepts the project design as given and measures project progress against predetermined targets. Performance looks beyond target and actual accomplishment. It monitors results keeping track the participation and satisfaction of target beneficiaries. This does not mean that the processes that range from input - output - outcome leading to results and impacts are not monitored. A close follow up is done all the way through to come up to the expected result at program and population levels. Therefore, performance monitoring is a process of collecting and analyzing data to measure the changes obtained through interventions, process or achievement of a project/program against expected results. It makes an assessment and focuses on the participation of beneficiaries to address replicability and sustainability issues. Moreover, the assignment of a goal owner becomes essential to effectively monitor achievements moving towards the desired goal to assist the management.

Monitoring and evaluation are separately defined. As a management tool, the role of each section is described below.

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## 1.1. MONITORING

**Monitoring:** is a continuous process of collecting, recording, measuring, processing and communicating information to assist project management in decision making.

Data collected on a daily basis is organized daily or weekly. The organized data serves as a data base from which monthly reports are generated and submitted to respective offices. Individuals submit to their immediate supervisors while the latter submit to their respective offices. By the same token, a committee member in a community reports to the committee secretary or to the committee. Water committee members of communities follow similar procedures in submitting their reports.

The management of an implementing agency or a community that has owned water supply and sanitation projects closely follows the application of monitoring functions indicated below.

**1.1.1. Performance Monitoring:** focuses on activity performances up to and including results. Therefore, managing for results becomes the center piece of project/program management in the process of performance monitoring. The objectives are fulfilled through changes that are measurable within a short term. The changes or improvements are observed in a period of one year in the following areas.

- Agriculture and food production
- Child nutrition
- Maternal and child health/water and sanitation

**1.1.2. Program Monitoring: has the following functions**

- Ensures that program inputs, activities and outputs have occurred
- Tracks progress over time the access to and quality of services by beneficiaries
- Tracks progress in terms of expected impacts of the program on the behaviors and well being of beneficiaries
  - Useful for improved management, administration, accountability, and as an initial basis for assessing impacts

**1.1.3. Program monitoring focused questions**

- Were the scheduled activities carried out as planned?
- How well were they carried out?
- Did the expected changes occur at program level, in terms of:
  - Improved access to services
  - Improved quality of services
  - Improved use of services by beneficiaries?
- Did the expected change occur at household and individuals levels?

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### 1.1.4. Performance Monitoring Beyond Hand over of Projects

The capability of community members in project management is attested on the management performances they prove after hand over of projects. This capability is gained through participation of community members from project inception to project implementation in which monitoring and evaluation is integrated into the whole planning cycle. Lack of adequate awareness and participation in project management, during project implementation, on the part of the community representatives leads to unexpected negative results. Community members in general and their representatives in particular need to accept and own projects following inculcated behavioral changes.

The sustainability issue arises and gets answered when projects are managed at the community level. It is at this point that ex-post evaluation comes in to check the capability of the community and sustainability of projects. Therefore, it is prerequisite that beneficiaries at the community level have acquired adequate knowledge for managing projects. Project implementing agencies should ensure the capability of beneficiaries and their feeling of project ownership during implementation.

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In a country like Ethiopia, where 19% of the rural population is estimated to have access to safe water supply and only 1% to sanitation based on pit latrine, it becomes absolutely necessary not only to proliferate rural water supply and sanitation projects with the participation of the rural community but also capacitate them with repair, maintenance and sanitation habit. The water committee and community health workers should also be equipped with monitoring and evaluation know how to effectively and efficiently manage these projects.

### 1.1.5 Managing Performance Monitoring

Performance monitoring is managed by taking different variables into consideration. These include Goal/objective, baseline, indicators and targets. It is essential to prepare performance monitoring plan (PMP) to effectively follow up activity performances leading to the desired objectives. The plan should answer the question "how do I check that my activities are

properly performed?" The plan needs to be tailored to serve users at different levels. The performance monitoring plan indicated in the table below could one simple example for use at the community level.

***Community Performance Monitoring Plan***
**(Hypothetical)**

| *Activity* | *Who does the job* | *When is it done* | *Responsible* |
|---|---|---|---|
| Repair water taps | Trained community. member | When reported | Water committee |
| Monitor Tidiness of Safe Water | Community Health Worker | Every week | PA/Woreda Council |
| Conduct Health Education | Community Health Worker | Monthly | PA/Woreda Council |

- The performance monitoring plan could be reviewed with the users. For instance, the question, "is the water supply working well?" could be asked to check whether or not the monitoring system is in place.
- Review your information flows. That is check every body in the position he/she plays.
- Check each step on a continuous level.

## 1.2. EVALUATION

Evaluation is a process for determining systematically and objectively the relevance, effectiveness and impact of activities in the light of their objectives. It is an organizational process for aiding management in future planning, programming and decision making.

Formal evaluation is not simply planned for evaluation sake. Because, a continuous internal ongoing evaluation is carried out through performance monitoring. However, there are indications that provide justifiable signal for conducting evaluations. The major ones are outlined below.

Evaluation is carried out when:

- Performance monitoring indicates an unexpected (positive or negative) result
- Information for key Management Decision Making is necessary

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- Implementation reviews identify key questions to be resolved
- A breakdown in a key assumption or critical element and
- An organization wants to extract key lessons learned

In view of the above categories, the types of evaluations are as follows:

## 1.2.1. Types of evaluation

**1.2.1.1. Pre-project/Start - up Evaluation:** It is carried out with the participation of the people in an area so that they can define their situations, speak their potentials and also propose solutions. This process is part of a planning process in which necessary data for project development is collected.

**1.2.1.2. Mid-term/Formative Evaluation:** carried out in the middle of project implementation within three or four years. As per the findings, do we need any mid-term correction? or are the goals and objectives still valid? It is the first comprehensive look by government and international funding agencies. Mid - Term evaluation, thus, reviews whether or not project activity performances are moving toward the set objectives.

Mid-term evaluators will not be able to assess the effects and impact of the project. They can critically examine the continuing validity of the assumptions on which the projects of likely impact were based and if necessary amend these in the light of developing circumstances. Mid-term evaluation serves in changing the nature of the impacts and services, modifying the intervention model and shifting the emphasis among target groups.

**1.2.1.3. Terminal/ Summative/End of Project Evaluation:** This is done at the end of project implementation when project's external funding is over. Terminal evaluation (project completion report) explores sustainability of the benefits accruing to the target population and the rates of return on investments. Terminal evaluation is primarily meant to improve the planning and design of future project.

**1.2.1.4. Ex-post Evaluation:** Carried out several years after the project's termination when its long term effects and impact are visible. It is carried out five to ten years after the completion of its funded implementation. Ex-post Evaluation often called impact evaluations are designed as in depth studies of the impact of an intervention and usually done five to ten years after the completion of its implementation.

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### 1.2.2. Dimensions of Evaluation

**1.2.2.1. Effectiveness:** Is the program making good progress toward objectives?

**1.2.2.2. Efficiency:** Are the effects being achieved at an acceptable cost, compared with alternative approaches to the same objectives?

**1.2.2.3. Relevance:** Are the project objectives still relevant? Is the problem being addressed still a major problem?

**1.2.2.4. Impact:** What are the results of the project/program? What are the effects on individuals, communities and institutions: long and short term; individual, community, institutional; planned and unplanned?

**1.2.2.5. Sustainability:** Will the activity continue after donor funding/special activities end?

### 1.2.3. Impact Evaluations

- Gauge the extent of which a program causes change in behaviors and well-being at the population level.
- The assessment of impact necessarily implies attribution of population impacts to program outputs.
- Impact evaluations are useful in assessing the effectiveness of programs, their relevance to the issues of concern and in future program design.

#### 1.2.3.1. Questions to be Answered by Impact Evaluations

- Is the program effective in achieving its intended goals?
- Can the results be explained by some alternative process that does not include the program?
- Is there a link between impact at the population level and the activities of the program?

### 1.2.4. Evaluation Approach

Evaluations need not be one-man, group or professionals show. People' participation in analyzing their situation helps them to take sustainable correction. Share of ownership also develops. Therefore,

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local communities, local governments, donors and other concerned bodies need to get involved in participatory evaluation.

## II. MONITORING AND EVALUATION SYSTEM

Development planning and management require effective systems for providing information on the progress of projects. Its purpose is for assessing the extent to which projects are achieving their objectives in an economical and timely manner. This will help for assessing the contribution of individual projects to overall sectors and national development objectives. This could be achieved through a national M&E system, which provides the information required by planners, policy makers, and managers at the national, sector, state and local levels.

System involves orderly procedures for specific output or product. One can not expect output prior to processing input. In view of this, the procedure is as follows:

Input ------→ Process -------→ Output

### 2.1. REPORTING REQUIREMENTS

Reporting formats could be internally developed. There are also donor driven formats with out which the receipient may not be able to fulfill the requirements of donors using own formats. Reports are governed by the structure and content that major stake holders would like them to be. Although level of reporting details differ, almost all donors and government offices would like to receive result oriented reports on a quarterly and annual basis. However, formats at the grass root level should serve the purpose of collecting data on daily basis and a different format on which monthly report could be prepared. Similarly, rural water and sanitation committees need to receive periodical reports on the general condition, number of households receiving services, volume and quality of water, sanitation, maintenance etc. On the basis of periodical or special reports, the committee takes adjustment measures as deemed necessary.

### 2.2. Monitoring and Evaluation systems supports efforts to improve:

- Management and administration
- The assessment of program changes
- Delivery of services
- Accountability

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- Program planning and policy development
- Resource allocation decisions

**2.3. There are key questions that should be answered by M&E systems.**

2.3.1. Does the program:

- Increase access of the target population to program services?
- Improve community participation in the program?
- Improve the quality of care to clients?
- Deliver the expected volume of services?
- Achieved an accepted ratio of cost per unit of output?

2.3.2. Has the desired change occurred at household level?

2.3.3. To what extent can observed changes be attributed to the program?

2.3.4. Which program inputs and activities have the greatest impact on the population?

**2.4. An Indicator:** Indicator identifies what verifiable information needs to be collected and what procedures will be used to collect the information about the level of performance against objectives. In general, it is a scale or dimension along which progress is measured. In view of this, activity indicators could be established in relation to the results and objectives.

Indicators are used for analytical purposes in relation to the objectives of programs/projects. Indicators are important instruments for project monitoring, evaluating and strengthen project appraisal. Moreover, indicators can help convince government of the need for action and priority intervention.

In order to measure the progress made towards the major objective, rural water supply and sanitation, result and impact indicators are used. Achievements in line with water supply and sanitation are compared with baseline values to clearly know the changes made because of the water supply and sanitation program intervention. Examples of major result and impact indictors are as follows:

1. % of households with access to protected water
2. % decrease in the number of people with water born diseases

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3. % increase in the number of households using pit latrine

## 2.5. Monitoring and Evaluation System Functions at Different Levels

### 2.5.1. System Functions at The National level

- Monitoring performance of public sector investments through identification of delays and problem projects, and correction of problems
- Monitoring disbursements, use of funds and cost overruns
- Selection of future projects
- Accountability to donors and national financial agencies

### 2.5.2. System Functions at the Sectoral and Ministerial Levels

- Monitoring performance of all projects for which the agency is responsible
- Identification and correction of problems
- Accountability to donors and national agencies

### 2.5.3. System Functions at the Local and Project Levels

- Tool for project managers
- Accountability
- Provision of information to donors and national agencies

## 2.6. Main Users of the System

There are three main users of the monitoring and evaluation system. These are:

2.6.1. International users: donor agencies, universities and researchers

2.6.2. National level users: council of ministers, planning ministry, finance ministry and line ministries

2.6.3. Local level users: project management, local government agencies, beneficiary groups and community organizations, universities and research institutions.

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# CHAPTER FOURTEEN

# OPERATION AND MAINTENANCE

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# CRDA - TRAINING ON COMMUNITY BASED WATER SUPPLY AND SANITATION

## COURSE TITLE -OPERATION AND MAINTENANCE

## 1. INTRODUCTION

### 1.1 Background

Water supply system components has to be sustainable and supply water with out interruption. In order to achieve such sustainability of the scheme the operation and maintenance of a scheme has to be carried out properly by the concerned body and organization. Such body could be the community for rural water supply schemes, water supply service offices for urban water supply schemes supported by the zone department or the regional bureau of water, mines and energy.

Operation and maintenance of particularly rural water supply schemes are not given due attention in the past where most of the rural schemes have failed due to incorrect operation and untimely maintenance works. Hand pumps fail due to non existence of operation demonstration not being given to some community members and the pump care taker. The care taker has to be also able to show to the other community members how to use the pump which otherwise the pump will break.

Training to the urban scheme operators has to be also given in order for them to run the scheme. Pump operators, plumbers, mechanics, electricians, etc., has to be trained to run the scheme as intended. Efficient organizational set up has to be installed to minimize bureaucratic ways of decision making. Supply and availability of spare parts is an other important aspect which has to be taken seriously for the efficient and reliable operation of the system.

At present the major problem in the maintenance of both urban and rural water supply schemes is lack of workshops and trained staff in the field of water supply sector at the proximity of the schemes. Every maintenance work will be referred to the capital city or to the regions capital where there are some better facilities for the work. Lack of local trained mechanics, shortage of mobile workshops in the regions, non existence of shops supplying spare parts, etc., are some of the major constraints hampering the operation and maintenance of water supply schemes.

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The problem is also aggravated due to the fact that the community is not contributing towards the cost of operation and maintenance in most of the rural schemes. Even in the urban areas the cost of energy is very high compared to the water revenue and tariff collected from the users which can not cover the operation and maintenance cost with out mentioning replacement and expansion of the system.

## 2. EXISTING OPERATION AND MAINTENANCE CONDITIONS

### 2.1 Operation and Maintenance Conditions

Both urban and rural water supply operation and maintenance activities are carried out by government institutions at regional and zone levels. There are also NGOs involved in the operation and maintenance for the schemes they themselves constructed.

The operation of urban water supply schemes are carried out by the water supply service office of that particular town. The operation of larger rural communities using motorized schemes is carried out by trained local technicians who are accountable to the nearest zone water department in the area. Obviously, hand pumps are operated by the individual using water from the source. In some communities there are guards who look after the pump, lubricates the chains, tightens loose bolts and watches how people operate the pump, etc.

Although the operation activities are given to identified bodies as stated above still there are problems hampering proper and efficient operation activities.

Maintenance works as stated above are mainly carried out by the government. There are also NGOs and communities who carry out some minor repairs and maintenance works.

Currently preventive maintenance to some extent is carried out by the town water supply service staff and by the zone water department of the regions. Curative maintenance is also carried out by the zone water department and crisis or emergency maintenance is carried out by the regional workshop. It should be however be clear that there are weak regions like Afar, Gambella, etc. who have very little or no capacity to carry out maintenance activities.

The rural water supply system has quite a variety of pumps and equipment. All the maintenance work for the rural schemes are carried out by government regional and zone water bureaus and departments.

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In general both urban and rural water supply schemes which are not properly operating and out of service are very many due to lack of proper operation and maintenance on time.

## 2.2 Sustainability and System Efficiency

Most of the water supply schemes, particularly in the rural areas do not function properly due to lack of proper operation and maintenance, lack of community feeling of ownership, inefficient management and institutional arrangements. Currently 35 - 40% of the rural water supply schemes are inoperative. For instance according to the information given by the Amharic bulletin published by Amhara Region in January 1997 special issue, out of 787 schemes in the region 234 schemes or 42% are not operational.

Similarly most of the urban water supply schemes are old and even the new ones are not properly managed. As a result of these the water loss in most of the towns is estimated to be over 30 - 40%. The unaccounted for water in Addis Ababa is estimated to be over 30% of water produced ( the World Bank Staff appraisal report for water supply development and rehabilitation project, March 1996).

On the other hand the unaccounted for water in some urban areas like Fitche, Debrezeit, Metehara, Debrebrihan, Sebeta, Negele Arsi, Awash and Adwa varies from 40% to 60% as calculated from the information given by the Water Supply and Sewerage Agency (Basic Data on Major Urban Water Supply Services, 3rd draft, February 1995).

Both urban and rural water supply schemes in earlier times and even now are not in most cases constructed based on the felt need of the community but from the top down principle. This has contributed to the inefficient operation and even breakage of the schemes due to many factors such as non priority and non participation of the community, selection of inappropriate technology, lack of awareness by the community, non involvement of women in the planning, implementation, operation, etc..

In general sustainability and system efficiency are not attained in most cases as it was planned during the project initiation and identification due to wrong approach at the planning stages.

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## 3. OPERATION OF WATER SUPPLY SCHEMES

### 3.1 Pump Operations

Operation of pumps is very essential for the water supply scheme to be considered reliable. Pumps could be hand pump, motorized pump or solar pump.

***Hand Pumps***: Hand pump is normally operated by the users themselves and will not require any special training as such except some demonstrations on how to use it. However, a care taker must be trained how to open the head of the pump and grease the chain and tightening of loose bolts and nuts. In some places the care taker will lock the handle of the pump by chain to the head of the pump so that children and careless persons will not operator with out his presence which helps him to control irregular operations.

***Motorized Pumps***: Motorized pump is normally operated by an operator assigned to work as pump attendant and will require training on how to put on and off the pump, apply greasing, refilling of fuel if diesel operated pump , etc. The pump attendant has to be able to run the pump when the reservoir is empty or when the water consumption is high. He has to also record the amount of fuel refilled and the time the pump has run in a day. He should also register the problems encountered during the operation of the pump.

***Solar Pump***: Solar pump, similar to the motorized pump, is also operated by an operator assigned to work as pump attendant and will require training on how to put on and off the pump and similar activities as that of motorized pump except the fuel refilling which is not required in this case.

### 3.2 Treatment plant Operations

Treatment plants need to be operated by a trained treatment plant operator depending on the type of plant. The following are some of the major treatment plant operation activities:

- Chemicals to be added to the raw water at the clarifiers has to be added as per the water quality test results.
- Dosing equipment has to be checked for proper operation and has to be regulated as needed.
- Clarifiers has to be checked for proper formation of flocks and settlement of impurities from the water.

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- Clarifiers should be cleaned by opening sludge valves.
- Sand in the filters has to be washed either by back washing system or by scraping the top part depending on the type of the filter.
- Valves and control mechanisms of the treatment plant has to be checked and regulated depending on the water quality and seasonal variations.
- Records of the treatment operation condition has to be made daily such as daily water treated, time between cleaning or washing of the filter, the filter sand level, quality of the treated water, etc.

### 3.3 Rising Main and Distribution System Operation

***Rising Main***: Rising main line requires little or no operations on daily basis. Air release valves and flushing devices have to be checked at certain intervals for proper operations. The rising main has to be flushed sometimes to remove accumulated silt in the pipe line. Disinfecting of the line might be required if the water is not disinfected always.

***Distribution System***: Distribution lines have to be checked for tightness and if there is any leakage has to be repaired by replacing the broken pipe or by tightening the loose joints. Leaking valves has to be checked every day and has to be repaired if any. Since the treated water is mostly disinfected every day the need for disinfecting the line may not be necessary. The lines have to be flushed on regular basis as per pre planned schedule. Connections to individual houses has to be made based on the request and guidelines established.

***Service Reservoirs***: Service reservoirs have to be checked for water tightness and if there is any leakage has to be repaired. Leaking valves has to be checked every day and has to be repaired if any. Since the treated water is mostly disinfected every day the need for disinfecting the service reservoir may not be necessary. The service reservoir has to be flushed and cleaned on regular basis as per pre planned schedule.

### 3.4 Collection of Bills and Water Charges

Collection of water sales and other service revenues has to be carried out as part of the operation of the water supply scheme. Water meter reading has to be made on monthly or bimonthly basis and bills have to be prepared for collection of the charges. The income and expenditure have to be registered daily.

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In the case of rural water supply schemes the cash contribution commitment by the community has to be fulfilled and the water committee has to collect such cash on time. The water seller at spot supply has to also collect the cash up on fetching of water by the community.

### 3.5 Role of the Community in Operation Works

The community plays a great role in the operation of both urban and rural water supply schemes. In rural areas the hand pump is operated by the community and for mechanized scheme the community has to contribute cash for the purchase of fuel and lubricants and other spare parts. In addition the community will be responsible for the management and administration of the schemes if the scheme is community managed.

In urban areas the community can also assist in the operation of the system although may not involve directly. The community can report leakage to the water supply service office, protect public fountains from being damaged by irresponsible persons, timely pay of the water charges, etc.

## 4. MAINTENANCE OF WATER SUPPLY COMPONENTS

### 4.1 Type of Maintenance

Water supply components maintenance activities require a concerted effort of the different parties involved in the water supply service sector. The type of maintenance which will be required can not be accomplished just by one party. Accordingly dividing the maintenance activities to different stages will help to identify the responsibility of the parties and also for planning and budgeting purpose. On this basis the types of maintenance for water supply schemes can be classified in to the following three categories:

***Preventive Maintenance***: Preventive maintenance usually is focusing on the day today operation of the components such as greasing of mechanical parts, cleaning of filters, changing of worn out parts that can be easily replaced, etc. Changing of oil and oil filter are also part of the preventive maintenance work. Such maintenance activities are mostly required for pumps and other mechanical and electrical components. The preventive maintenance shall be done in most cases by the hand pump care takers, plant operators and the zone water department staff.

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***Curative Maintenance***: Curative maintenance is a bit on a higher scale compared to preventive maintenance and focuses on remedying parts which are broken or loosen on site. Such maintenance works include welding of broken parts on site, replacing bearings, plastering and refurbishing leaking structures, replacing leaking pipe lines and valves, changing filter sand, etc. This work is usually carried out by the urban water supply service office for urban areas and the zone department both for urban and rural areas. Mobile workshops, local garages and local workshop could be used to carry out the maintenance works. Spare parts will have to be made available for such kind of maintenance in the store or from a nearest shop or supplier.

***Major Maintenance or Overhauling***: Major maintenance or overhauling will be required when the water supply component has given service for longer period or when there is serious damage due to other reasons. Such kind of maintenance include pump motor rewinding, complete changing of filter material, replacement of old pipes, maintenance of concrete structures, changing of hand pump cylinder and similar other activities. This type of maintenance is usually carried out by the regional bureau and at bigger workshops for instance at regional capitals and at Addis Ababa.

## 4.2 Cost of Maintenance

The maintenance work in most of the cases is done by the zone water department or by the regional bureau. The cost for the maintenance is also covered by the same organizations particularly for rural areas with the exception of few cases. The cost of maintenance for urban water supply schemes will be covered from the revenue collected by the office except for the cost of transportation and staff cost. However there are some urban water supply schemes which are making surplus and transfer the same to the regional office.

In rural areas the community has to contribute the cost of maintenance as per the principles and guidelines of the government although not fully practiced. Spare parts for the schemes has to be also purchased from the community contribution and expenses for the staff and transport has to be also covered by the community.

The urban schemes operation and maintenance cost coverage is more or less based on the revenues collected by the water supply service office. The approach followed is in accordance to the principles and guidelines of the government although some urban water supply schemes can not cover such costs due to the level of the scheme and its long service life time.

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### 4.3 Spare Parts and Workshops

The other aspect which is very essential for the proper operation and maintenance of water supply scheme is the availability of spare parts and maintenance workshops to the proximity of the schemes. The establishment of zone water department will improve such situation as the department is closer to the schemes than the regional offices. However, private shops for supply of spare parts and private workshops for maintenance have to be also encouraged so that the users can get the service very easily at their closest possible areas.

The regional bureaus have to also strengthen the zone departments in terms of providing maintenance equipment and training of technicians. The zone department has to also try to encourage private sector to participate in the maintenance activities and supply of spare parts.

Training of hand pump care takers, masons, carpenters, plumbers, local technicians and electricians might be important and the zone department has to organize such training with other organizations. For instance there are NGOs who are providing such kind of training at regional level. The training has to focus on community based water supply schemes but not the sophisticated ones.

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# CHAPTER FIFTEEN

# MONITORING AND EVALUATION

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# I. MONITORING AND EVALUATION

An integration of monitoring and evaluation (M&E) into the whole planning cycle is indispensable. It is a matter of giving emphasis to the process. Other wise, monitoring and evaluation remained part of the implementation processes quite for a long time. An effective use of monitoring and evaluation (M&E) system improves program coordination and management.

The traditional approach of (M&E) focused mainly on keeping track of inputs and outputs. It accepts the project design as given and measures project progress against predetermined targets. Performance looks beyond target and actual accomplishment. It monitors results keeping track the participation and satisfaction of target beneficiaries. This does not mean that the processes that range from input - output - outcome leading to results and impacts are not monitored. A close follow up is done all the way through to come up to the expected result at program and population levels. Therefore, performance monitoring is a process of collecting and analyzing data to measure the changes obtained through interventions, process or achievement of a project/program against expected results. It makes an assessment and focuses on the participation of beneficiaries to address replicability and sustainability issues. Moreover, the assignment of a goal owner becomes essential to effectively monitor achievements moving towards the desired goal to assist the management.

Monitoring and evaluation are separately defined. As a management tool, the role of each section is described below.

## 1.1. MONITORING

**Monitoring:** is a continuous process of collecting, recording, measuring, processing and communicating information to assist project management in decision making.

Data collected on a daily basis is organized daily or weekly. The organized data serves as a data base from which monthly reports are generated and submitted to respective offices. Individuals submit to their immediate supervisors while the latter submit to their respective offices. By the same token, a committee member in a community reports to the committee secretary or to the committee. Water committee members of communities follow similar procedures in submitting their reports.

The management of an implementing agency or a community that has owned water supply and sanitation projects closely follows the application of monitoring functions indicated below.

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**1.1.1. Performance Monitoring** focuses on activity performances up to and including results. Therefore, managing for results becomes the center piece of project/program management in the process of performance monitoring. The objectives are fulfilled through changes that are measurable within a short term. The changes or improvements are observed in a period of one year in the following areas.

- Agriculture and food production
- Child nutrition
- Maternal and child health/water and sanitation

**1.1.2. Program Monitoring: has the following functions**

- Ensures that program inputs, activities and outputs have occurred
- Tracks progress over time the access to and quality of services by beneficiaries
- Tracks progress in terms of expected impacts of the program on the behavior and well being of beneficiaries
  - Useful for improved management, administration, accountability, and as an initial basis for assessing impacts

**1.1.3. Program monitoring focused questions**

- Were the scheduled activities carried out as planned?
- How well were they carried out?
- Did the expected changes occur at program level, in terms of:
  - Improved access to services
  - Improved quality of services
  - Improved use of services by beneficiaries?
- Did the expected change occur at household and individuals levels?

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### 1.1.4. Performance Monitoring Beyond Hand over of Projects

The capability of community members in project management is attested on the management performances they prove after hand over of projects. This capability is gained through participation of community members from project inception to project implementation in which monitoring and evaluation is integrated into the whole planning cycle. Lack of adequate awareness and participation in project management, during project implementation, on the part of the community representatives leads to unexpected negative results. Community members in general and their representatives in particular need to accept and own projects following inculcated behavioral changes.

The sustainability issue arises and gets answered when projects are managed at the community level. It is at this point that ex-post evaluation comes in to check the capability of the community and sustainability of projects. Therefore, it is prerequisite that beneficiaries at the community level have acquired adequate knowledge for managing projects. Project implementing agencies should ensure the capability of beneficiaries and their feeling of project ownership during implementation.

In a country like Ethiopia, where 19% of the rural population is estimated to have access to safe water supply and only 1% to sanitation based on pit latrine, it becomes absolutely necessary not only to proliferate rural water supply and sanitation projects with the participation of the rural community but also capacitate them with repair, maintenance and sanitation habit. The water committee and community health workers should also be equipped with monitoring and evaluation know how to effectively and efficiently manage these projects.

### 1.1.5 Managing Performance Monitoring

Performance monitoring is managed by taking different variables into consideration. These include Goal/objective, baseline, indicators and targets. It is essential to prepare performance monitoring plan (PMP) to effectively follow up activity performances leading to the desired objectives. The plan should answer the question "how do I check that my activities are

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properly performed?" The plan needs to be tailored to serve users at different levels. The performance monitoring plan indicated in the table below could one simple example for use at the community level.

***Community Performance Monitoring Plan***
**(Hypothetical)**

| *Activity* | *Who does the job* | *When is it done* | *Responsible* |
|---|---|---|---|
| Repair water taps | Trained community member | When reported | Water committee |
| Monitor Tidiness of Safe Water | Community Health Worker | Every week | PA/Woreda Council |
| Conduct Health Education | Community Health Worker | Monthly | PA/Woreda Council |

- The performance monitoring plan could be reviewed with the users. For instance, the question, "is the water supply working well?" could be asked to check whether or not the monitoring system is in place.

- Review your information flows. That is check every body in the position he/she plays.

- Check each step on a continuous level.

## 1.2. EVALUATION

Evaluation is a process for determining systematically and objectively the relevance, effectiveness and impact of activities in the light of their objectives. It is an organizational process for aiding management in future planning, programming and decision making.

Formal evaluation is not simply planned for evaluation sake. Because, a continuous internal ongoing evaluation is carried out through performance monitoring. However, there are indications that provide justifiable signal for conducting evaluations. The major ones are outlined below.

Evaluation is carried out when:

- Performance monitoring indicates an unexpected (positive or negative) result

- Information for key Management Decision Making is necessary

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- Implementation reviews identify key questions to be resolved
- A breakdown in a key assumption or critical element and
- An organization wants to extract key lessons learned

In view of the above categories, the types of evaluations are as follows:

## 1.2.1. Types of evaluation

**1.2.1.1. Pre-project/Start - up Evaluation:** It is carried out with the participation of the people in an area so that they can define their situations, speak their potentials and also propose solutions. This process is part of a planning process in which necessary data for project development is collected.

**1.2.1.2. Mid-term/Formative Evaluation:** carried out in the middle of project implementation within three or four years. As per the findings, do we need any mid-term correction? or are the goals and objectives still valid? It is the first comprehensive look by government and international funding agencies. Mid - Term evaluation, thus, reviews whether or not project activity performances are moving toward the set objectives.

Mid-term evaluators will not be able to assess the effects and impact of the project. They can critically examine the continuing validity of the assumptions on which the projects of likely impact were based and if necessary amend these in the light of developing circumstances. Mid-term evaluation serves in changing the nature of the impacts and services, modifying the intervention model and shifting the emphasis among target groups.

**1.2.1.3. Terminal/ Summative/End of Project Evaluation:** This is done at the end of project implementation when project's external funding is over. Terminal evaluation (project completion report) explores sustainability of the benefits accruing to the target population and the rates of return on investments. Terminal evaluation is primarily meant to improve the planning and design of future project.

**1.2.1.4. Ex-post Evaluation:** Carried out several years after the project's termination when its long term effects and impact are visible. It is carried out five to ten years after the completion of its funded implementation. Ex-post Evaluation often called impact evaluations are designed as in depth studies of the impact of an intervention and usually done five to ten years after the completion of its implementation.

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### 1.2.2. Dimensions of Evaluation

**1.2.2.1. Effectiveness:** Is the program making good progress toward objectives?

**1.2.2.2. Efficiency:** Are the effects being achieved at an acceptable cost, compared with alternative approaches to the same objectives?

**1.2.2.3. Relevance:** Are the project objectives still relevant? Is the problem being addressed still a major problem?

**1.2.2.4. Impact:** What are the results of the project/program? What are the effects on individuals, communities and institutions: long and short term; individual, community, institutional; planned and unplanned?

**1.2.2.5. Sustainability:** Will the activity continue after donor funding/special activities end?

### 1.2.3. Impact Evaluations

- Gauge the extent of which a program causes change in behaviors and well-being at the population level.
- The assessment of impact necessarily implies attribution of population impacts to program outputs.
- Impact evaluations are useful in assessing the effectiveness of programs, their relevance to the issues of concern and in future program design.

#### 1.2.3.1. Questions to be Answered by Impact Evaluations

- Is the program effective in achieving its intended goals?
- Can the results be explained by some alternative process that does not include the program?
- Is there a link between impact at the population level and the activities of the program?

### 1.2.4. Evaluation Approach

Evaluations need not be one-man, group or professionals show. People' participation in analyzing their situation helps them to take sustainable correction. Share of ownership also develops. Therefore,

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local communities, local governments, donors and other concerned bodies need to get involved in participatory evaluation.

## II. MONITORING AND EVALUATION SYSTEM

Development planning and management require effective systems for providing information on the progress of projects. Its purpose is for assessing the extent to which projects are achieving their objectives in an economical and timely manner. This will help for assessing the contribution of individual projects to overall sectors and national development objectives. This could be achieved through a national M&E system, which provides the information required by planners, policy makers, and managers at the national, sector, state and local levels.

System involves orderly procedures for specific output or product. One can not expect output prior to processing input. In view of this, the procedure is as follows:

Input ------→ Process -------→ Output

### 2.1. REPORTING REQUIREMENTS

Reporting formats could be internally developed. There are also donor driven formats with out which the receipient may not be able to fulfill the requirements of donors using own formats. Reports are governed by the structure and content that major stake holders would like them to be. Although level of reporting details differ, almost all donors and government offices would like to receive result oriented reports on a quarterly and annual basis. However, formats at the grass root level should serve the purpose of collecting data on daily basis and a different format on which monthly report could be prepared. Similarly, rural water and sanitation committees need to receive periodical reports on the general condition, number of households receiving services, volume and quality of water, sanitation, maintenance etc. On the basis of periodical or special reports, the committee takes adjustment measures as deemed necessary.

### 2.2. Monitoring and Evaluation systems supports efforts to improve:

- Management and administration
- The assessment of program changes
- Delivery of services
- Accountability

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- Program planning and policy development
- Resource allocation decisions

**2.3. There are key questions that should be answered by M&E systems.**

2.3.1. Does the program:

- Increase access of the target population to program services?
- Improve community participation in the program?
- Improve the quality of care to clients?
- Deliver the expected volume of services?
- Achieved an accepted ratio of cost per unit of output?

2.3.2. Has the desired change occurred at household level?

2.3.3. To what extent can observed changes be attributed to the program?

2.3.4. Which program inputs and activities have the greatest impact on the population?

**2.4. An Indicator:** Indicator identifies what verifiable information needs to be collected and what procedures will be used to collect the information about the level of performance against objectives. In general, it is a scale or dimension along which progress is measured. In view of this, activity indicators could be established in relation to the results and objectives.

Indicators are used for analytical purposes in relation to the objectives of programs/projects. Indicators are important instruments for project monitoring, evaluating and strengthen project appraisal. Moreover, indicators can help convince government of the need for action and priority intervention.

In order to measure the progress made towards the major objective, rural water supply and sanitation, result and impact indicators are used. Achievements in line with water supply and sanitation are compared with baseline values to clearly know the changes made because of the water supply and sanitation program intervention. Examples of major result and impact indictors are as follows:

1. % of households with access to protected water
2. % decrease in the number of people with water born diseases

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3. % increase in the number of households using pit latrine

## 2.5. Monitoring and Evaluation System Functions at Different Levels

### 2.5.1. System Functions at The National level

- Monitoring performance of public sector investments through identification of delays and problem projects, and correction of problems
- Monitoring disbursements, use of funds and cost overruns
- Selection of future projects
- Accountability to donors and national financial agencies

### 2.5.2. System Functions at the Sectoral and Ministerial Levels

- Monitoring performance of all projects for which the agency is responsible
- Identification and correction of problems
- Accountability to donors and national agencies

### 2.5.3. System Functions at the Local and Project Levels

- Tool for project managers
- Accountability
- Provision of information to donors and national agencies

## 2.6. Main Users of the System

There are three main users of the monitoring and evaluation system. These are:

2.6.1. International users: donor agencies, universities and researchers

2.6.2. National level users: council of ministers, planning ministry, finance ministry and line ministries

2.6.3. Local level users: project management, local government agencies, beneficiary groups and community organizations, universities and research institutions.

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# *CHAPTER SIXTEEN*

## *SPECIFICATION AND CONTRACT DOCUMENT*

## *TENDERING AND EVALUATION*

## *CONTRACT MANAGEMENT*

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# SPECIFICATION AND CONTRACT DOCUMENT

## 1. Procurement

### *1.1 Types of procurement*

Procurement is the general name for the acquisition of works, goods and services. The types of works, goods and services to be procured for a community based water supply and sanitation programme may be grouped as:

- Training and capacity building
- Consultancy services, i.e. for water resources surveys, planning and design, construction supervision.
- Equipment purchase (survey, terrameters, measuring tapes, construction equipment, pumps,
- Material purchase (pipes, cement, aggregates etc.)
- Construction of water supply and sanitation

### *1.2 Procurement Guidelines*

Procurement guidelines could emanate from:

- Implementing agency
- Funding agency

Procurement guidelines stipulate the following:

Specify the category of procurement.

These are:

- Local Shopping, Local Competitive Bidding, International Procurement, and International Competitive Bidding
- Clearance/ approval required (what, by whom, at which level)

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## 2. Procurement Documentation

### *2.1 Tender Document.*

The tender document is the set of information provided to bidders to enable them to quote their prices to provide the defined, goods, services or civil works. Such information could include commercial, technical, financial and legal stipulations.

### *2.2 Contract Document*

This is a document binding the parties to an agreement defining their respective obligation, rights, duties and responsibilities with respect to a procurement. The contract document contains the prices quoted by the selected bidder, and any points of negotiation made henceforth.

### *2.3 Standardization*

Some components of the tender and contract documents may be standardized to suit repetitive bids, as will be elaborated in the following sections.

## 3. Contract Documents (Civil Works)

Contract Documents are the link between:

i. The designer who decides what work is to be done;
ii. The agency which provides the money to pay for the work;
iii. The contractor who will carry out the work;
iv. The community who are to benefit from the work when it has been completed

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If the documents are badly prepared there will certainly be difficulties in completing the work. However all the people involved must play their part if the project is to be a success.

## 4. The Contract

A contract is a legal document and provides the authority for the payment by the contracting body or an International funding agency for (usually) large sums of money. It must therefore be written clearly to describe precisely its intended meaning, but it must not be more complicated than is necessary for its intended purpose. For instance, the contract documents for a small local contract would be shorter and simpler than that for a large international contract, even though they would contain the same basic elements.

## 5. Conditions of Contract

The heart of the contract document is the section entitled conditions of Contract which sets down its legal framework and the general obligations of the contractor, the employing authority and their employees, including the consulting engineer if there is one (The Conditions make reference to the "Engineer" but he is frequently a direct employee of the authority responsible for construction of the project). The conditions will state amongst other things:

i. What law is to be used in interpreting it. This is usually the law of the country in which the work is carried out.

ii. Who is responsible for measurement of work and for valuing completed or part completed work.

iii. What certificates have to be issued and by whom so that payment can be made for work done.

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iv. What action is to be taken in cases of a dispute (for example arbitration may be preferred, in other cases arbitration would be ruled out and disputes would have to settled in the Courts).

The Conditions of Contract must be written by experienced staff. They are normally in the form of a standard document, with provision for the insertion at the end of clauses specific to a particular project or country. One internationally well-know document is "FIDIC", but others are favored by some funding agencies. A shorter version is normally used for small local contracts. If it is decided to modify a standard document, this work should also be entrusted to lawyers. In Ethiopia the Ministry of Public Work and Urban Development has issued a standard document, applicable for Government jobs.

## 6. Drawings

The drawings must illustrate all the works to be constructed. They will normally consist of:

i) A small scale general layout showing the project area in relation to adjacent roads, villages and towns;

ii) A large scale layout will show the project, and all its parts, for example water source, pipe line, treatment plant, reservoir, pumping sites;

iii) Each part of the project must have its own drawing;

a) Pipelines whether new or to be changed, must be illustrated by long - and cross - sections.

b) Structures such as reservoirs need to be elaborated to show overall layout, reinforcement details, etc.

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## 7. The Specification

The specification normally commences with a brief description of the project and a list of major work items: for example so many km of pipelines, treatment, reservoirs etc. to be constructed.

These lists provide a good reference for tenderers who can quickly gauge the scope of the project, and also form a useful check list for engineers writing the remainder of the Specification and Bill of Quantities, to ensure they have not omitted anything.

The Specification then deals with general matters such as the order in which the work is to be constructed, dates to which access to different parts of the site may be given and facilities to be provided such as offices, transport, housing, testing laboratories.

Following the general matters, the requirements of each operation, and of materials to be used, are detailed. These parts of the Specification must take into account the type of contractor who will be tendering. This Section of the specification is a long one, unless the contract is confined to one or two operations only, but most authorities will have built up sets of standard clauses which they have found by experience to be effective, though some special clauses will usually be required. If standard clauses are incorporated care must be taken to make sure they fully cover what is required in the particular contract in which they are being used and that they are consistent with other clauses.

Sometimes, at the end of each clauses describing a particular requirement, for example concrete, shuttering, excavation, fill etc. an additional paragraph is add defining the method by which the work is to be measured in the Bill of Quantities. Sometimes however this information is included, in the preface to the Bill of Quantities and is properly specified.

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## 8. Bonds

Bonds are essentially insurance's taken out by the person tendering, or by the contractor after the tender has been accepted, to safeguard the employing authority against financial loss if the contractor (or tenderer) fails to carry out that which he has undertaken to do. The contractor has to pay for these and the cost forms part of his contract price so that the employing authority is really paying, though indirectly. For this reason some authorities take out their own insurance, as they find it cheaper. The wording of the Bonds must be in accordance with the forms included in the specification.

A tender/bid bond is a form of guarantee supplied by a contractor when he tenders. He will have purchased this form a bank or insurance company and the amount written in it (which will have been stated in the specification) will be paid to the employing authority if the contractor having tendered refuses to accept a contract. The money is intended to meet the expenses of the authority in obtaining fresh tenders.

A performance bond will often be for a substantial amount of money and intended to compensate the employing authority for his extra costs if the contractor fails to complete a contract, and another contractor has to be brought in. However a small local contractor may not be able to obtain a performance bond, in which case the employing authority will have to take the risk. This should make him extra careful in his choice of contractor.

An advance payment bond is sometimes required when the contract provides for a large initial payment to the contractor to assist in financing his mobilization costs. This payment will be made before the construction of any permanent works and the bond will provide for it to be repaid if the contractor defaults at this stage. This protection could form part of the performance bond.

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## 9. Tender Form

The tender form is usually a single piece in paper summarizing the value of the tender and listing the currency or currencies in which payment is to be made. It will also state the period in which the contractor has undertaken to complete the works, the retention and its method of calculation and the period of maintenance. This page is signed on acceptance of the tender by the contractor and the employing authority and (together with any relevant correspondence entered into between submission of the tender and its acceptance) forms the basis of the contract.

## 10. Maintenance Period

The Conditions of Contract will normally contain references to "Maintenance Periods" and the "Maintenance Certificate". As defined in the documents, "maintenance" refers to the contractor obligation to put right any fault that develops in the work he has constructed. If he has not done this during construction he must do it during the maintenance period, which usually lasts for about 1 to 12 months after he has completed construction. If the fault arises because of his bad workmanship or use of incorrect materials no payment is made. If the fault arises because of a mistake in the design or other reason not the contractor fault, he is paid.

The Maintenance Certificate is issued at the end of the maintenance period or later when he has completed the repair of faults. The contract is then at an end, and all monies withheld from the contractor (the retention) should be paid.

"Maintenance" in this context does not mean day to day repairs due to wear the tear.

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## 11. Insurance

In addition to the Bonds the contractor must taken out up to four types of insurance and it is usual for the employing authorities to approve the policies before the contractor starts work.

In some types of contract the contractor must insure the works he is constructing, in case they are damage or destroyed by accident, for example by flood. It will be the responsibility of the employing authority to decide when writing the contract documents what risks are to be covered since he (either through a Bill of Quantity item or indirectly if the cost is included in other items) will be paying the premiums.

The contractor must take out insurance to provide compensation for any of his staff or workman, and for employees of the employing authority, who are killed or injured during construction.

The contractor must also take out insurance to provide compensation against claims by third parties (any local people or passers by) who are injured, or whose property is damaged, by the contractors operations.

In addition to the above the contractor will have to take out normal motor insurance for any transport he provides either for himself or the employing authority.

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## 12. Bills of Quantities

### *12.1 Introduction*

Bills of Quantity enable the cost of a project to be assessed. The accuracy with which this can be done depends partly on how the various items are described.

For example, suppose a mass concrete structure is to be built in a location where the foundations are below the water table. If the Bill contains only three items:

i) excavation
ii) concrete
iii) Shuttering

Then the cost of the necessary pumping must be included in one or more of those items. Also the cost of temporary support for the excavation, which must be included in the excavation rate, is likely to be higher than if the ground is dry. There are tow drawbacks to this method of billing:

i) With no specific item for pumping the estimator may not give its likely cost sufficient thought (or any thought) and either omit any allowance or make insufficient allowance.

ii) Even if a correct allowance is included, and converted to a rate per cubic meter, probably in the excavation rate, the contractor will only recover the correct amount if the quantity as finally measured is the same as that originally billed. Otherwise he will recover too much or too little. This is the problem resulting from expecting a time - based cost to be included in a volume - based measurement.

Both on large and small contracts cases can arises when pumping forms a large proportion of foundation costs of a particular structure. In such cases the inclusion of an item for 'pumping' in the Bill of Quantities can be helpful to the contractor when tendering and to the employing authority in evaluation the cost of any change that has to be made to the design during construction.

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## 12.2 Method for Carrying out Work

The engineer making up the Bill should therefore consider carefully how the work is likely to be carried out. Since he or a colleague will use it first to price it and so obtain an estimate of total cost, in order to obtain funds, he should use this exercise to modify it to correct any weaknesses, and ensure that the Bill contains sufficient items for realistic pricing.

## 12.3 Sections in Bill of Quantities

The Bill for a larger project will usually be divided into several sections. The first section will deal with "general items" common to all the project and the other will describe each part, for example:

pipe line
Reservoirs
Treatment plant
Access roads

Alternatively the Bill may be divided so that each geographical area has its own section. This could be preferable where access problems or ground conditions differ substantially from one section to another, so that the prices for the various items could reflect these differences.

### 12.3.1 General Section

The "general" section of Bill contains items for the provision of offices, housing (if required), contractors camp, communication and transport. Sometimes there is an item for "mobilization" or "contractors overheads". If there is no provision in the contract for the contractor to be paid an advance of money he will frequently price the item for contractors camp at a much higher rate than it will cost him. Since he

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will build this first he will in effect obtain the advance he requires. But he will have to reduce his unit rates for the remainder of the work to keep his total tendered price competitive.

It is preferable to include two items for overheads - one, a lump sum, to be paid at the beginning of a contract and the other, a monthly rate, to cover his on-going overhead costs. This has further advantages: the monthly - paid item will only be paid up to the time the contractor has undertaken to complete. If he is late due to his own fault he will lose his payment, so there will be an added incentive for him to keep to programme. On the other hand if for some reason it is judged that the contractor has been delayed by some action of the employing authority, he will have to be granted an extension of time to complete, and in nearly all such cases he will claim his overheads during this period. If there is a Bill of Quantities item, at least there should be no argument as to the monthly sums involved.

### 12.3.2 Day works

It is usual to include one Bill section for work to be carried out on "day works". This refers to work where the contractor is paid by the hour or day for his labour and machinery, and for the cost of the actual material used. It is an unpopular form of payment with the contractor because of the argument which usually arise over the records which he submits for signature, and with the employer's staff because they frequently consider the contractors use of his labour and plant on these occasions to be inefficient. However it is sometimes the only way to value work, for emergency repairs carried out by the contractor for instance.

## *12.4 Progress Monitoring*

Once a contract has been let, financial as well as physical progress should be closely monitored, so that early warning is available if the budget appears to be in danger of being exceeded. A valuable tool to aid financial control is a small computer in which the Bill of Quantities can be stored and printed in spread sheet form. It is

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useful to have three sets of quantity rate and cost columns, the first duplicating the figures in the contract, the second giving the data applicable to a particular month and the third to forecast final quantities extrapolated from the second column. The accuracy of this final column will increase as the work proceeds.

The computer can also be programmed to calculate quantities and is particularly useful for structures built to standard drawings as it is only necessary to enter dimensions of the structure for it to calculate all the quantities in a matter of seconds.

## 12.5 Method of Quantity Calculation

The method by which quantities are calculated is set down either in the specification or in a preface or preamble to the Bill of Quantities. It is sometimes difficult to express clearly what is meant and great care must be taken if future arguments are to be avoided.

## 12.6 Increases in Rates and Prices

Some provision to protect the contractor against increase in labour rates or commodity prices or taxation is sometimes included, thought not in contracts expected to last a year or less. It is very difficult to devise a method of evaluation such increases which is fair to both parties to the contract and reasonably simple to operate. If actual cost increases form the basis then the contractor has to produce all his invoices and receipts. These are very difficult to check and offer easy scope for fraud since they may not record what he actually paid.

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## 12.7 Contingency Allowance

Bills of Quantities sometimes but not always include a "contingency allowance". A lump sum usually 10% or 15% of the tender total. Its inclusion recognizes that despite careful preparation of the contract documents conditions may arise which will require additional expenditure, which can be met from this allowance. However some funding agencies will not permit this, preferring instead to include the allowance in their own confidential estimates. The reason for this is that the inclusion of a contingency allowance in the contract encourages the contractor to claim monies up to that limit, because he knows it is available.

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# CONTRACT MANAGEMENT

## OUTLINE

**1. Project Implementation**

**1.1** Procurement of Goods and Services
**1.2** Works Implementation

**2. Construction Supervision**

2.1 Method of Construction
2.2 Organization and Staffing
2.3 Program and Progress Charts
2.4 Price Increases, Extras, and Claims
2.5 Site Surveys, investigations and layout

**3. Construction Control Procedure**

3.1 Shallow Wells With Hand Pump
3.2 Bore hole Drilling
3.3 Spring Development and Protection
3.4 Pumping Stations
3.5 Reservoirs
3.6 Conveyance and Distribution Pipeline Works

**4. Report Preparation**

4.1 Daily Reports
4.2 Weekly/Monthly Reports
4.3 Quarterly Reports
4.4 Annual Reports
4.5 Final Report

**5. Payment Certification**

5.1 Interim Payment
5.2 Retention
5.3 Final Payment

**6. Acceptance and Hand over**

**6.1** Provisional Acceptance
**6.2** Final Acceptance
**6.3** Project Hand over

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## 9.0 RESPONSIBILITIES AND PROCEDURES OF CONSTRUCTION CONTROL AND INSPECTION

### 9.1 GENERAL PROCEDURES

Construction control plays an important role in any construction activity by insuring that the different components of a scheme are built in accordance to the designs, that the quality and types of materials used in constructing components of the scheme are also in accordance to the specifications. Hence, enabling the completed structure to give the required level of service for which it is designed with minimum operational and maintenance difficulties during its lifetime.

Construction of rural water supply facilities is carried out in the southern region by the government owned contractor (EWWCA) or by the construction services division of the WRDCD and by construction crews of NGO'S (NCA, Oxfam, Catholic mission, etc.). A water system, whether it is constructed by EWWCA or NGO'S needs to be checked and tested, then get provisional acceptance by the construction control section, before it is handed over to the community and put into operation.

During the inspection stage of a completed water supply system, each component is checked for defects (transmission and distribution mains are tested for leaking parts) every deficiency is recorded by both parties representing the contractor or the body who carried out the construction and the construction control section of WSSA (WRDCD). The defects could be rectified while the system is giving service and if any failure occurs during the period before final acceptance protocol is signed,the contractor or the constructor is responsible for repairing the failed part. The length of the time between the provisional and final acceptance is fixed in the contract agreement and it is usually one month.

Construction control activities should begin early at the start of construction work on the community water supply system. This means that in each community water supply project a construction inspector must be assigned by the construction control section and has to move to the site together with the construction crew. Where construction is going on in different communities or villages at same time, say in different Kebeles of a Woreda or Awraja, One inspector may be sufficient to cover more than one kebele depending on their location accessibility and the type of water supply scheme.

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The inspector should keep records of all his daily activities and the daily report formats. See sample formats in Appendix A, Forms 011-007. The daily report formats are one of the most important documents of the construction inspector, which are the basis for certifying payment requests of the contractor by ascertaining the actual volume of the work done within a given period of time. Furthermore, they are useful in preparation of monthly, quarterly, semi annual and annual work progress report which are required by management and higher level decision making body.

The construction inspector and control procedure to be followed during the construction of each component of water supply scheme are given below.

.1 Shallow Wells With Hand Pump

- **Digging/Augering Work**

  - Check and be sure that the well is being sunk in the appropriate location as decided by the hydrogeologist and the community. This is when the inspector is not a hydrogeologist/geologist. But it is recommended that shallow well and deep wells (BH) construction be deferred until the well is ready for top work pump installation.

  - Check and record the starting well diameter

  - Measure and record the depth dug/augered per hour and at the end of day.

  - Check for type of soil or formation excavated in each meter of depth and record depth at which material changes, calculate and record volume excavated per hour, per day and when the final depth is reached.

  - Measure the depth of water encountered and record.

  - The final depth is decided when the well is found to give the required volume of water as per the site specification. This could be confirmed by emptying the well by pumping or bailing out the water and the by calculating the rate of recovery and comparing it with the rate of withdrawal using a

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hand pump. (For more detail on test pumping wells and boreholes refer to previous section.)

- **Lining or Casing the Well**

The next task is to inspect the quality of the material to be used for lining the wells. In some cases excavation or digging might be difficult due to the softness of the soil which caves in or collapses before lowering the casings. In such cases it would be necessary to lower the casings while the digging or excavation work progresses. The conventional lining material used in the Southern Region is concrete prepared in the form of cylinders. Concrete cylinders could be cast on site or as it is done in the Region, in EWWCA'S compound and then transported to site. Wherever the concrete cylinders are cast, the inspector should check and ascertain before they are lowered and installed into the well that:

- The concrete cylinders were kept for a minimum of 7 days and well cured.
- They are not damaged and cracked as a result of miss handling.
- The cylinders to be used as screens have the proper perforations as specified in the design.

The construction control section should regularly inspect the production of concrete cylinders in the contractor's yard (EWWCA compound) by assigning an inspector for controlling the mix proportions, the water cement ratio used during mixing the quality and size of coarse and fine aggregates, storage of fresh cylinders and curing operations. For cylinders cast on the construction site as in the OXFAM Method, it is the site inspector's job to control the concrete mixing process.

The strength of the concrete cylinders, the mix proportions and size and quality of aggregate are not usually specified for each shallow well construction, but since they are designed to be applicable in all wells of different site conditions, they are set once and are to be found in the general specifications for shallow well constructions.

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Check the plumbness of the casing lowered by looking at the annular space. The space between the wall of the well and casing should be equal in width and uniform all around. This should be checked before filter gravel package is placed.

Check the type,quality and size of filter gravel delivered on site before gravel packing.

Record the type, size and total volume of gravel packed.

Check that the last 3 to 5 metres of the annular space up to the ground level is sealed by compacting selected clay soil or some other material as per the specifications.

**Wellhead and Top Work Construction**

Check and record the quality and the quantity of cement, sand,coarse aggregate, and reinforcing bar and stone delivered on site for top work.

After making sure that the cement is properly stored and has adequate quality, that the sand fulfils all requirements regarding its clay content, moisture content grain size, etc. and the coarse aggregate of its strength durability,grain size, etc., follow the mixing process to produce concrete of strength as specified in the general specification.

Measure and check the dimension of the box used for proportioning sand and aggregate. Follow that per bag of cement the specified number of boxes filled with the aggregate are mixed for producing the required volume of concrete. Check the quantity and quality of water added per bag of cement, that it is in conformity with the specified water cement ratio. Only concrete mixed under full supervision of the inspector should be allowed to be poured in place.

Record the total volume of concrete used for preparing top slab, and top work in general in each well.

Check and follow that proper size and spacing of reinforcement bars is kept while casting the cover slab.

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Check all the necessary anchor bolts to be placed in freshly poured concrete and proper size of openings / holes including dimensions are done in accordance to the design prior to hand pump installation.

Make sure that the cover slab and top work surface are built to slope in the same direction as the surrounding ground and they are properly cured for seven days.

- **Hand Pump Installation**

Check and make sure that required quality and specified type of hand pumps complete with all the necessary accessaries are delivered on time and properly stored.

Make sure that well extensions (pump rod, drop pipes, and couplings) are prepared to match the pump setting position already determined. Note that at least 25cm clearance must be left between bottom of the well and the foot valve.

Make sure that all parts to be lowered in the well which make contact with water are kept clean before they are installed.

Make sure that the proper disinfection task is carried out before any water from the well is used for drinking.

A typical Daily Records form is provided in Appendix A, Form No. 001.

.2 Borehole Drilling

Production boreholes are drilled to be equipped with hand pumps sometimes, but mostly they are drilled to be fitted with motorized pumps. In both cases the drilling operation is the same, but the final depth of the hole is usually less in hand pump boreholes than boreholes for motorized pumping. The construction control and inspection procedures in all types of boreholes are similar. Thus the procedures listed below are applicable in the drilling of boreholes both for hand and motorized pumping.

The inspection and supervision tasks during borehole construction should be carried out by a hydrogeologist or an engineer who has sufficient

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experience in supervising activities of borehole drilling. Many of the different stages of borehole construction require close, day to day supervision by the hydrogeologist. Experience in the Southern Region shows that when deciding for the final depth of the borehole and designing the screen (length, position) then ordering in time the exact quantity of casings, gravel, etc. needed, the non-availability or absence of a hydrogeologist ( inspector), is one of the many factors that contribute to the prolonged time it takes to complete a production borehole. Therefore it is important to emphasize that one inspector should be assigned at each borehole drilling site from WSSA'S/WRDCD'S engineering service division and he has to be present on site before drilling starts and has to supervise the drilling, casing installing, gravel packing, developing and test pumping stages of the borehole construction. The daily records on the daily drilling report format (see Appendix A, Form No. 002) are helpful for casting the borehole, preparation of progress report and for preparation of geologic/hydro-geological and construction logs of the borehole for documentation.

- **Drilling**

  Check and record, materials delivered on site, trade and number of manpower employed, type of drilling rig, drilling start date, etc.

  Supervise the site clearance and rigging up operations, record total area cleared.

  Check the proper size of drill bit is used when drilling starts.

  Record drilling rate, depth drilled per hour.

  Collect or see that samples (chips) are collected at each meter drilled and record depth at which type of soil/rock formation changes.

  Measure and record depth at which water is first struck.

  If formation is soft and collapsing, check diameter, length of temporary casing used and record.

  Follow that bail tests are carried out every 3 metres below the depth of first water encountered. This is important to decide on the final depth of the whole and to stop the drilling operation. The hydrogeologist (inspector) at this stage is expected to evaluate the

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bail test results and if possible to consult the engineer who designed the water supply system to determine whether the borehole yields the required quantity of water at that depth or if further drilling is necessary. If possible the electrical conductivity of at least one bailed sample should be measured each day and recorded on the daily drilling reports, to ensure that a borehole with an acceptable water quality is completed. (Bail and pump testing procedures are discussed in Section 7.1.)

## Installation of Casings

Based on the analysis of samples collected during the drilling activity and on the nature, depth and location of aquifer; design the screen and specify its size, length, position in the borehole; then instruct the driller to prepare the blind and screen casings accordingly.

Check that while lowering the casings, the lower most casing is capped or properly plugged at its end and centralizers are tied on the screens (exact centering of the screen is important for uniform distribution of gravel pack around the slots of the screen). (Refer to Section 7.1 for more detail on borehole design and construction.)

## Gravel Packing

Gravel packing should begin immediately after the casings are installed. Delay in packing gravel may result in collapse of aquifer material against screen openings. Thus calculate the volume of gravel required and make sure the required quantity and grain size of gravel is delivered and properly stored in advance.

Follow gravel packing operation, which should be poured slowly and continuously, starting from the bottom of annular space up to 3 or 5 metres below the ground level.

The remaining depth of the annular space is filled with clay or cement grouted depending on the specifications. Control and check the preparation and the pouring of material in filling this space.

Make sure that after gravel packing is completed, the borehole is thoroughly developed and cleaned. Developing should continue until clear and sand free water is discharged from the borehole or if the

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length of time for developing is fixed in the specifications, developing should continue for the specified period. Record start and complete time and method used for developing.

Contact headquarters for test pumping crew to be arranged and moved to site on time to start testing the borehole immediately after development is completed.

Supervise the test pumping operation: measure and record all information on the pump test result forms and make sure that testing is conducted for the specified length of time.

Prepare borehole completion report, including vertical section drawings of the completed borehole together with the geologic log in sufficient copies, then submit to the construction control for distribution to the concerned bodies.

## 3 Spring Development and Protection

### General

The first task of the inspector when the construction of a spring development head works starts is to lay out the protection and collection structures. This requires clearing the whole area around the eyes of the spring. The size of the area to be cleared depends on the number and relative position of the spring eyes (if the spring comes from different outlet points). Generally it is helpful to clear a wider area, to check and to be sure that only spring eyes of emerging ground water are capped, excluding those which come from seeping surface water, which are sometimes misleadingly considered as springs of ground water. Sometimes the inspector may find the plans on the working drawings not to match with the site conditions, after it is thoroughly cleared. Maybe the dimensions of the protection as given on the plans are bigger or smaller than the actual area to be capped due to the discovery of new eyes or that the actual outlet points of the spring are not those considered to be during the survey work. This situation is bound to happen in many spring development construction sites due to the difficult nature of spring locations or due to the inadequacy of the time taken and thoroughness of the investigation work. The above discussion leads to the conclusion that if the inspector is not the engineer who

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designed the system, it is mandatory for the designer to be present at the site at least at the start of construction in order to see if some modifications of the design are required and to decide at the spot, so that no delays are created in the construction progress. The routine tasks of the inspector in the construction of spring head works are listed below and as in the other type of scheme, great care and attention must be given in the recording daily activities in the daily report format (see sample format in Appendix A, Form No. 004).

## Site Clearance and Excavation

Follow that the spring site is adequately cleared - plants, grass, any growth is removed, all effective eyes (outlet points) are fully exposed and differentiated from surface water seepage, no hindrance exists on the direction of flow of the spring water nor there is an accumulation of water in or near the eyes, if any, see to it that it is allowed to drain. Measure and record the total area cleared.

Make sure that excavation for foundation of protection structure does not disturb the natural flow of the spring.

Check that (if the protection structure is stone masonry wall) this rests on firm foundation. Measure and record total volume excavated.

## Masonry, Concrete and Pipe Works

Supervise preparation of mortar, and check type of stone for masonry work, record volume of masonry work done per hour. Make sure that plastering and pointing works are properly done so as to ensure water tightness.

As the inlet level of collection box is required to be below the ground level or below the level of the spring, as is shown on the working drawings make sure/check the required level is kept while, foundation wall and floor works of the box are started.

Check material delivered for masonry and concrete work, supervise the preparation of concrete.

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Make sure the proper material, size and quantity of pipes,fittings and valves are delivered and kept in good condition.

Make sure that inlet, outlet, drainage, overflow pipe, fitting and valves of the specified type and size are installed in accordance to the designer.

Record any variations from the original design,and submit as built information to the design section.

.4 Pumping Stations

- **General**

Construction of a pump station includes installation of mechanical and electrical equipment in addition to the construction of the buildings which house the pumps, engines, electric generators, and control panels.

Inspection of the works related to erection of electro-mechanical equipment should be carried by a mechanical/electrical engineer or an experienced technician from the operation and maintenance division in collaboration with the construction control section. Inspection procedures of electromechanical works are beyond the scope of this manual. A typical Daily Report form is shown in Appendix A, Form No. 005.

Following are the basic points to be noted during inspecting the construction of the civil works.

- **Pump and Generator House**

Standard designs of pump and generator houses are generally used in rural community water supply systems in the Southern Region. If the pump selected is a mono lift type which is driven by a diesel engine, the standard mono pump house with corrugated house walls and roof is usually recommended, but if the pump is a submersible or surface type driven by an electric motor, the house is the standard generator house made of either corrugated iron sheet or concrete hollow blocks, depending on the design and space of the water scheme. In any case, when laying out the pump or the generator

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house, make sure that its, orientation is such that no difficulty or unnecessary bends are encountered while connecting suction and delivery pipes. See that the location is not exposed to flooding, otherwise make sure that proper drainage and protection measures are taken.

Supervise site clearing and excavation for foundation works. Check depth and sizes of foundation holes for wooden or trench for wall foundation record area cleared volume of earth excavated.

Check the quality of stone for foundation and hard coring record volumes.

Follow concrete mixing and pouring activities for machine foundation (base), beams, columns and slab works. Record volumes.

Check machine bases are properly aligned and level.

Supervise work on walls,doors and windows and check that doors and windows are exactly sized and located.

Ventilation openings should be of adequate dimensions and wire meshes fixed of proper quality.

Check that the roof work is of good quality with no holes and loose joints, which doesn't allow rainwater in, and which is not likely to be removed by wind force.

**Valves**

Make sure that check valves are installed on the delivery side and foot valves on the suction side of all pumps.

See that gate valves are placed next to check valves on the delivery side.

Besides the tasks listed above the inspector should check and ascertain that the capacities of the pump and power plant are in conformity to that recommended in the design.

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.5 Reservoirs

Standard designs of reservoirs of different capacities and material are employed in rural community water systems. The inspector should supervise every activity and has to check, measure and record dimensions and volume of works as construction progresses. Special attention should be given to the following items:

Elevated Steel Tanks

- Size and depth of trench foundation footing.
- Concrete work for footings.
- Plumbness of tower.
- Welding of tank body, test for water tightness.
- Painting work, number of coats anti rust and metal paints.
- Inlet, outlet, overflow and drainage pipe works, leaking joints.

Masonry and Concrete Reservoirs

- Supervise and check foundation work.
- Check quantity of sand, crushed stone, masonry stone, cement and reinforcement bar etc.
- Follow and check bar cutting, bending, and placing.
- Supervise the operation of concrete of different grades.
- Check construction joints are properly placed.
- Check that concrete parts are cured adequately for the specified period.
- Check pipes are located exactly.
- Test completed reservoir for water tightness.
- Record daily work and volumes of work etc., similar to the Daily Reporting Form No. 006 in Appendix A.

Large capacity reservoirs will have detailed working drawings and detail specifications. The inspector is advised to familiarize himself with those details early before construction commences.

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.6 Conveyance and Distribution Pipeline Works

### Trench Excavation

Trenches are excavated by community labour in almost every rural community where piped water supply is to be constructed. The inspector should get assistance of a CP worker to coordinate and mobilize the community for excavating pipe trenches according to the construction schedule.

Lay out the pipeline route, as per the pipe layout plans. If pegs are not driven already or removed, conduct alignment surveying and put pegs on the center line of trenches.

Check and measure width and depth of trenches at regular intervals, refer to longitudinal profile drawings and see that trench grade is kept accordingly. Locate and record every variation in trench depth on the drawings.

Record length of trench excavated per hour and total labour force deployed on the daily work report.

Follow that the pipe bending is prepared with selected soil and has the required thickness.

Follow pipe laying operation; works on joints. Before backfilling and covering the pipe, see to it that each joint is tested for leakage.

Locate and put on the construction drawings all valves, pipe fittings and any variation from the original design for as-built information.

Supervise connection works to water points and reservoir.

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SR RURAL WATER SUPPLY AND SANITATION PROJECT

CONSTRUCTION INSPECTION DAILY REPORT

Form № 001

TYPE OF WATER SYSTEM : SHALLOW WELL + HAND PUMP

METHOD OF CONSTRUCTION :

BUCKET AUGUR ☐ HAND DUG ☐ OXFAM METHOD ☐

I. DIGGING / AUGURING

1.1 WELL DIAMETER : _____

1.2 START DATE : _____

1.3 DEPTH DUG : _____

1.4 TIME ELAPSED : _____

1.5 FORMATION / SOIL TYPE ENCOUNTERED

FORM _____ m TO _____ m _____

FORM _____ m TO _____ m _____

FORM _____ m TO _____ m _____

1.6 DEPTH OF WATER ENCOUNTER : _____ m

1.7 VOLUME DUG : _____ $m^3$

II. LINING ( CASING )

2.1 LINING MATERIAL : _____

2.2 INTERNAL / EXTERNAL DIAMETER : _____

2.3 NUMBER OF RINGS INSTALLED :

2.3.1 PERFORATED : _____

2.3.2 BLANK : _____

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III. GRAVEL PACK

3.1 GRAVEL TYPE : _____

3.2 GRAVEL SIZE : _____
3.3 VOLUME PACKED : _____

IV. TOP WORK

4.1 MATERIALS USED :

- CEMENT _____ BAGS
- SAND _____ $m^3$
- COARSE AGGREGATE _____ $m^3$
- REINFORCEMENT BAR _____ Kg

4.2 PERCENT COMPLETED _____ %

V. PUMP INSTALLATION

5.1 TYPE OF HAND PUMP ( MAKE ) _____

5.2 COMPLETION DEPTH OF WELL _____

5.3 PUMP POSITION _____

5.4 OTHERS _____
_____
_____

VI. REMARK ( COMMENTS ON THE DAY'S WORK PROGRESS; PROBLEMS ENCOUNTERED AND SOLUTION TAKEN ETC. )

_____
_____
_____

VII. MAN POWER AND EQUIPMENT DEPLOYED

_____
_____
_____

INSPECTOR'S NAME _____

SIGNATURE _____ DATE _____

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SR RURAL WATER SUPPLY AND SANITATION PROJECT

CONSTRUCTION INSPECTION DAILY REPORT

Form № 002

TYPE OF WATER SYSTEM : BOREHOLE DRILLING

METHOD OF CONSTRUCTION ( EQUIPMENT USED ) :

CABLE TOOLS ☐ ROTARY ☐

I. DRILLING

1.1 STARTING BIT SIZE : _____

1.2 START DATE : _____

1.3 DEPTH DRILLED : _____

1.4 TIME ELAPSED : _____

1.5 FORMATION / SOIL TYPE ENCOUNTERED

FORM _____ m TO _____ m _____

FORM _____ m TO _____ m _____

FORM _____ m TO _____ m _____

1.6 DEPTH OF WATER ENCOUNTER : _____ m

II. CASING

2.1 SURFACE CASING :
- DIAMETER _____ LENGTH _____
- TEMPORARY _____
- PERMEANT _____

2.2 SCREEN CASING :
- MATERIAL TYPE _____
- DIAMETER _____
- LENGTH _____

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2.3 BLANK CASING :
- MATERIAL TYPE _____
- DIAMETER _____
- LENGTH _____

III. GRAVEL PACK

3.1 GRAVEL TYPE : _____

3.2 GRAVEL SIZE : _____

3.3 VOLUME PACKED : _____

IV. TOP WORK

4.1 MATERIALS USED :
- CEMENT _____ BAGS
- SAND _____ $m^3$
- COARSE AGGREGATE _____ $m^3$
- REINFORCEMENT BAR _____ Kg

4.2 PERCENT COMPLETED _____ %

VI. REMARK ( COMMENTS ON THE DAY'S WORK PROGRESS; PROBLEMS ENCOUNTERED AND SOLUTION TAKEN ETC. )

_____
_____
_____

VII. MAN POWER AND EQUIPMENT DEPLOYED

_____
_____
_____

INSPECTOR'S NAME _____

SIGNATURE _____ DATE _____

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SR RURAL WATER SUPPLY AND SANITATION PROJECT

CONSTRUCTION INSPECTION DAILY REPORT

Form № 003

TYPE OF WORK : PIPE LAYING

I. TRENCH EXCAVATION

1.1 PIPE LINE LENGTH :
- WIDTH _____ m DEPTH _____ m
- LENGTH _____
- VOLUME _____

1.2 PIPE LAID :
- DIAMETER _____ mm LENGTH _____ m
- DIAMETER _____ mm LENGTH _____ m
- DIAMETER _____ mm LENGTH _____ m

1.3 BACKFILL AND TEST :
- SELECTED SOIL _____
- VOLUME _____

1.4 STATE METHOD USED FOR TESTING LEAKAGE AND TEST RESULTS

_____

_____

_____

1.5 TYPE, SIZE AND LOCATIONS OF VALVES AND PIPE FITTINGS INSTALLED.

_____

_____

_____

II. REMARK ( COMMENTS ON THE DAY'S WORK PROGRESS; PROBLEMS ENCOUNTERED AND SOLUTION TAKEN ETC. )

_____

_____

_____

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III. MAN POWER AND EQUIPMENT DEPLOYED

_____

_____

_____

INSPECTOR'S NAME _____

SIGNATURE _____ DATE _____

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SR RURAL WATER SUPPLY AND SANITATION PROJECT

CONSTRUCTION INSPECTION DAILY REPORT

Form № 004

I. TYPE OF WORK : SPRING CAPPING

II. SITE CLEARANCE & EXCAVATION :

2.1 START DATE / TIME :_____

2.2 TOTAL AREA CLEARED :_____$m^2$

2.3 EXCAVATION FOR FOUNDATION :_____$m^3$

2.4 EXCAVATION FOR DRAINAGE : _____$m^3$

III. MASONRY WORK

TYPE OF MATERIAL : _____

_____

STONE :_____$m^3$

CEMENT :_____BAGS

SAND :_____$m^3$

IV. CONCRETE WORK : AGGREGATES SIZES :_____mm_____$m^3$

_____mm_____$m^3$

_____mm_____$m^3$

CEMENT _____ BAGS

REINFORCING STEEL : DIAMETER _____QUANTITY_____Kg

_____ " _____Kg

_____ " _____Kg

V. PIPE WORK : ( INCLUDING VALVES & FITTINGS )_____

VI. MAN POWER & EQUIPMENT DEPLOYED_____

_____

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VII. REMARK : _____

( STATE ANY VARIATION ) _____

_____

INSPECTOR'S NAME_____ DATE :_____

SIGNATURE_____

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SR RURAL WATER SUPPLY AND SANITATION PROJECT

CONSTRUCTION INSPECTION DAILY REPORT

Form № 005

TYPE OF WORK : PUMP STATION

TYPE OF CONSTRUCTION

STANDARD PUMP HOUSE ☐ GENERATOR HOUSE ☐ OTHER TYPE ☐

I. MATERIALS USED :

- CEMENT _____ BAGS
- SAND _____ $m^3$
- STONE _____ $m^3$
- GI SHEET _____ $m^3$
- COURSE AGGREGATE _____ $m^3$
- REINFORCEMENT BAR _____ Kg

II. PUMP INSTALLATION :

2.1 TYPE ( MAKE ) OF PUMP _____

_____

2.2 POWER SOURCE : DIESEL GENERATOR ☐ EELPA ☐

KVA / KW _____

PHASE _____

FREQUENCY _____

VOLTAGE _____

DIESLE ENGINE : HP / KW _____

TYPE _____

2.3 WORK DONE : _____

_____

_____

2.4 PERCENT COMPLETED : _____ %

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2.5 PUMP POSITION _____ M FROM TOP

2.6 STATE ANY VARIATIONS :

_____

_____

III. REMARK ( COMMENTS ON THE DAY'S WORK PROGRESS; PROBLEMS ENCOUNTERED AND SOLUTION TAKEN ETC. )

_____ *p1746X

_____

_____

IV. MAN POWER AND EQUIPMENT DEPLOYED

_____

_____

_____

INSPECTOR'S NAME _____

SIGNATURE _____ DATE _____

CCRDA

SR RURAL WATER SUPPLY AND SANITATION PROJECT

CONSTRUCTION INSPECTION DAILY REPORT

Form № 006

TYPE OF WORK : RESERVIOR

CAPACITY : _____ $m^3$

MATERIAL TYPE USED :

STEEL ☒ STONE / BRICK MASONRY ☐ CONCRETE ☐

I. SITE CLEARANCE AND EXCAVATION

- AREA CLEARED _____ $m^2$
- FOUNDATION _____ $m^3$

II. ELEVATING STRUCTURE :

- STEEL TOWER ☐ CONCRETE ☐ MASONRY WALL ☐
- STEEL PIPE FOR TOWER : DIAMETER _____ mm LENGTH _____ m
- MATERIALS USED :
  - CEMENT _____ BAGS
  - SAND _____ $m^3$
  - STONE _____ $m^3$
  - COARSE AGGREGATE _____ $m^3$
  - REINFORCEMENT BAR _____ Kg

III. MASONRY WORK TYPE, SIZE & VOLUME OF MATERIAL

- CEMENT _____ BAGS
- SAND _____ $m^3$
- STONE _____ $m^3$
- COARSE AGGREGATE _____ $m^3$
- REINFORCEMENT BAR : $\phi$ _____ mm _____ Kg

  $\phi$ _____ mm _____ Kg

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$\phi$ _____ mm _____ Kg

IV. CONCRETE WORK TYPE, SIZE & VOLUME OF MATERIAL

- CEMENT _____ BAGS
- SAND _____ $m^3$
- STONE _____ $m^3$
- COARSE AGGREGATE _____ $m^3$
- REINFORCEMENT BAR : $\phi$ _____ mm _____ Kg

  $\phi$ _____ mm _____ Kg

  $\phi$ _____ mm _____ Kg

V. REMARK ( COMMENTS ON THE DAY'S WORK PROGRESS; PROBLEMS ENCOUNTERED AND SOLUTION TAKEN ETC. )

_____

_____

_____

VI. MAN POWER AND EQUIPMENT DEPLOYED

_____

_____

_____

INSPECTOR'S NAME _____

SIGNATURE _____ DATE _____

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SR RURAL WATER SUPPLY AND SANITATION PROJECT

CONSTRUCTION INSPECTION DAILY REPORT

Form № 00

TYPE OF WORK : WATER POINT

NUMBER OF WATER POINTS : _____

STANDARD TYPE :

FOUR FAUCET ☐ SIX FAUCET ☐ OTHER (

I. SITE CLEARANCE AND EXCAVATION
- AREA CLEARED _____ m
- FOUNDATION _____ m

II. MATERIALS USED :
- CEMENT _____ BAGS
- SAND _____ $m^3$
- STONE _____ $m^3$
- COARSE AGGREGATE _____ $m^3$
- REINFORCEMENT BAR _____ Kg

III. REMARK ( COMMENTS ON THE DAY'S WORK PROGRESS; PROBLEM ENCOUNTERED AND SOLUTION TAKEN ETC. )

_____

_____

_____

III. MAN POWER AND EQUIPMENT DEPLOYED

_____

_____

_____

INSPECTOR'S NAME _____

SIGNATURE _____ DATE _____

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# TENDERING AND EVALUATION

## OUTLINE

1. **Invitation for Bids**
2. **Issue of Bidding Documents**

    **2.1** Contents of Bidding Documents
    **2.2** Clarification of Bidding Documents
    **2.3** Amendment of Bidding Documents

3. **Submission of Bids**

    **3.1** Sealing and Marking of Bids
    **3.2** Deadline for submission of Bids
    **3.3** Late Bids
    **3.4** Modification and Withdrawal of Bids

4. **Bid Opening**
5. **Bid Evaluation**

    **5.1** Process to be Confidential
    **5.2** Clarification of Bids
    **5.3** Responsiveness of Bids
    **5.4** Correction of Errors
    **5.5** Currency for Bid Evaluation (for Supply Contracts)
    **5.6** Evaluation and Comparison of Bids

6. **Award of Contract**

    **6.1** Award Criteria
    **6.2** Notification of Award
    **6.3** Signing of Contract
    **6.4** Performance Security/Bond
    **6.5** Advance Payment and Security

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# Section 1. Instructions to Bidders

## A. General

1. Scope of Bid

**1.1** The Employer[7] as defined in the Contract Data, invites bids for the construction of Works, as described in the Contract Data. The name and identification number of the Contract is provided in the Contract Data.

[7] See also definitions of capitalized terms in Section 3, Conditions of Contract ("the Contract").

**1.2** The successful Bidder will be expected to complete the Works by the Intended Completion Date specified in the Contract Data.

2. Source of Funds

**2.1** The Borrower, as defined in the Bidding Data, intends to apply part of the funds of a loan from the World Bank, as defined in the Bidding Data, towards the cost of the Project, as defined in the Bidding Data, to cover eligible payments under the Contract for the Works. Payments by the World Bank will be made only at the request of the Borrower and upon approval by the World Bank in accordance with the Loan Agreement, and will be subject in all respects to the terms and conditions of that Agreement. Except as the World Bank may specifically otherwise agree, no party other than the Borrower shall derive any rights from the Loan Agreement or have any rights to the loan proceeds.

3. Eligible Bidders

**3.1** This Invitation for Bids is open to all bidders from eligible countries as defined in the *Procurement Guidelines*. Any materials, equipment, and services to be used in the performance of the Contract shall have their origin in eligible source countries.

**3.2** All bidders shall provide in Section 2, Forms of Bid and Qualification Information, a statement that the Bidder (including all members of a joint venture and subcontractors) is not associated, nor has been associated in the past, directly or indirectly, with the consultant or any other entity that has prepared the design, specifications, and other documents for the Project or being proposed as Project Manager for the Contract. A firm that has been engaged by the Borrower to provide consulting services for the preparation or supervision of the Works, and any of its affiliates, shall not be eligible to bid.

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3.3 Majority publicly-owned enterprises from the Borrower country may be eligible to qualify if, in addition to meeting all the above requirements, they are also:

(a) commercially-oriented legal entities distinct from the Employer, and are not a government department;

(b) financially autonomous, as demonstrated by requirements in their statutes or by-laws to provide separate audited accounts and return on capital, powers to raise loans and obtain revenues through the sale of goods or services; and

(c) managerially autonomous.

**4. Qualification of the Bidder**

4.1 All bidders shall provide in Section 2, Forms of Bid and Qualification Information, a preliminary description of the proposed work method and schedule, including drawings and charts, as necessary.

4.2 In the event that prequalification of potential bidders has been undertaken, only bids from prequalified bidders will be considered for award of Contract. These qualified bidders should submit with their bids any information updating their original prequalification applications or, alternatively, confirm in their bids that the originally-submitted prequalification information remains essentially correct as of the date of bid submission. The update or confirmation should be provided in Section 2.

4.3 If the Employer has not undertaken prequalification of potential bidders, all bidders shall include the following information and documents with their bids in Section 2, unless otherwise stated in the Bidding Data:

(a) copies of original documents defining the constitution or legal status, place of registration, and principal place of business; written power of attorney of the signatory of the Bid to commit the Bidder;

(b) total monetary value of construction work performed for each of the last five years;

(c) experience in works of a similar nature and size for each of the last five years, and details of work under way or contractually committed; and clients who may be contacted for further

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(d) major items of construction equipment proposed to carry out the Contract;

(e) qualifications and experience of key site management and technical personnel proposed for the Contract;

(f) reports on the financial standing of the Bidder, such as profit and loss statements and auditor's reports for the past five years;

(g) evidence of adequacy of working capital for this Contract (access to line(s) of credit and availability of other financial resources);

(h) authority to seek references from the Bidder's bankers;

(i) information regarding any litigation, current or during the last five years, in which the Bidder is involved, the parties concerned, and disputed amount; and

(j) proposals for subcontracting components of the Works amounting to more than 10 percent of the Contract Price.

4.4 Bids submitted by a joint venture of two or more firms as partners shall comply with the following requirements, unless otherwise stated in the Bidding Data:

(a) the Bid shall include all the information listed in Sub-Clause 4.3 above for each joint venture partner;

(b) the Bid shall be signed so as to be legally binding on all partners;

(c) all partners shall be jointly and severally liable for the execution of the Contract in accordance with the Contract terms;

(d) one of the partners will be nominated as being in charge, authorized to incur liabilities, and receive instructions for and on behalf of any and all partners of the joint venture; and

(e) the execution of the entire Contract, including payment, shall be done exclusively with the partner in charge.

4.5 To qualify for award of the Contract, bidders shall meet the following minimum qualifying criteria:

(a) annual volume of construction work of at

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(b) experience as prime contractor in the construction of at least two works of a nature and complexity equivalent to the Works over the last 10 years (to comply with this requirement, works cited should be at least 70 percent complete);

(c) proposals for the timely acquisition (own, lease, hire, etc.) of the essential equipment listed in the Bidding Data;

(d) a Contract Manager with five years' experience in works of an equivalent nature and volume, including no less than three years as Manager; and

(e) liquid assets and/or credit facilities, net of other contractual commitments and exclusive of any advance payments which may be made under the Contract, of no less than the amount specified in the Bidding Data[9].

A consistent history of ligitigation or arbitration awards against the Applicant or any partner of a Joint Venture may result in disqualification.

[8] This amount is usually not less than 2.5 times the estimated annual cash flow for the Contract.

[9] Usually the equivalent of the estimated payments flow over 4-6 months at the average (straight line distribution) construction rate. The actual period of reference will depend on the speed with which the Employer will pay the Contractor's monthly certificates.

**4.6** The figures for each of the partners of a joint venture shall be added together to determine the Bidder's compliance with the minimum qualifying criteria of Sub-Clause 4.5(a) and (e); however, for a joint venture to qualify, each of its partners must meet at least 25 percent of minimum criteria 4.5(a), (b), and (e) for an individual Bidder, and the partner in charge at least 40 percent of those minimum criteria. Failure to comply with this requirement will result in rejection of the joint venture's Bid. Subcontractors' experience and resources will not be taken into account in determining the Bidder's compliance with the qualifying criteria, unless otherwise stated in the Bidding Data.

**4.7** Domestic bidders and joint ventures of domestic and foreign bidders applying for eligibility for a 7½-percent margin of preference in bid evaluation shall supply all information to satisfy the criteria for eligibility as described in Clause 30 of these Instructions to Bidders.[10]

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[10] Delete Sub-Clause 4.7 where not applicable (see Clause 30).

5. One Bid per Bidder

**5.1** Each Bidder shall submit only one Bid, either individually or as a partner in a joint venture. A Bidder who submits or participates in more than one Bid (other than as a subcontractor or in cases of alternatives that have been permitted or requested) will cause all the proposals with the Bidder's participation to be disqualified.

6. Cost of Bidding

**6.1** The Bidder shall bear all costs associated with the preparation and submission of his Bid, and the Employer will in no case be responsible or liable for those costs.

7. Site Visit

**7.1** The Bidder, at the Bidder's own responsibility and risk, is encouraged to visit and examine the Site of Works and its surroundings and obtain all information that may be necessary for preparing the Bid and entering into a contract for construction of the Works. The costs of visiting the Site shall be at the Bidder's own expense.

## B. Bidding Documents

8. Content of Bidding Documents

**8.1** The set of bidding documents comprises the documents listed in the table below and addenda issued in accordance with Clause 10:

| | | |
|---|---|---|
| Section | 1 | Instructions to Bidders |
| | 2 | Forms of Bid and Qualification Information |
| | 3 | Conditions of Contract |
| | 4 | Contract Data |
| | 5 | Specifications |
| | 6 | Drawings |
| | 7 | Bill of Quantities[11] |
| | 8 | Forms of Securities |

[11] In lump sum contracts, delete "Bill of Quantities" and replace with "Activity Schedule".

**8.2** Three copies of Sections 2, 4, and 7 are supplied to the prospective Bidder. The number of copies to be completed and returned with the Bid is specified in the Bidding Data.

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**9. Clarification of Bidding Documents**

9.1 A prospective Bidder requiring any clarification of the bidding documents may notify the Employer in writing or by cable ("cable" includes telex and façsimile) at the Employer's address indicated in the invitation to bid. The Employer will respond to any request for clarification received earlier than 28[12] days prior to the deadline for submission of bids. Copies of the Employer's response will be forwarded to all purchasers of the bidding documents, including a description of the inquiry, but without identifying its source.

[12] It may be necessary to extend the deadline for submission of bids if the Employer's response results in substantial changes to the Bidding Documents. See Clause 10 below.

**10. Amendment of Bidding Documents**

10.1 Before the deadline for submission of bids, the Employer may modify the bidding documents by issuing addenda.

10.2 Any addendum thus issued shall be part of the bidding documents and shall be communicated in writing or by cable to all purchasers of the bidding documents.[13] Prospective bidders shall acknowledge receipt of each addendum by cable to the Employer.

[13] It is therefore important that the Employer maintain a complete and accurate list of recipients of the bidding documents and their addresses.

10.3 To give prospective bidders reasonable time in which to take an addendum into account in preparing their bids, the Employer shall extend, as necessary, the deadline for submission of bids, in accordance with Sub-Clause 20.2 below.

## C. Preparation of Bids

**11. Language of Bid**

11.1 All documents relating to the Bid shall be in the language specified in the Contract Data.[14]

[14] Only English, French, or Spanish should be used in International Competitive Bidding.

**12. Documents Compris-**

12.1 The Bid submitted by the Bidder shall comprise the following:

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(b) Bid Security;

(c) priced Bill of Quantities[15];

(d) Qualification Information Form and Documents;

(e) Alternative offers where invited;

and any other materials required to be completed and submitted by bidders, as specified in the Bidding Data.

**13. Bid Prices**

**13.1** The Contract shall be for the whole Works, as described in Sub-Clause 1.1, based on the priced Bill of Quantities[15] submitted by the Bidder.

[15] In lump sum contracts, delete "priced Bill of Quantities" and replace with "priced Activity Schedule".

**13.2** The Bidder shall fill in rates and prices for all items of the Works described in the Bill of Quantities.[16] Items for which no rate or price is entered by the Bidder will not be paid for by the Employer when executed and shall be deemed covered by the other rates and prices in the Bill of Quantities.

[16] In lump sum contracts, delete "described in the Bill of Quantities" and replace with "described in the drawings and specifications and listed in the Activity Schedule".

**13.3** All duties, taxes, and other levies payable by the Contractor under the Contract, or for any other cause, as of the date 28 days prior to the deadline for submission of bids, shall be included in the rates, prices, and total Bid price submitted by the Bidder.[17]

[17] In lump sum contracts, delete "rates, prices, and".

**13.4** The rates and prices[18] quoted by the Bidder shall be subject to adjustment during the performance of the Contract if provided for in the Bidding and Contract Data and the provisions of Clause 47 of the Conditions of Contract. The Bidder shall submit with the Bid all the information required under the Contract Data and Clause 47 of the Conditions of Contract.

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[18] In lump sum contracts, delete "rates and prices" and replace with "lump sum price".

**14. Currencies of Bid and Payment**

**14.1** The unit rates and prices[19] shall be quoted by the Bidder entirely in the currency of the Employer's country specified in the Contract Data. Foreign currency requirements shall be indicated as a percentage of the Bid price (excluding provisional sums[20]) and shall be payable at the option of the Bidder in (a) the currency of the Bidder's home country, **or** (b) in the international trading currency[21] specified in the Bidding Data, always provided that a Bidder expecting expenditures in currency(ies) other than those stated in (a) or (b) above for portions of the foreign currency requirements, and wishing to be paid accordingly, shall indicate the relevant currencies and percentages in the Bid.

[19] In lump sum contracts, delete "unit rates and prices" and replace with "lump sum price".

[20] Provisional sums are monetary sums specified by the Employer in the Bill of Quantities, to be used at his discretion for nominated subcontractors and other specified purposes.

[21] The Employer should select and specify a currency widely used in international trade, such as the U.S. dollar or pound sterling. At the Employer's option, in addition, the European Currency Unit (ECU) can also be permitted for use in place of the specified international currency.

**14.2** The rates of exchange to be used by the Bidder in arriving at the local currency equivalent and the percentage(s) mentioned in para. 14.1 above shall be the selling rates for similar transactions established by the authority specified in the Contract Data prevailing on the date 28 days prior to the latest deadline for submission of bids. These exchange rates shall apply for all payments so that no exchange risk will be borne by the Bidder. If the Bidder uses other rates of exchange, the provisions of Clause 28.1 shall apply. In any case, payments will be computed using the rates quoted in the Bid.

**14.3** Bidders shall indicate details of their expected foreign currency requirements in the Bid.

**14.4** Bidders may be required by the Employer to clarify their foreign currency requirements and to substantiate that the amounts included in the rates and prices[22] and in the Contract Data are reasonable and

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[22] For lump sum contracts, delete "rates and prices" and replace with "Lump Sum".

**15. Bid Validity**

**15.1** Bids shall remain valid for the period[23] specified in the Bidding Data.

[23] The period is a realistic time, usually not less than 35 days nor more than 105, allowing for bid evaluation, clarifications, and the World Bank's "no objection" (where awards of Contract are subject to prior review). The time should be the same as that specified in the Invitation for Bids.

**15.2** In exceptional circumstances, the Employer may request that the bidders extend the period of validity for a specified additional period. The request and the bidders' responses shall be made in writing or by cable. A Bidder may refuse the request without forfeiting the Bid Security. A Bidder agreeing to the request will not be required or permitted to otherwise modify the Bid, but will be required to extend the validity of Bid Security for the period of the extension, and in compliance with Clause 16 in all respects.

**15.3** If the period of Bid validity is so extended, and if the Contract Price is fixed (not subject to price adjustment), the total Bid price of the Bidder selected for award shall be increased up to the date of signing the Contract by applying to both the local and the foreign currency component of the price for each day that has elapsed from the expiration of the initial Bid validity to the date of notification of award to the successful Bidder the respective factors[24] specified in the Bidding Data. Bid evaluation will be based on the Bid prices without taking into consideration the above correction.

[24] The value of the foreign currency factor should be based on, or comparable to, the expected annual increases in international prices. The value of the local currency factor should be based on the projected inflation in the Employer's country for the period in question.

**16. Bid Security**

**16.1** The Bidder shall furnish, as part of the Bid, a Bid Security in a freely convertible currency, in the amount specified in the Bidding Data.[25]

[25] The same as quoted in the Invitation for Bids (IFB). It should not exceed 3 percent of the estimated value of the Works. For reasons of confidentiality, a fixed sum should be specified, in preference to a percentage of the Bid price.

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16.2 The Bid Security shall, at the Bidder's option, be in the form of a certified check, bank draft, standby letter of credit, guarantee, or bond from a bank or surety located in the country of the Employer or directly from a foreign bank or surety which has been determined by the Bidder to be acceptable to the Employer. The format of the Bid Security should be in accordance with the form of Bid Security included in Section 8 or another form acceptable to the Employer. Bid Security shall be valid for 28 days beyond the validity of the Bid.

16.3 Any Bid not accompanied by an acceptable Bid Security shall be rejected by the Employer.

16.4 The Bid Security of unsuccessful bidders will be returned within 28 days of the end of the Bid validity period specified in Sub-Clause 15.1.

16.5 The Bid Security of the successful Bidder will be discharged when the Bidder has signed the Agreement and furnished the required Performance Security.

16.6 The Bid Security may be forfeited

(a) if the Bidder withdraws the Bid after Bid opening during the period of Bid validity;

(b) if the Bidder does not accept the correction of the Bid price, pursuant to Clause 27; or

(c) in the case of a successful Bidder, if the Bidder fails within the specified time limit to

(i) sign the Agreement; or

(ii) furnish the required Performance Security.

**17. Alternative Proposals by Bidders**

17.1 Bidders shall submit offers that comply with the requirements of the bidding documents, including the basic technical design as indicated in the drawings and specifications. Alternatives will not be considered, unless specifically allowed in the Bidding Data. If so allowed, Sub-Clause 17.2 shall govern.

17.2 If so allowed in the Bidding Data, bidders wishing to offer technical alternatives to the requirements of the bidding documents must also submit a Bid that complies with the requirements of the bidding

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drawings and specifications. In addition to submitting the basic Bid, the Bidder shall provide all information necessary for a complete evaluation of the alternative by the Employer, including design calculations, technical specifications, breakdown of prices, proposed construction methods and other relevant details. Only the technical alternatives, if any, of the lowest evaluated Bidder conforming to the basic technical requirements shall be considered by the Employer.

18. Format and Signing of Bid

18.1 The Bidder shall prepare one original of the documents comprising the Bid as described in Clause 12 of these Instructions to Bidders, bound with the volume containing the Form of Bid, and clearly marked "**ORIGINAL**". In addition, the Bidder shall submit copies of the Bid, in the number specified in the Bidding Data, and clearly marked as "**COPIES**". In the event of discrepancy between them, the original shall prevail.

18.2 The original and all copies of the Bid shall be typed or written in indelible ink and shall be signed by a person or persons duly authorized to sign on behalf of the Bidder, pursuant to Sub-Clauses 4.3(a) or 4.4(b), as the case may be. All pages of the Bid where entries or amendments have been made shall be initialled by the person or persons signing the Bid.

18.3 The Bid shall contain no alterations or additions, except those to comply with instructions issued by the Employer, or as necessary to correct errors made by the Bidder, in which case such corrections shall be initialled by the person or persons signing the Bid.

## D. Submission of Bids

19. Sealing and Marking of Bids

19.1 The Bidder shall seal the original and all copies of the Bid in two inner envelopes and one outer envelope, duly marking the inner envelopes as "**ORIGINAL**" and "**COPIES**".

19.2 The inner and outer envelopes shall

(a) be addressed to the Employer at the address[26] provided in the Bidding Data;

(b) bear the name and identification number of the Contract as defined in the Bidding and Contract Data; and

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(c) provide a warning not to open before the specified time and date for Bid opening as defined in the Bidding Data.

[26] The receiving address should be an office that is staffed during normal working hours by personnel authorized to certify time and date of receipt and assure safe-keeping until Bid opening. A post office address is not satisfactory. The address must be the same as the receiving address described in the Invitation for Bids.

19.3 In addition to the identification required in Sub-Clause 19.2, the inner envelopes shall indicate the name and address of the Bidder to enable the Bid to be returned unopened in case it is declared late, pursuant to Clause 21.

19.4 If the outer envelope is not sealed and marked as above, the Employer will assume no responsibility for the misplacement or premature opening of the Bid.

**20. Deadline for Submission of Bids**

20.1 Bids shall be delivered to the Employer at the address specified above no later than the time and date specified in the Bidding Data.

20.2 The Employer may extend the deadline for submission of bids by issuing an amendment in accordance with Clause 10, in which case all rights and obligations of the Employer and the bidders previously subject to the original deadline will then be subject to the new deadline.

**21. Late Bids**

21.1 Any Bid received by the Employer after the deadline prescribed in Clause 20 will be returned unopened to the Bidder.

**22. Modification and Withdrawal of Bids**

22.1 Bidders may modify or withdraw their bids by giving notice in writing before the deadline prescribed in Clause 20.

22.2 Each Bidder's modification or withdrawal notice shall be prepared, sealed, marked, and delivered in accordance with Clauses 18 and 19, with the outer and inner envelopes additionally marked "**MODIFICATION**" or "**WITHDRAWAL**", as appropriate.

22.3 No Bid may be modified after the deadline for submission of Bids.

22.4 Withdrawal of a Bid between the deadline for submission of bids and the expiration of the period of Bid validity specified in the Bidding Data or as extended pursuant to Sub-Clause 15.2 may result in the

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22.5 Bidders may only offer discounts to, or otherwise modify the prices of their bids by submitting Bid modifications in accordance with this clause, or included in the original Bid submission.

## E. Bid Opening and Evaluation

**23. Bid Opening**

23.1 The Employer will open the bids, including modifications made pursuant to Clause 22, in the presence of the bidders' representatives who choose to attend at the time and in the place specified in the Bidding Data.

23.2 Envelopes marked "**WITHDRAWAL**" shall be opened and read out first. Bids for which an acceptable notice of withdrawal has been submitted pursuant to Clause 22 shall not be opened.

23.3 The bidders' names, the Bid prices, the total amount of each Bid and of any alternative Bid (if alternatives have been requested or permitted), any discounts, Bid modifications and withdrawals, the presence or absence of Bid Security, and such other details as the Employer may consider appropriate, will be announced by the Employer at the opening.

23.4 The Employer will prepare minutes of the Bid opening, including the information disclosed to those present in accordance with Sub-Clause 23.3.[27]

[27] A copy of the minutes should be sent by the Employer to the World Bank together with the Bid evaluation report.

**24. Process to Be Confidential**

24.1 Information relating to the examination, clarification, evaluation, and comparison of bids and recommendations for the award of a contract shall not be disclosed to bidders or any other persons not officially concerned with such process until the award to the successful Bidder has been announced. Any effort by a Bidder to influence the Employer's processing of bids or award decisions may result in the rejection of his Bid.

**25. Clarification of Bids**

25.1 To assist in the examination, evaluation, and comparison of bids, the Employer may, at the Employer's discretion, ask any Bidder for clarification of the Bidder's Bid, including breakdowns of unit rates.[28] The request for clarification and the response shall be in writing or by

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Bid shall be sought, offered, or permitted except as required to confirm the correction of arithmetic errors discovered by the Employer in the evaluation of the bids in accordance with Clause 27.

[28] In lump sum contracts, delete "unit rates" and replace with "the prices in the Activity Schedule".

**26. Examination of Bids and Determination of Responsiveness**

**26.1** Prior to the detailed evaluation of bids, the Employer will determine whether each Bid (a) meets the eligibility criteria defined in Clause 3; (b) has been properly signed; (c) is accompanied by the required securities; and (d) is substantially responsive to the requirements of the bidding documents.

**26.2** A substantially responsive Bid is one which conforms to all the terms, conditions, and specifications of the bidding documents, without material deviation or reservation. A material deviation or reservation is one (a) which affects in any substantial way the scope, quality, or performance of the Works; (b) which limits in any substantial way, inconsistent with the bidding documents, the Employer's rights or the Bidder's obligations under the Contract; or (c) whose rectification would affect unfairly the competitive position of other bidders presenting substantially responsive bids.

**26.3** If a Bid is not substantially responsive, it will be rejected by the Employer, and may not subsequently be made responsive by correction or withdrawal of the nonconforming deviation or reservation.

**27. Correction of Errors**

**27.1** Bids determined to be substantially responsive will be checked by the Employer for any arithmetic errors. Errors will be corrected by the Employer as follows:[29]

(a) where there is a discrepancy between the amounts in figures and in words, the amount in words will govern; and

(b) where there is a discrepancy between the unit rate and the line item total resulting from multiplying the unit rate by the quantity, the unit rate as quoted will govern, unless in the opinion of the Employer there is an obviously gross misplacement of the decimal point in the unit rate, in which case the line item total as quoted will govern, and the unit rate will be corrected.

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[29] In lump sum contracts, delete from "as follows" to the end, and replace with the following: "as follows: where there is a discrepancy between the amounts in figures and in words, the amount in words will govern."

27.2 The amount stated in the Bid will be adjusted by the Employer in accordance with the above procedure for the correction of errors and, with the concurrence of the Bidder, shall be considered as binding upon the Bidder. If the Bidder does not accept the corrected amount, the Bid will be rejected, and the Bid Security may be forfeited in accordance with Sub-Clause 16.6(b).

**28. Currency for Bid Evaluation**

28.1 Bids will be evaluated as quoted in the currency of the Employer's country as defined in the Contract Data in accordance with Sub-Clause 14.1, unless a Bidder has used different exchange rates than those prescribed in Sub-Clause 14.2, in which case the Bid will be first converted into the amounts payable in different currencies using the rates quoted in the Bid and then reconverted to the Employer's currency using the exchange rates prescribed in Sub-Clause 14.2.

**29. Evaluation and Comparison of Bids**

29.1 The Employer will evaluate and compare only the bids determined to be substantially responsive in accordance with Clause 26.

29.2 In evaluating the bids, the Employer will determine for each Bid the evaluated Bid price by adjusting the Bid price as follows:

(a) making any correction for errors pursuant to Clause 27;

(b) excluding provisional sums and the provision, if any, for contingencies in the Bill of Quantities[30], but including Daywork[31], where priced competitively;

(c) making an appropriate adjustment for any other acceptable variations, deviations, or alternative offers submitted in accordance with Clause 17; and

(d) making appropriate adjustments to reflect discounts or other price modifications offered in accordance with Sub-Clause 22.5.

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[30] In lump sum contracts, delete "Bill of Quantities" and replace with "Activity Schedule".

[31] **Daywork** is work carried out following instructions of the Project Manager and paid for on the basis of time spent by workers, and the use of materials and the Contractor's equipment, at the rates quoted in the Bid. For Daywork to be priced competitively for Bid evaluation purposes, the Employer must list tentative quantities for individual items to be costed against Daywork (e.g., a specific number of tractor driver staff-days, or a specific tonnage of Portland cement), to be multiplied by the bidders' quoted rates and included in the total Bid price.

**29.3** The Employer reserves the right to accept or reject any variation, deviation, or alternative offer. Variations, deviations, and alternative offers and other factors which are in excess of the requirements of the bidding documents or otherwise result in unsolicited benefits for the Employer will not be taken into account in Bid evaluation.

**29.4** The estimated effect of any price adjustment conditions under Clause 47 of the Conditions of Contract, during the period of implementation of the Contract, will not be taken into account in Bid evaluation.

**29.5**[32]

[32] If the Bidding Documents include two or more lots, add Clause 29.5:

"In the case of several lots, pursuant to Clause 29.2(d), the Employer will determine the application of discounts so as to minimize the combined cost of all the lots."

## 30. Preference for Domestic Bidders

**30.1** If so indicated in the Bidding Data, domestic contractors may receive a margin of preference in Bid evaluation, for which this clause shall apply.[33]

[33] This Clause may be used only where the domestic preference is expressly permitted by the Loan Agreement. In all other cases, the whole of Clause 30 and Sub-Clause 4.7 may be omitted, as well as reference to domestic preference in the Bidding Data, the Invitation for Bids, and Qualification Information; in such cases, indicate "Clause 30 not applicable" in the Bidding Data.

**30.2** Domestic bidders shall provide all evidence necessary to prove that they meet the following criteria to be eligible for a 7½-percent margin

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(a) be registered within the country of the Employer;

(b) have majority ownership by nationals of the country of the Employer;

(c) not subcontract more than 50 percent of the Works measured in terms of value to foreign contractors; and

(d) satisfy any other criteria specified for the purpose of domestic preference eligibility, as specified in the Bidding Data.[34]

[34] The Borrower and the Employer may add other criteria for domestic preference eligibility acceptable to the World Bank.

**30.3** Joint ventures between domestic and foreign firms may be eligible for the margin of preference provided the domestic partner or partners

(a) individually satisfy the above criteria of eligibility for the preference;

(b) demonstrate a beneficiary interest of no less than 50 percent in the joint venture, as demonstrated by the profit and loss sharing provisions of the joint venture agreement;

(c) will, under the arrangements proposed, carry out at least 50 percent of the Works measured in terms of value (always provided that the domestic partner or partners are qualified to carry out that amount of work, in accordance with the criteria of Sub-Clause 4.3); and

(d) satisfy any other criteria specified for the purpose of domestic preference eligibility, as specified in the Bidding Data.[34]

**30.4** The following procedure will be used to apply the margin of preference:

(a) Responsive bids will be classified into the following groups:

(i) Group A: bids offered by domestic bidders and joint ventures meeting the respective criteria of Sub-Clauses 30.2 and 30.3 above; and

(ii) Group B: all other bids.

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(b) For the purpose of further evaluation and comparison of bids only, an amount equal to 7½ percent of the evaluated Bid prices determined in accordance with Clause 29.2(a), (b), and (d), will be added to all bids classified in Group B.

## F. Award of Contract

**31. Award Criteria**

**31.1** Subject to Clause 32, the Employer will award the Contract to the Bidder whose Bid has been determined to be substantially responsive to the bidding documents and who has offered the lowest evaluated Bid price, provided that such Bidder has been determined to be (a) eligible in accordance with the provisions of Clause 3, and (b) qualified in accordance with the provisions of Clause 4.

**32. Employer's Right to Accept any Bid and to Reject any or all Bids**

**32.1** Notwithstanding Clause 31, the Employer reserves the right to accept or reject any Bid, and to cancel the bidding process and reject all bids, at any time prior to the award of Contract, without thereby incurring any liability to the affected Bidder or bidders or any obligation to inform the affected Bidder or bidders of the grounds for the Employer's action.[35]

[35] Employers should not reject bids or annul bidding processes, except as permitted in the *Procurement Guidelines*.

**33. Notification of Award and Signing of Agreement**

**33.1** The Bidder whose Bid has been accepted will be notified of the award by the Employer prior to expiration of the Bid validity period by cable, telex, or facsimile confirmed by registered letter. This letter (hereinafter and in the Conditions of Contract called the "Letter of Acceptance") will state the sum that the Employer will pay the Contractor in consideration of the execution, completion, and maintenance of the Works by the Contractor as prescribed by the Contract (hereinafter and in the Contract called the "Contract Price").

**33.2** The notification of award will constitute the formation of the Contract, subject to the Bidder furnishing the Performance Security in accordance with Clause 34 and signing the Agreement in accordance with Sub-Clause 33.3.

**33.3** The Agreement will incorporate all agreements between the Employer and the successful Bidder. It will be signed by the Employer and sent to the successful Bidder, within 28 days following the notification of

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the successful Bidder will sign the Agreement and deliver it to the Employer.

**33.4** Upon the furnishing by the successful Bidder of the Performance Security, the Employer will promptly notify the other bidders that their bids have been unsuccessful.

34. Performance Security

**34.1** Within 21 days after receipt of the Letter of Acceptance the successful Bidder shall deliver to the Employer a Performance Security in the form of a Bank Guarantee[36] or (at the Bidder's option) a Performance Bond in an amount specified in the Contract Data,[37] denominated in the types and proportions of currencies in the Letter of Acceptance and in accordance with the Conditions of Contract.

[36] A **Bank Guarantee** can be conditional or unconditional (on demand) (see forms in Section 8). An amount of 5 to 10 percent of the Contract Price is commonly specified for Performance Bank Guarantees.

[37] A **Performance Bond** is an undertaking by a bonding or insurance company (surety) to complete the construction in the event of default by the Contractor, or to pay the amount of the Bond to the Employer. An amount of 30 percent of the Contract Price is commonly used internationally for this type of security (see form in Section 8).

**34.2** If the Performance Security is provided by the successful Bidder in the form of a Bank Guarantee, it shall be issued either (a) at the Bidder's option, by a bank located in the country of the Employer or a foreign bank through a correspondent bank located in the country of the Employer, or (b) with the agreement of the Employer directly by a foreign bank acceptable to the Employer.

**34.3** If the Performance Security is to be provided by the successful Bidder in the form of a Bond, it shall be issued by a surety which the Bidder has determined to be acceptable to the Employer.

**34.4** Failure of the successful Bidder to comply with the requirements of Sub-Clause 34.1 shall constitute sufficient grounds for cancellation of the award and forfeiture of the Bid Security.

35. Advance Payment and Security

**35.1** The Employer will provide an Advance Payment on the Contract Price as stipulated in the Conditions of Contract, subject to a maximum amount,[38] as stated in the Bidding Data.

CHAPTER SEVENTEEN
EVALUATION
CORDA

# *CHAPTER SEVENTEEN*

## *EVALUATION OF TRAINING PROGRAMME*

CCRDA

# COMMUNITY BASED RURAL WATER SUPPLY AND SANITATION PROGRAMME

## 4 - 13 January, 1999

## COURSE EVALUATION

*Please answer the following questions. Tick (✓) the relevant box.*

**SECTION A - Course content**

1. **How effective has the course been in achieving the course objectives?**

Very effective ☐ Effective ☐ Fairly effective ☐ Not effective ☐

2. **What is your opinion of the course content?**

Very good ☐ Good ☐ Fairly good ☐ Poor ☐

3. **What is your opinion of the course material (handouts)?**

Very good ☐ Good ☐ Fairly good ☐ Poor ☐

4. **Where the training methods used .....**

Very effective ☐ Effective ☐ Fairly effective ☐ Not effective ☐

5. **What comments do you have on the style and methods of lecturing/teaching?**

6. **Was the course duration .....**

Too Long ☐ About right ☐ Too short ☐ Much too short ☐
If not about right, what duration would you recommend?

7. **Where you satisfied with the manner of presentation of the course materials?**

Very satisfied ☐ Satisfied ☐ Fairly satisfied ☐ Not satisfied ☐
If not satisfied, please explain why ...

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8. **Which parts of the course were most useful or interesting to you?**

9. **Which parts of the course were least useful or interesting to you?**

10. **How have the following been improved by the course ....**

Your knowledge

Your skills

Your attitude

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11. **How do you think the course could be improved?**

12. **Do you have any further comments about the course?**