DESIGN MANUAL

RURAL WATER SUPPLY

VOLUME I

REPUBLIC OF THE PHILIPPINES
NATIONAL WATER RESOURCES COUNCIL
8th FLOOR, NIA BLDG., E. DELOS SANTOS AVENUE, Q. C.

24 March 1980

MEMORANDUM

For: The Honorable Members
National Water Resources Council

Subject: Rural Water Supply — Design Manual

We are pleased to submit herewith the Rural Water Supply Design Manual which is Volume I of the three-volume Technical Manual on Rural Water Supply Systems.

This manual was prepared to serve as reference material for training local engineers in preparing the design and feasibility studies of rural water supply projects in the provinces.

We hope that it would help accelerate the national government's program to provide water to all our people by the year 2000.

ANGEL A. ALEJANDRIÑO
Executive Director

FOREWORD

The national government is embarking on a massive program to provide water to all areas of the country by providing technical, financial and institutional assistance to local communities. This will require the adoption of appropriate technologies especially for rural water supply systems and the transfer of such technologies to local engineers that will be involved in the implementation of projects.

There will be a need to develop local expertise on the technical aspects of water supply projects to support the program. Local engineers will have to be trained in the design, construction, operation and maintenance of water supply projects.

With this in mind, the National Water Resources Council, through its Task Force on Rural Water Supply, made studies on rural water supply systems and is coming out with a three-volume technical manual on rural water supply. This Design Manual comprises Volume I of the Technical manual. The Construction and Installation Manual will comprise Volume II and the Operation and Maintenance Manual will comprise Volume III.

This manual is intended to be used as reference and training materials for people who will prepare the design and feasibility studies of rural water supply projects in the provinces. This design text in its present edition may be used in the design of water systems with a design population up to about 4000 with services extended up to one faucet per household. Future revisions will expand the manual so that it can be used for systems with up to 20,000 users.

The reader is advised that this manual will be useful for low cost small water supply systems where only the basic water needs of the intended consumers are catered to by the design criteria chosen. It is not intended to replace the technical expertise that is required for systems of magnitudes beyond its present limitation.

Comments and suggestions regarding the contents of this manual would be most welcome and should be sent to the National Water Resources Council.

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CHAPTER 1

THE NATURE AND IMPORTANCE OF WATER

1.01 USES AND IMPORTANCE OF WATER

1) Water is essential to life. It is primarily used for drinking and the preparation of foods and is a necessary element in the metabolic processes of all living things, both plants and animals. Without water there can be no life. Man himself is 80% water and he can live nearly two months without food, but can live only three to four days without water.

2) Water is essential in the maintenance and improvement of health and sanitation of a community. It is used in food preparation, washing of dishes, laundering of clothes, cleaning of household, bathing and/or for personal hygiene, watering of plants, and cleaning of yards and streets.

3) Water is essential in food production. Farmers employ it primarily for growing food crops as well as in raising of livestocks.

4) Water plays a critical role in the balanced relationship between living things and the environment in which they live. For example, some animal life depends upon vegetation for food and vegetation, in turn, needs water for its growth processes. Furthermore, decaying organic matter, like dead plants and animals, is converted into soil by bacteria. On the other hand, bacteria need water for their growth processes. Then, new plants growing in this soil take up nutrients dissolved in water through their roots. And then finally, plants are eaten by animals and the cycle repeats itself.

5) Water provides man with some means of recreation, such as swimming, boating, fishing and hunting.

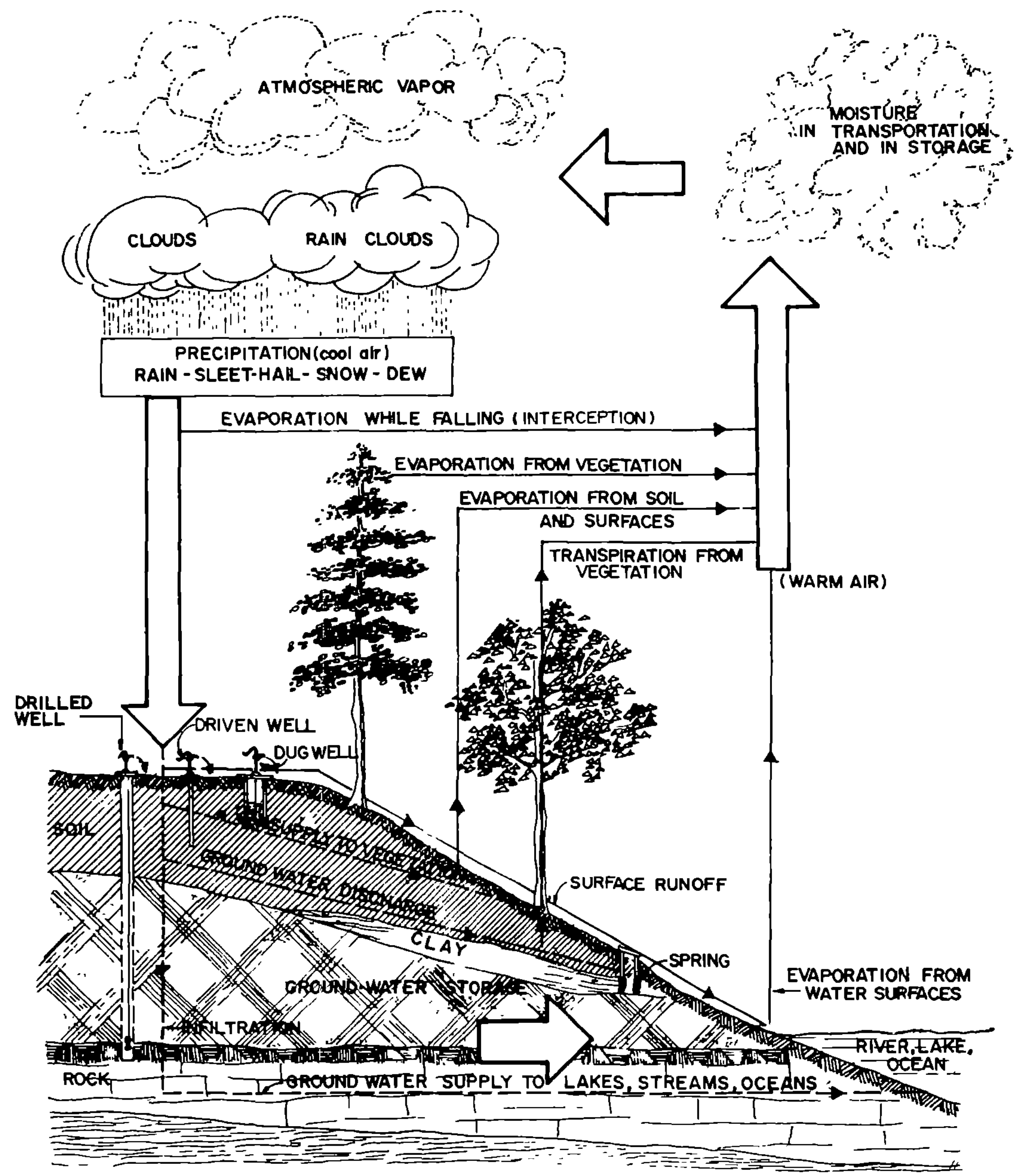
6) Water is also used in protecting life and property against fire.

7) Water is employed in various industrial processes, power generation and also for navigation and transportation of products.

8) Water carries waste from homes, factories, and business establishments to the point of disposal.

1.02 PHYSICAL AND CHEMICAL PROPERTIES OF WATER

Water in its purest state is tasteless, odorless and colorless. Chemically, water molecules consist of hydrogen and oxygen and its chemical formula is H_2O, where H stands for hydrogen and O for oxygen.



OF THE TOTAL PRECIPITATION ABOUT ONE-THIRD RUNS OFF TO STREAMS, LAKES, AND OCEANS; ONE-THIRD PERCOLATES INTO THE GROUND TO FORM THE UNDERGROUND WATER SUPPLY; AND ONE-THIRD RETURNS TO THE ATMOSPHERE ALMOST IMMEDIATELY BY EVAPORATION AND TRANSPIRATION.

FIGURE 1.1

THE HYDROLOGIC OR WATER CYCLE

Water in liquid form has a density of 1 gm/cc. In the vapor or gas form, water is lighter than air, thus, it rises up into the atmosphere.

Water is considered as the universal solvent because of its ability to dissolve almost all organic and inorganic solids and gases it comes in contact with.

1.03 HYDROLOGIC OR WATER CYCLE

The hydrologic cycle is the term used to describe the natural circulation of water on, above and below the earth's surface. Water occurs in three forms (solid, liquid and vapor) as it moves through this cycle. Shown in Figure 1.1 is a simplified illustration showing the steps in the cycle.

The hydrologic cycle includes evaporation,transpiration, precipitation, infiltration and runoff. The heat of the sun evaporates water from the ground, leaves of plants (through transpiration), rivers, streams, lakes and other exposed water containing surfaces. The water vapor goes up into the atmosphere until it reaches the cold upper air where it condenses into clouds. Clouds drift around according to the direction of the wind until they strike the colder atmosphere where uncondensed water vapor precipitates. At this point, the clouds become heavier than air and they begin to fall to the earth as rain, sleet or snow.

A portion of the rain evaporates before it reaches the ground, some flows over the earth as runoff into lakes and streams, and the remainder percolates into the soil, and thence, into the underlying rock formations by seepage or infiltration. Eventually, the water which has seeped through the earth, will find its way to the ground surface through springs, wells, or will flow through porous media until intercepted by streams, lakes or the ocean. Also, some water is held in the soil as soil moisture.

The cycle does not always progress through a regular sequence; steps may be omitted or repeated at any point. For example, in hot climates where precipitation is very low it may be almost wholly evaporated and returned to the atmosphere. In such instances, the steps of infiltration, transpiration and runoff are omitted.

CHAPTER 2

WATER SOURCES

The Philippines has abundant water resources, having an average annual precipitation of 2,260 mm, an average annual runoff of about 256,900 million cubic meters, available 90% of the time, and large reservoirs of groundwater covering some 50,000 square kilometers concentrated mostly beneath its major river basins. The distribution of these water resources varies widely with time and location due to the archipelagic nature of the country's geography and climatic conditions.

CLASSIFICATION OF WATER SOURCES ACCORDING TO THEIR RELATIVE LOCATION ON THE EARTH'S SURFACE

2.01 RAIN OR ATMOSPHERIC WATER

The most common form of precipitation is rain. In places where rain is uniformly distributed throughout the year and where groundwater and surface water are not available, rain water may be used as a source of water supply.

Figure 2.1 shows the rainfall distribution in the Philippines. It is indicated in the figure that the annual rainfall ranges from less than 1,000 mm in Southern Mindanao to more than 4,000 mm in the eastern portion of the country. Generally, the east and west coasts of the country receive the heavier rainfall. The northeast monsoon brings frequent rains to the east coast of the islands, while the southwest monsoon brings rainy season in Manila and the western coast, as well as to the northern parts of the archipelago. The central parts particularly Cebu, Bohol and a part of Cotabato receive the smallest amount of rainfall.

2.02 SURFACE WATER

Surface water is a mixture of surface runoff and groundwater. Surface water sources include rivers, lakes, streams, ponds, impounding reservoirs, seas, and oceans.

The quantity of surface runoff depends upon a large number of factors; the most important of which are the amount and intensity of rainfall, the climate and vegetation and the geological, geographical, and topographical features of the catchment area.

The quality of surface water is determined by the amount of pollutants and contaminants picked up by the water in the course of its travel. As rain falls from the atmosphere, it collects dusts and absorbs gases

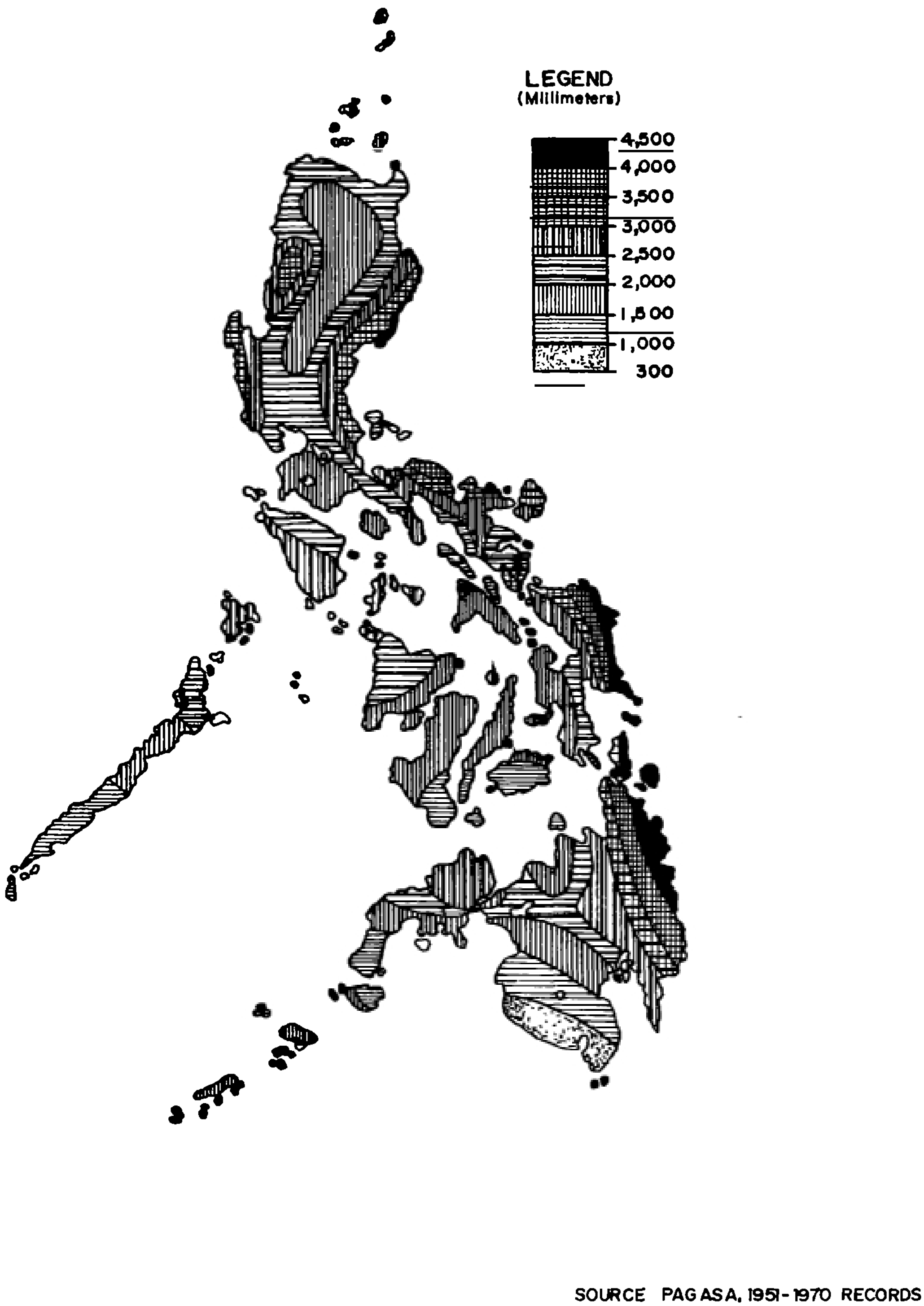


FIGURE 2.1

ANNUAL RAINFALL IN THE PHILIPPINES

from air. While flowing over the ground, surface water collects silt, decaying organic matter, bacteria and other microorganisms from the soil. Thus, all surface water sources should be presumed to be unsafe for human consumption without some form of treatment. For rural water supply systems, surface water sources should be avoided as much as possible due to the high costs of treatment and the general lack of expertise for the maintenance and operations of such kind of treatment.

2.03 GROUNDWATER

Groundwater is that portion of rain water which has percolated into the earth to form underground deposits called aquifers (water-bearing soil formations). Groundwater is often clear, free of organic matter and bacteria due to the filtering effect of soil on the water percolating through it. However, groundwater almost always contains minerals dissolved from the soils. Groundwater as a source of water supply can be extracted through the following:

1) **Springs** — spring water occurs when water in water-bearing stratum reaches the surface of the ground. Springs can be developed by enlarging the water outlet and constructing an intake structure for water catchment and storage. The methodology is discussed in detail in Chapter 4.

2) **Wells** — groundwater can be tapped by digging a hole or sinking pipes into the ground and installing water drawing equipment such as pumps. Wells can be classified according to their construction: dug, driven, bored, jetted or drilled wells. Wells are discussed in detail in Chapter 5.

3) **Infiltration Galleries** — infiltration galleries are sometimes used to make groundwater available. Infiltration galleries are horizontal wells, constructed by digging a trench into the water-bearing sand and installing perforated pipes in it. Water collected in these pipes converge into a "well" where it is pumped out. Infiltration galleries are discussed more in Chapter 4.

CHAPTER 3

WATER QUALITY

Before the development of any water resource, the quality of water it yields must be examined to determine its potability. Potable water is water that is satisfactory for drinking purposes. The Philippine Standards for Drinking Water provide the minimum standards for quality (Table 3.1). These standards set the limits on the physical, chemical and bacteriological characteristics of water.

3.01 PHYSICAL PROPERTIES

1) **Turbidity** — is a measure of the degree of cloudiness or muddiness of water. It is caused by suspended matter in water like silt, clay, organic matter or microorganisms. Turbidity has little detrimental effect on health, however, it has adverse aesthetic and psychological effects to the consumers.
2) **Color** — is due to the presence of colored substances in solution, such as vegetable matter and iron salts. Like turbidity, it has no detrimental effects on health. Color intensity could be measured through visual comparison of the sample to the distilled water.
3) **Odor** — can be detected by smelling. Pure water is odorless, hence, the presence of undesirable odor in water is indicative of the existence of contaminants in water. Odor should be absent or very faint for water to be acceptable for drinking.
4) **Taste** — Pure water is tasteless, hence, the presence of undesirable taste in water indicates the presence of contaminants. Algae, decomposing organic matter, dissolved gases, and phenolic substances may cause tastes.

3.02 CHEMICAL PROPERTIES

1) **Hardness** — hardness is due primarily to calcium and magnesium carbonates and bicarbonates (carbonate hardness can be removed by boiling) and calcium and magnesium sulfate and chloride, (this can be removed by chemical precipitation using lime and sodium carbonate). Hardness in water is objectionable due to the following reasons:
   a. Magnesium and Calcium sulfate has a laxative effect.
   b. It increases soap consumption as lathering is more difficult.
   c. In boilers, pots and kettles, hardness causes scaling, resulting in the reduction of the thermal efficiency and restriction of flow.

2) **Alkalinity and Acidity** — the presence of acid substances is indicated by pH below 7.0 and alkaline substances by a pH greater than 7.0. Acidic water is corrosive to metallic piping systems.

TABLE 3.1

PHILIPPINE NATIONAL STANDARDS FOR DRINKING WATER (1978)

PARAMETERS	Maximum Permissible Level
A. Physical	
Color (units)	5 units*
Odor, Threshold Odor No. (units)	Not more than 3
Solids, Total	500 mg/l*
Turbidity, as SiO_2 (units)	5 units
B. Chemical	
Calcium	75 mg/l
Chloride	200 mg/l*
Magnesium	50 mg/l*
Nitrate as N	30 mg/l
Oil & Grease	Nil
pH	6.5-8.5
Phenolic Substance	0.001 mg/l
Sulfate	200 mg/l*
C. Trace Elements	
Arsenic	0.05 mg/l
Barium	1.00 mg/l
Cadmium	0.01 mg/l
Chromium, Total	0.05 mg/l
Copper	1.00 mg/l
Cyanide	0.05 mg/l
Flouride	0.06 mg/l
Iron	1.00 mg/l*
Lead	0.05 Mg/l
Manganese	0.50 mg/l*
Mercury	0.002 mg/l*
Selenium	0.01 mg/l
Zinc	5.00 mg/l*
D. Radionuclide	
Alpha emitter, uuc/l	3 (gross alpha)
Beta emitter, uuc/l	30 (gross beta)
E. Pesticides	
Aldrin	0.001 mg/l
DDT	0.05 mg/l

TABLE 3.1 Continued . . .

PARAMETERS	MAXIMUM PERMISSIBLE LEVEL
Dieldrin	0.001 mg/l
Chordane	0.003 mg/l
Endrin	0.0002 mg/l
Heptachlor	0.0001 mg/l
Lindane	0.004 mg/l
Toxaphane	0.005 mg/l
Methoxychlor	0.10 mg/l
PCB	Nil
2, 4 – D	0.10 mg/l
2, 4, 5 – TP	0.01 mg/l
F. **Bacteriological**	
Coliform, MPN/100 ml	Not more than one for treated water Not more than 3 for untreated water

*Secondary Standards· Compliance with the standard and the analysis are not obligatory

3) **Carbon Dioxide** — the presence of appreciable quantities of carbon dioxide makes water corrosive.

4) **Dissolved Oxygen** — water devoid of oxygen frequently has a flat taste and may be an indication that particular water (except ground water) contains appreciable oxygen-consuming organic substances.

5) **Organic Nitrogen** — Organic nitrogen is a constituent of all waste protein products from sewage, kitchen wastes and all dead organic matter. Freshly produced wastes normally contain pathogenic bacteria. All water high in organic nitrogen should therefore be suspected for possible contaminants.

6) **Chemical Oxygen Demand (COD)** — COD is a measure of the amount of organic content of water. As COD increases the dissolved oxygen in water decreases because bacteria utilizes it in the oxidation of organic matter.

7) **Iron and Manganese** — groundwaters usually contain more of these two minerals than surface waters. Iron and manganese are nuisances that must be removed if the quantity is greater than 0.3 mg/L and 0.1 mg/L respectively, as they cause staining of clothing and plumbing fixtures. Also, the growth of iron bacteria causes the clogging of strainers, screens and rusting of metallic pipes. The appearance of a reddish brown precipitate in a water sample after shaking indicates the presence of iron.

8) **Toxic Substances** — a number of chemical substances, if present in appreciable concentration in drinking water may constitute a danger to health. These toxic substances include arsenic, barium, cadmium, hexavalent chromium, cyanide, lead, selenium and silver.

9) **Phenolic Compounds** — cause undesirable taste in water whenever present.

3.03 BACTERIOLOGICAL CHARACTERISTICS

The greatest danger associated with drinking untreated water is that it may recently have been contaminated by sewage or by human and animal excrement.

If such contamination has been caused by carriers of infectious diseases such as dysentery or typhoid fever, and if it has occurred recently, the water may contain the living pathogens (germs) of these diseases. This water if not treated prior to its consumption, can cause an epidemic of water-borne diseases. Pathogens in water can be removed by filtration or by disinfection.

The two basic methods used for the enumeration of coliform organisms (most commonly used indicators of faecal contamination) in water are the multiple-tube fermentation method and the membrane filtration method.

Estimates of the numbers of coliform organisms are given in terms of Most Probable Numbers (MPN) per 100 ml, when determined using the multiple-tube fermentation method, and colonies per 100 ml, when determined by the membrane filter technique.

CHAPTER 4

DEVELOPMENT OF WATER SOURCES

4.01 RAIN WATER

In areas in the Philippines, where rain water is abundant and well distributed throughout the year and where surface and ground water are scarce, rain water can be utilized as the main source of individual water supply. Rain water can be collected from roofs of buildings, houses, etc. and conducted to a cistern or storage tank (Figure 4.1).

Dust, dirt, leaves and bird droppings may fall on the roof and be washed down by the first rain so that a provision to bypass the first 5-10 minutes of rain should be made.

The average annual rainfall and the collecting area determine the amount of water which can be collected. One millimeter of rain falling on one square meter of roof will yield 0.8 to 0.9 liters of water depending on the type of roof. For example, if the annual rainfall is 2,360 mm and the available collecting surface has the dimension of 5 x 10 meters, the amount of water which can be collected in a year is equal to:

$$2{,}360 \text{ mm} \times 0.8 \text{ 1/M}^2\text{/MM} \times 5 \text{ M} \times 10 \text{ M} = 94{,}400 \text{ liters/year}$$

$$\text{or } \frac{94{,}400}{365} = 259 \text{ liters/day}$$

Figure 2.1 shows the rainfall distribution in the Philippines. The size of the cistern or storage tank to be built is determined by the amount of water needed, the collection area, the intensity of rainfall and the length of dry season.

Cast-in-place reinforced concrete or concrete hollow blocks (CHB) cisterns are often used for storing rain water for underground and above ground cisterns. Galvanized metal or ferrocement tanks, clay jars and plastic containers may be also employed for storage above ground.

4.02 SPRINGS

Springs are outcrops of groundwater and often appear as small water holes or wet spots at the foot of hills or along river banks. The presence of green vegetation in dry areas usually indicates the existence of springs. However, the local inhabitants are usually the best guides in locating springs.

1) **Steps in Developing Springs**

a. Enlarge the eye of the spring to increase the quantity of water

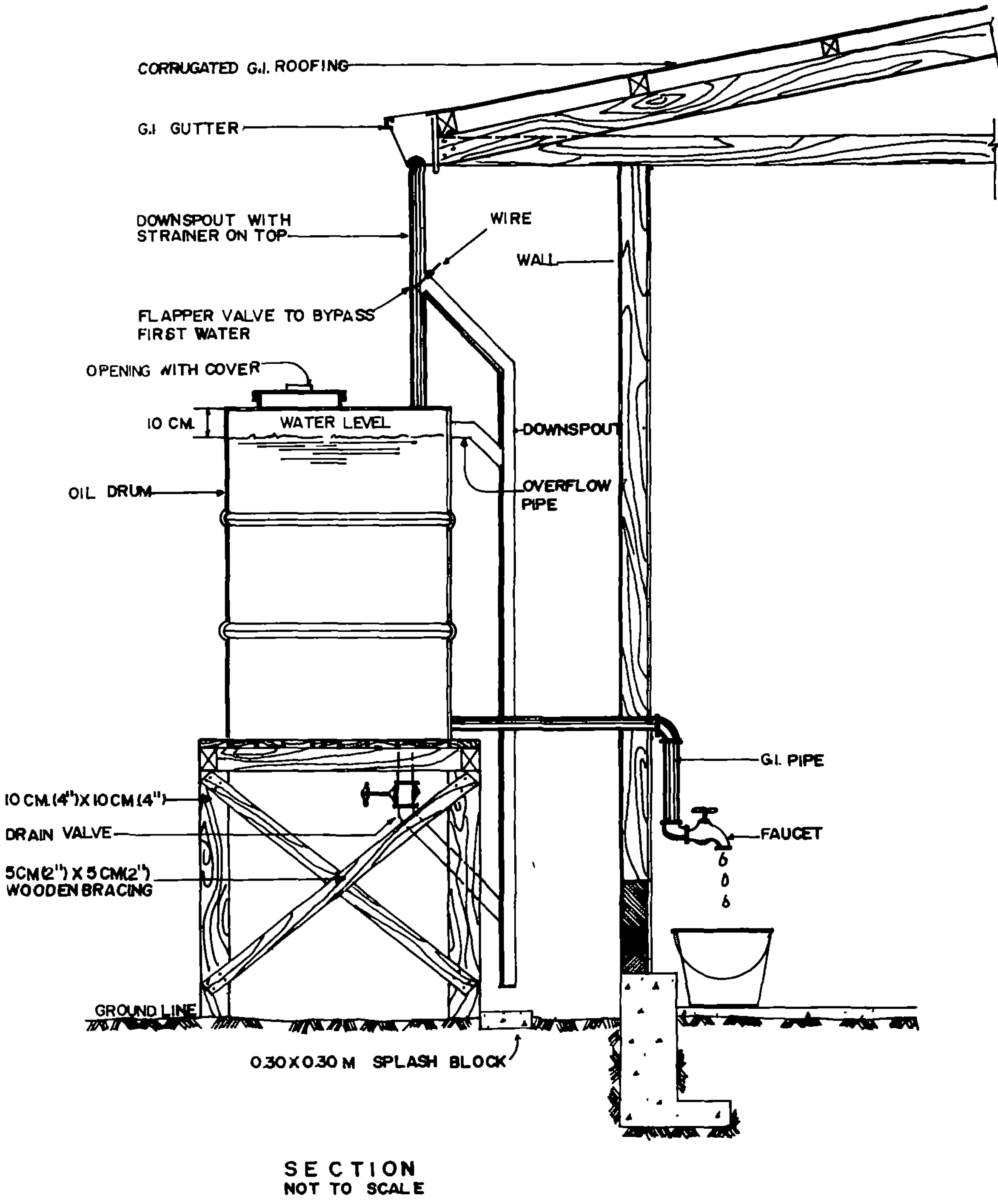
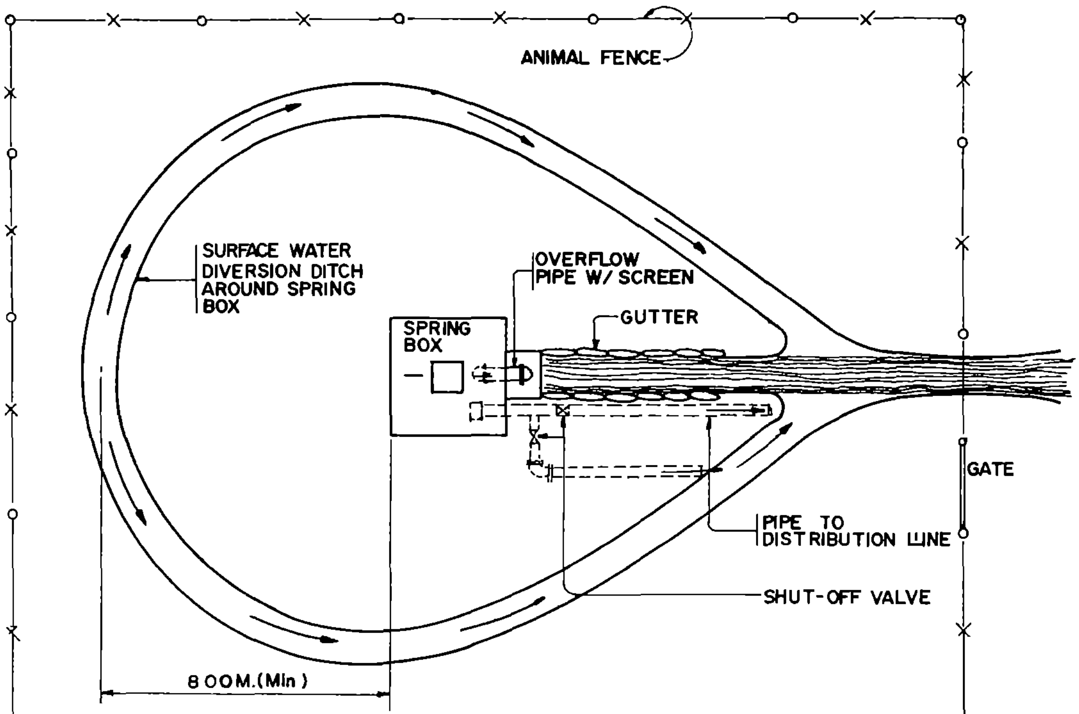
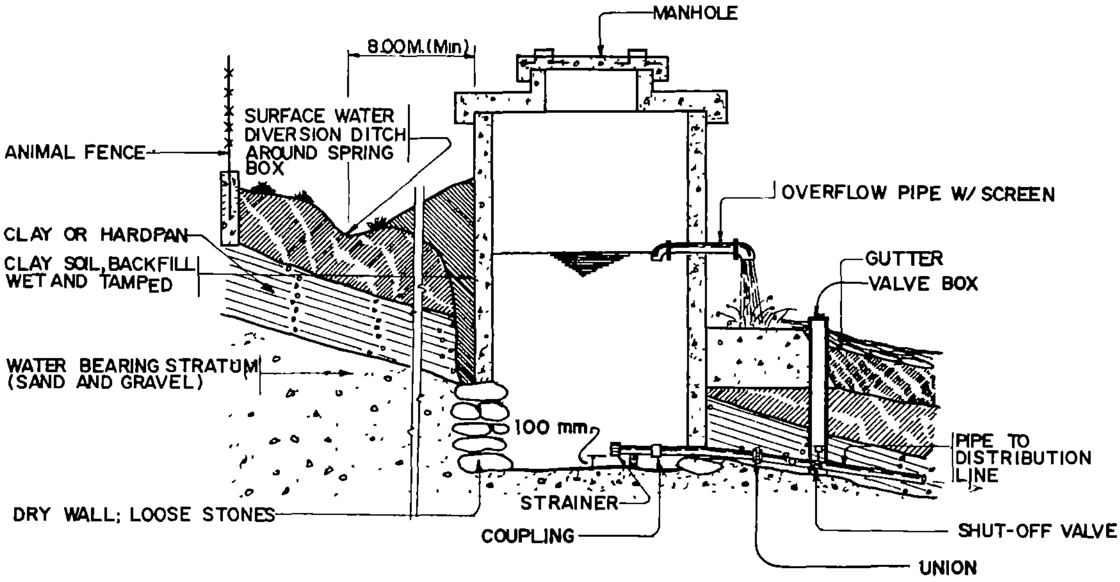


FIGURE 4 1

RAIN WATER STORAGE



LOCATION PLAN
NOT TO SCALE



ENLARGED SECTION OF SPRING BOX
NOT TO SCALE

FIGURE 4.2

LOCATION & DETAILS OF SPRING BOX

yield. This is accomplished by digging out the area around the hole down to the impervious layer to remove silt, mineral matter ($CaCO^3$), and other rock fragments. During excavation, disturbance of underground rock formation must be avoided to prevent the deflection of the spring to another direction or rock formation.

b. Pile stones against the eye of the spring that will serve as the foundation of the spring box.

c. Construct a spring box around the enlarged eye of the spring. This is to protect the spring water from contamination.

d. If there are several small springs located in the same area, a silt trap is constructed which will serve as the reservoir collecting water from small springs.

2) **Spring Box**

Figure 4.2 shows a spring box. It is covered with a concrete slab with an access manhole for cleaning purposes. The hole should have a raised edge to prevent dirty water from running into the box. Also, the outlet pipe should be at least 100 mm above the bottom of the box. To prevent stones, rubbish and frogs from blocking the pipes, the end of the outlet pipe inside the box shoul be covered with a screen. There should also be an overflow pipe which is big enough to carry the maximum flow of the spring during wet season. The end of the overflow pipe should be covered with a screen fine enough to keep out insects and frogs which may enter the box. Moreover, a drain pipe is necessary for removing silt at the bottom of the spring box.

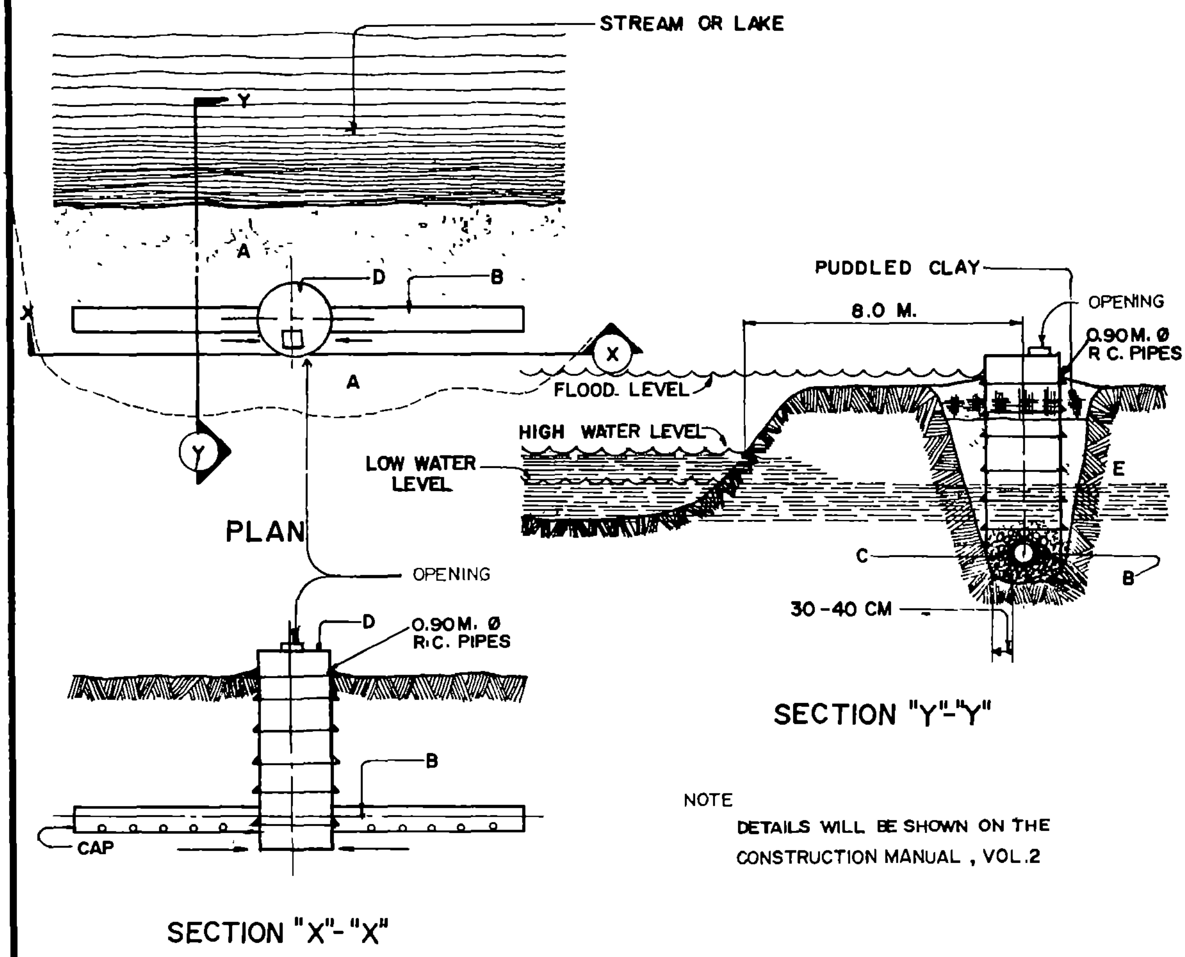
The space behind the spring box should be filled with soil, the space at the bottom and at the level with the eye of the spring should be filled with gravel or sand.

To prevent pollution of spring water, a ditch at least 8 meters uphill and around on each side of the spring box should be dug to intercept and divert surface water away from the spring.

4.03. INFILTRATION GALLERIES

Infiltration galleries are horizontal wells which collect water over their entire lengths as shown in Figure 4.3. An infiltration gallery is a simple means of obtaining naturally filtered water. It is constructed by digging a trench into water-bearing sand, then collecting the water in perforated pipes which lead to a central sump from where water may be pumped out or cnveyed through gravity. The length of the trench depends upon the amount of water desired.

Careful tests to measure yield should be made to determine the length of collecting pipes before constructing an infiltration gallery. The best galleries collect water well below the ground water level, thus making it necessary to dewater the working trench. This usually requires cribbing and dewatering pumps and is therefore more expensive than a simple



NOT TO SCALE

A = SAND BANKS BESIDE STREAMS OFFER EXCELLENT OPPORTUNITIES FOR INFILTRATION GALLERIES OR SHALLOW DUG WELLS.

B = PERFORATED PIPE SHOULD BE LAID ON A PREPARED FILTER BED AND MORE FILTER GRAVEL SHOULD BE PLACED OVER IT.

C = ROUND, 12-25mm.(1/2-1 In.) STONES SHOULD BE LAID AROUND THE PIPE, AND THE FILTER SHOULD BE BUILT OUT AWAY FROM THE PIPE WITH GRADED SAND AND GRAVEL. FILTER SHOULD BE 30-40Cm.(12-16 In) IN THICKNESS FROM PIPE TO EXTREME EDGE

D = WELL IN THE MIDDLE OF GALLERY FOR MOUNTING PUMP AND COLLECTING WATER

E = WATER TABLE

FIGURE 4.3

DETAILS OF INFILTRATION GALLERIES

bored or driven well. This system, however, offers better possibilities of obtaining larger quantities of water if a suitable formation, such as coarse sand, can be found on the bank of a river, lake or small stream.

4.04 SURFACE WATER SUPPLIES

Surface water supplies include water from rivers, streams, lakes, ponds, seas and oceans. Surface water usually contains organic and inorganic minerals and needs expensive water treatment. For this reason, surface water should be avoided for rural water supplies, as much as possible.

CHAPTER 5

WELLS

Groundwater extracted through wells is widely used as a source of water supply for rural areas in the Philippines. A well may be a hole or a pipe sunk into the earth to a depth below the water table or into deep water bearing strata.

Bacteriologically, groundwaters can be regarded as safe, except in creviced limestone areas. Experience has shown that if a well is protected in the top 3.0 meters, the water entering the well below that point will be safe to drink. This means that a dug, bored or driven well only 5 to 6 Meters deep can be a safe source if properly protected. From the standpoint of disease transmission, contamination is determined by careful sanitary inspection to make sure the well is protected from surface contamination in the top 3.0 meters.

5.01 GUIDELINES IN THE CONSTRUCTION/IMPROVEMENT OF WELLS AS A SOURCE OF WATER SUPPLY

1) Investigate if there is an existing well. If there is, evaluate its existing condition;

   a. Determine water chemical quality. If the water is not potable, find other sources.

   b. Determine the amount of water yield. The well will be acceptable if it satisfies the maximum water demand (discussed in Chapter 8) of the area to be served. In cases when it fails to meet the requirements, find a supplementary source.

   c. Investigate the condition of the structural parts. The well cover, lining and other accessories must be checked for defects and these defects must be correspondingly repaired or corrected.

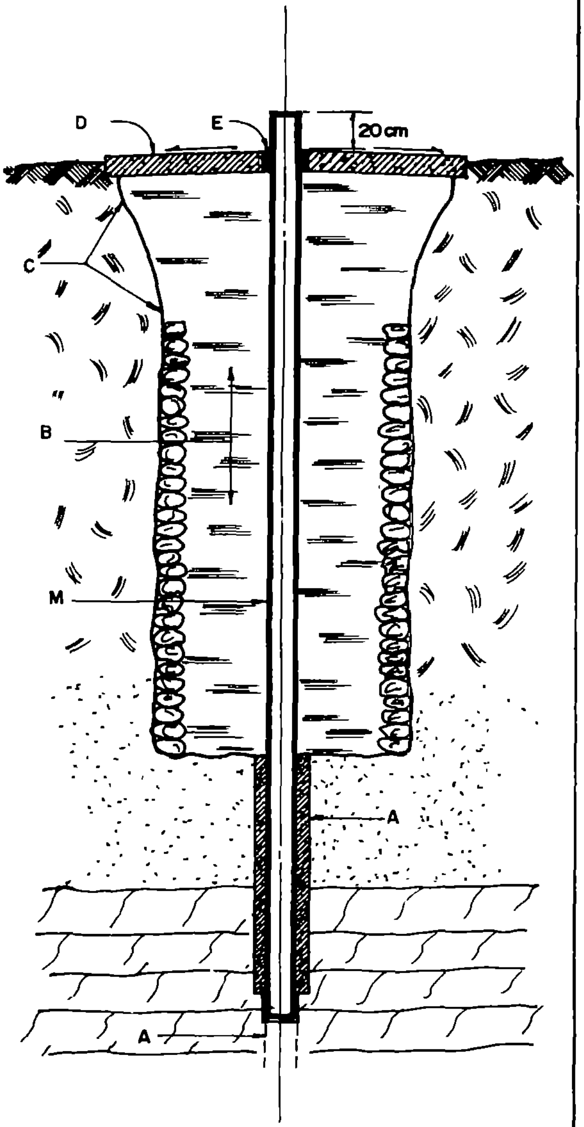
2) In case there is no existing well or if the existing well yields poor quality or inadequate water, a new well should be constructed.

5.02 DESIGN OF WELL

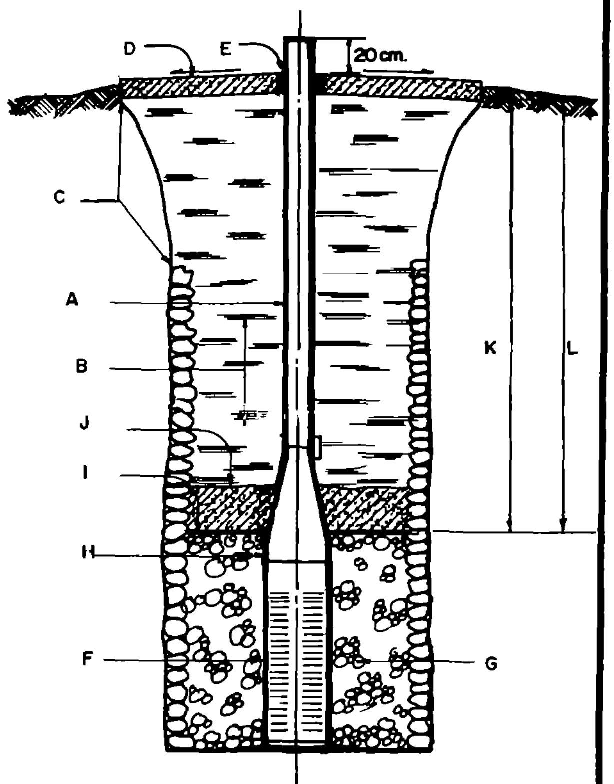
The quantity of water the well will yield depends upon the diameter of the well, the depth of the water-bearing strata penetrated, and recharge area and aquifer characteristics.

1) **Well Depth**

   Generally, wells are drilled up or dug up to the bottom of water-bearing strata so that more water can be drawn by the intake of the pump. However, in cases where the bottom of the aquifer yields poor quality water, it is advisable to adjust the depth until what is yielded is potable.



A = STANDARD-WEIGHT CASING
B = PUDDLED CLAY OR EQUIVALENT
C = CURBING REMOVED
D = NEW PLATFORM
E = PLASTIC COMPOUND
M = DRILL HOLE AND CASING

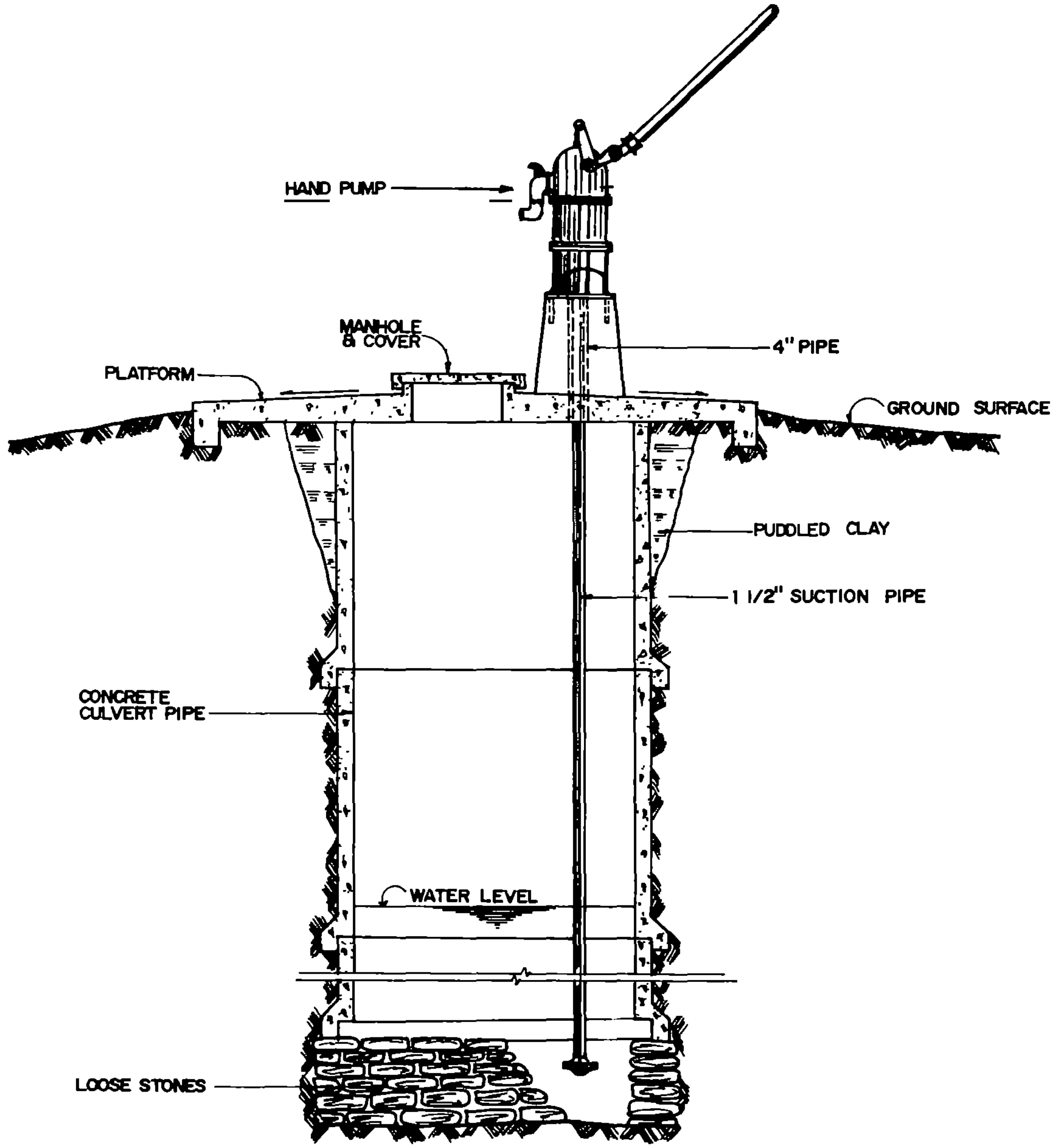


A = STANDARD WEIGHT CASING
B = PUDDLED CLAY OR EQUIVALENT
C = CURBING REMOVED
D = NEW PLATFORM
E = PLASTIC COMPOUND
F = METAL OR CONCRETE SCREEN OR PVC
G = WASHED, ROUND GRAVEL
H = REDUCER
I = METAL PLATE
J = POURED CONCRETE
K = 3.6 M (12 ft) IN CLAY
L = 6.0 M (20 ft) IN SAND OR GRAVEL

SOURCE. WATER SUPPLY FOR RURAL AREAS AND SMALL COMMUNITIES BY, E.G. WAGNER and J.N. LANOIX

FIGURE 51

IMPROVEMENT OF EXISTING DUG WELLS

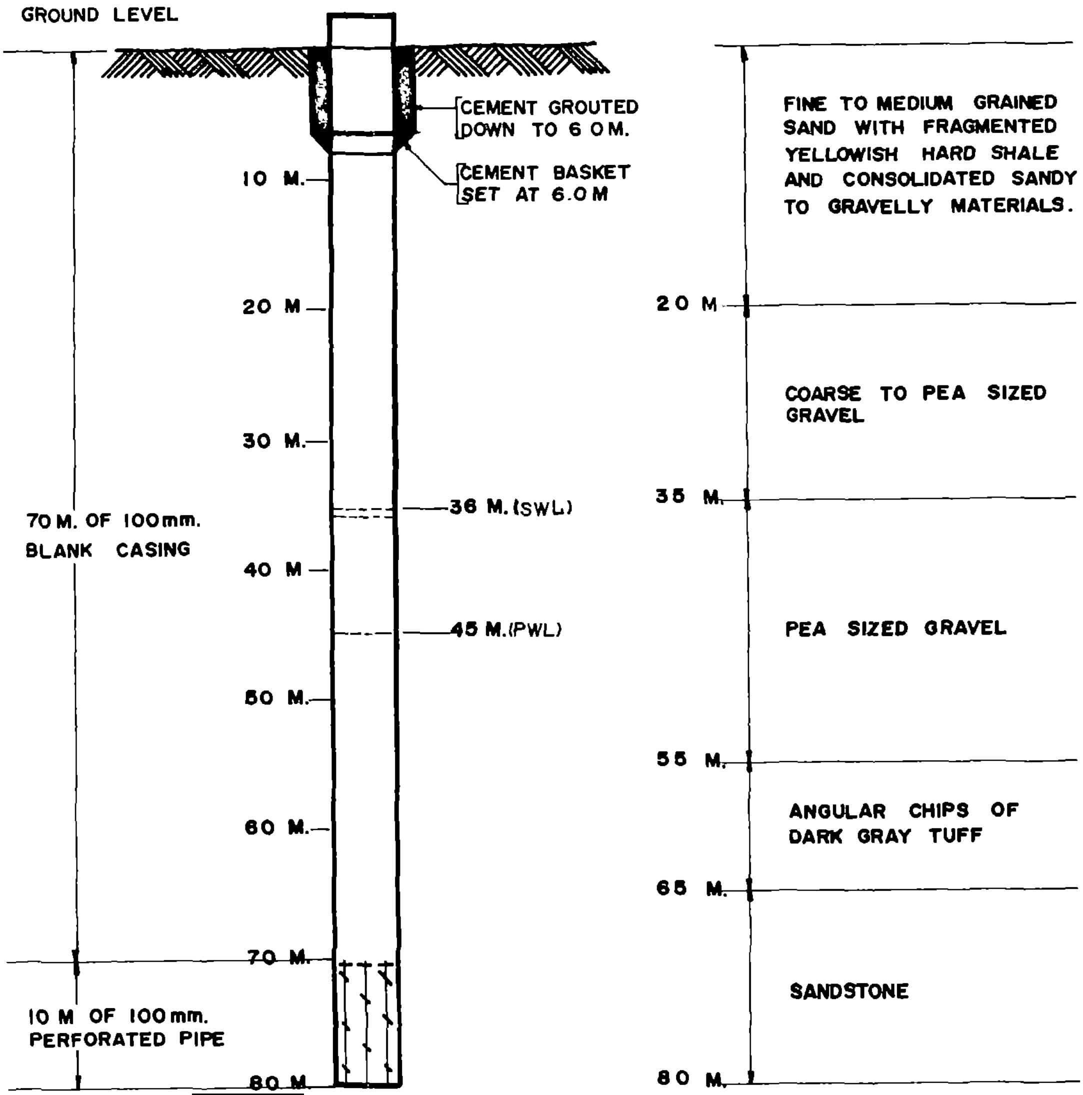


SOURCE WATER SUPPLY FOR RURAL AREAS AND SMALL COMMUNITIES BY E.G WAGNER and J N. LANOIX

FIGURE 5.2

ALTERNATE DUG WELL PROTECTION

SAMPLE
CROSS-SECTION OF WELL DRILLED FOR
BO SALOMAGUE, PANIQUI, TARLAC



PUMPING DATA:

STATIC WATER LEVEL — 36 M.
PUMPING LEVEL — 45 M.
DRAWDOWN — 9 M.
DISCHARGE (Q) — 1.25 LPS
EQUIPMENT USED — 5 HP. DEMING PUMP SET 50 M.
SPECIFIC CAPACITY — 0.14 LPS/M. (1.25/9)

DATE STARTED AUG. 20, 1978
DATE COMPLETED SEPT. 5, 1978
WELL DRILLER ____________

FIGURE 5 3

SAMPLE ONLY
WELL LOG & REPORT

2) **Selection of Well Diameter/Pipe Casing**

Well diameter is determined by the pumping rate and the porosity of the aquifer which controls the rate that water enters the well. In a porous sand formation water can move easily so a small diameter well (38 mm) may be able to supply water at the pumping rate. In a tighter clay formation the water will move more slowly, and it will be necessary to store water to meet the pumping rate. Such a well might be a bored well 30 to 38 cm. in diameter or a dug well 0.90 to 1.20 M in diameter.

For shallow wells, the pipe casing can serve both as the well casing and drop pipe of the pump.

For deep wells, the well casing must be large enough to accommodate the pump bowl, column or drop pipe with proper clearance for installation and efficient operations. The optimum casing size is equal to two nominal pipe sizes larger than the pump bowls. For example, if the size of the pump bowl is 50 mm, the size of the casing must be 75 mm.

5.03 IMPROVEMENT OF EXISTING WELLS

Existing wells may be improved and the water yield rendered safe for consumption by taking the following measures:

a. To increase the well yield, deepen the existing well.

b. If the existing casing can not prevent the infiltration of contaminated surface water, repair it as shown in Figure 5.1.

c. Build a strong and impervious concrete platform or apron, extending 1 meter around the mouth of the well. (Figure 5.2).

d. Cover the well and install pumping equipment.

5.04 CONSTRUCTION OF NEW WELLS

Before constructing a new well, it is useful to investigate the water level of existing wells within the vicinity and ask well drillers about the local soil conditions. Rock formations might be present, making well-digging hard or even impossible. Groundwater investigation, however, will be more accurate if nearby well logs are made available. (A sample well log and report is shown in Figure 5.3).

The different types of wells that can be constructed are dug well,driven well, bored well, jetted well or drilled well. Shown in Figure 5.4 are the five types of well construction.

The selection of the type of well to be constructed largely depends upon the depth and diameter of the well to be constructed, the characteristics of soil formations of the site and the cost of construction. The depth of wells is dependent on the depth of the water bearing layer. Moreover, the amount of water obtained from wells depends

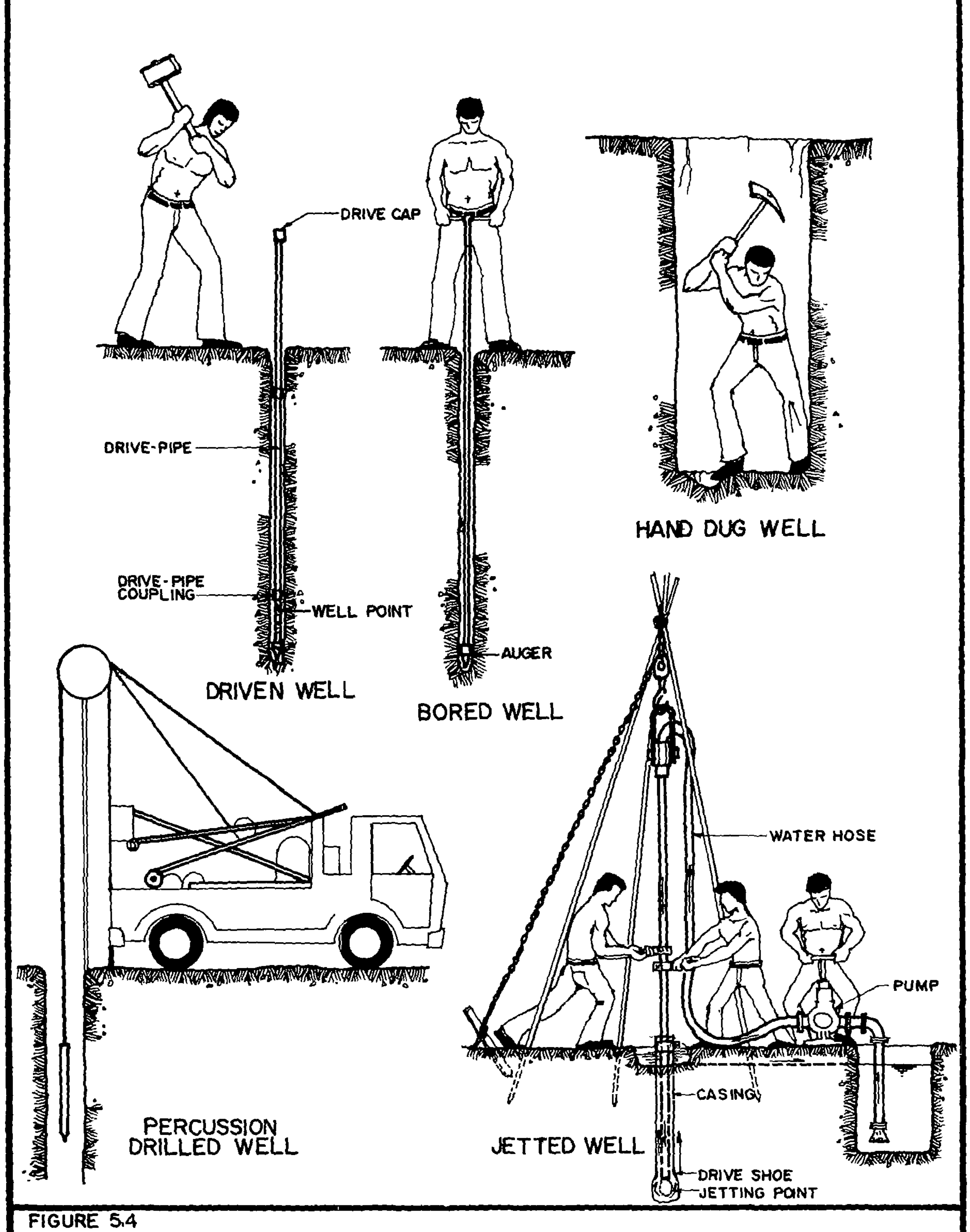


FIGURE 5.4

FIVE BASIC METHODS OF WELL CONSTRUCTION

upon the amount of groundwater available at the location and the capacity of the pump to draw that water.

A new well should always be disinfected. The well should be safeguarded from any sources of contamination, such as seepage from sewage disposal areas, entrance of surface water drainage from barnyards, graveyards and manured fields, which make the water unsafe for human consumption.

1) Dug Wells

Dug wells are normally circular in shape, although they may also be rectangular. The diameter of a dug well ranges from 1 to 1.5 meters. After the well is dug it is necessary to put a lining made of permanent materials like masonry, brickwork, or reinforced concrete. This lining serves as protection during construction agains caving in and collapse and as a seal to prevent polluted surface water from entering the well. The lining also acts as a foundation and support for the well top and any pump or other mechanism which may be fitted upon well completion.

2) Driven Wells

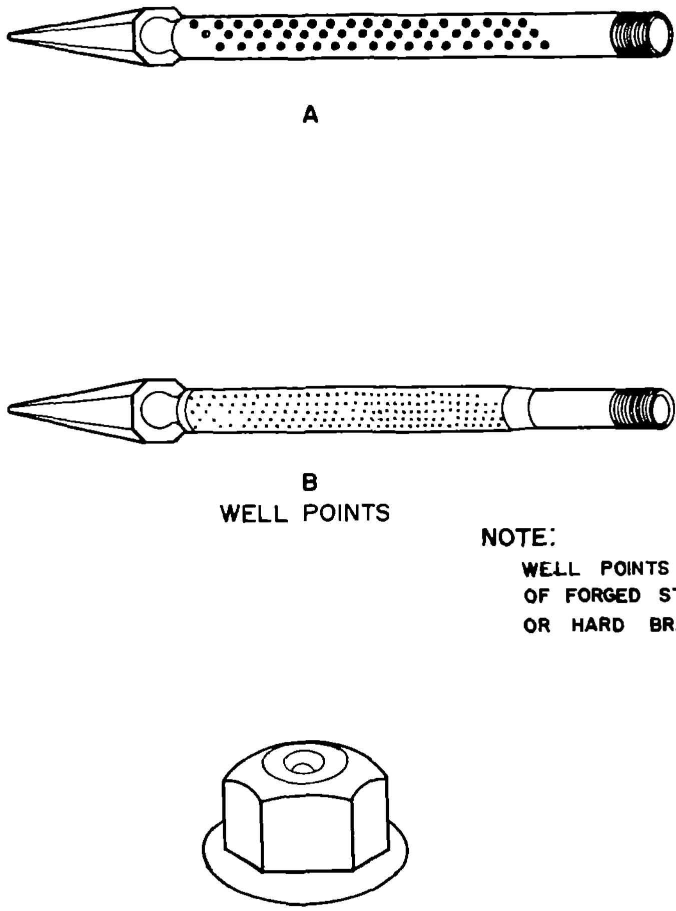
The easiest type of well to construct is the driven well, which is made by hammering a G.I. pipe into the ground. The depth of driven wells normally ranges from 4 to 15 meters, depending upon the soil conditions. A driven well point is a metal tube with a point at the lower end and holes or slits on the sides where water can pass through, (Figure 5.5 A and B).

The well point is driven into the ground by hitting the top with a heavy weight. As the point is driven further into the ground, lengths of steel pipes are added at the top. The pipe should be twisted after each blow of the hammer to ensure that the pipe joints are tight. The top should be protected from damage while driving by placing a wooden block or steel cap. Shown in Figure 5.5 C is the drive cap.

3) Bored Wells

Another type of well which can be constructed cheaply with local materials is the bored well. It consists of a hole bored by hand augers or similar tools and can be put down to a depth of about 15 meters using a hand tool.

The first section of the hole is normally bored with a hand auger and when water is reached, with a bailer. In soils, where the sdies of the hole tend to cave-in, a casing, normally made of steel or plastic and the same diameter as the hole is needed to hold the soils up while boring. The casing is pushed down as the hole is bored, usually with the connecting rods of the auger. The hole should be bored at least 1-2 meters below the water table. After drilling, a perforated PVC Pipe is inserted inside the casing, and the casing is slowly pulled out while gravel or stones are poured



NOTE:
WELL POINTS ARE USUALLY MADE OF FORGED STEEL, STAINLESS STEEL, OR HARD BRASS.

SOURCE RURAL WATER SUPPLY AND SANITATION BY F B WRIGHT

FIGURE 5.5
TWO TYPES OF WELL POINTS & DRIVE CAP

into the gap between the tube and the sides of the well up to 3.0 meters below the surface. The rest of the gap is filled with puddled clay to prevent surface contamination.

4) **Jetted Wells**

Jetting can be used to sink wells up to 80 meters deep depending on soil conditions. It involves the pumping of water down the hole. The water loosens the soil and overflows from the hole carrying soil from the bottom, so that a pipe can be pushed down into the hole. Jetting requires plenty of water, steel pipes, and usually a manual or power pump.

The simplest method of jetting is known as the sludger method and it needs no pump. However, it is only useful in fine loose soils, such as sands and silts, and is difficult to use when the water level is more than 40 meters deep. It is most appropriate for delta areas where the soil is suitable and groundwater is near the surface. In constructing a jetted well, a hole about a meter deep is dug by hand and filled with water, then a piece of steel pipe is inserted vertically into the hole. A pipe coupling, sharpened at the edge with a file, is attached to the bottom end of the pipe to help the pipe cut its way into the soil. A scaffolding of wood or bamboo is built beside the hole and a lever is fixed to it, with one end tied to the pipe by a chain so that by operating the lever, the pipe is lifted up and down the hole. Repeating the up and down process with the lever and pumping water into the pipe causes the pipe to sink into the ground. As it sinks, further lengths of steel or threaded PVC pipe are added at the top. Meanwhile, the hole should be kept full of water. If the soil is very permeable and the water table is deep, it may be difficult to keep the hole full of water. Adding a little clay to the water (about one part in twenty) for the top 5 to 10 meters, will help in sealing the soil and slowing down the rate at which the water is seeping into the soil. A casing is not usually necessary with this method. When the hole is complete, the pipe is pulled out, carefully keeping the hole full of water. A casing with a well screen at the bottom is then inserted.

5) **Drilled Wells**

The most expensive type of well is the borehole, drilled by large drilling rigs. Expert advice should be obtained especially on the selection of the drilling site. There are two kinds of drilling rigs used: the percussion rig which drills the hole by repeatedly dropping a heavy weight into it and the rotary rig which drills by rotating a sharp bit to make a hole.

The percussion drilling rig may be of mechanical or manual type. In mechanical percussion drilling, the drilling tool, well casing, screen and all materials and equipment used to construct the well are suspended and manipulated from the derrick. Drilling is accomplished by alternately dropping and raising the percussion bit in and out of the hole which cause the loosening of the ground. The loosened particles are then brought to the surface by means of a bailer.

The manual type of drilling rig (Figure 5.6) which is suspended through the pulley and tied on top of the tripod is operated by a man who alternately pulls and releases the rope which is connected to the drill bit. The drill bit is hoisted up when the man pulls the rope and it drops down when the man releases the rope. This alternate raising and dropping of drill bit loosen the ground, and the loosened earth is brought to the surface by means of a bailer or similar tool.

In areas where hand methods are not successful in constructing wells, a light-jet percussion rig can be used to drill holes 38 to 150 mm in diameter and up to a depth of 70 meters. These light rigs can drill through soft rock and hard-pan. Such rigs are portable, cost less than US$5,000.00 based on 1978 price and the drilling technique is simple and can be learned easily. Wells drilled with this type of rig are much cheaper than a borehole drilled with a standard large percussion rig.

Rotary rigs are much more varied in construction and operation. In the normal rotary process, mud is pumped down to the center of the drill stem or shaft. The mud returns through the annular space between the drill stem and the bore hole walls carrying with it loosened material from the bit. The pressure of the flow forces mud into the bore hole wall which seals and supports it. Other rotary methods use water and high pressure pumps or compressed air to blow the loosened materials to the surface. In these types of rotary drilling, a variety of bits is used, from the simple roller bit, for normal work, to the diamond drill. A bit tipped with industrial diamonds will penetrate the hardest rock formations.

Rotary rigs are faster and can drill in harder rock, but are more expensive than the percussion rigs.

The construction of drilled wells is a very specialized work and requires considerable experience. Before constructing this type of well, careful consultation with competent well drilling firms or consulting engineers should be made.

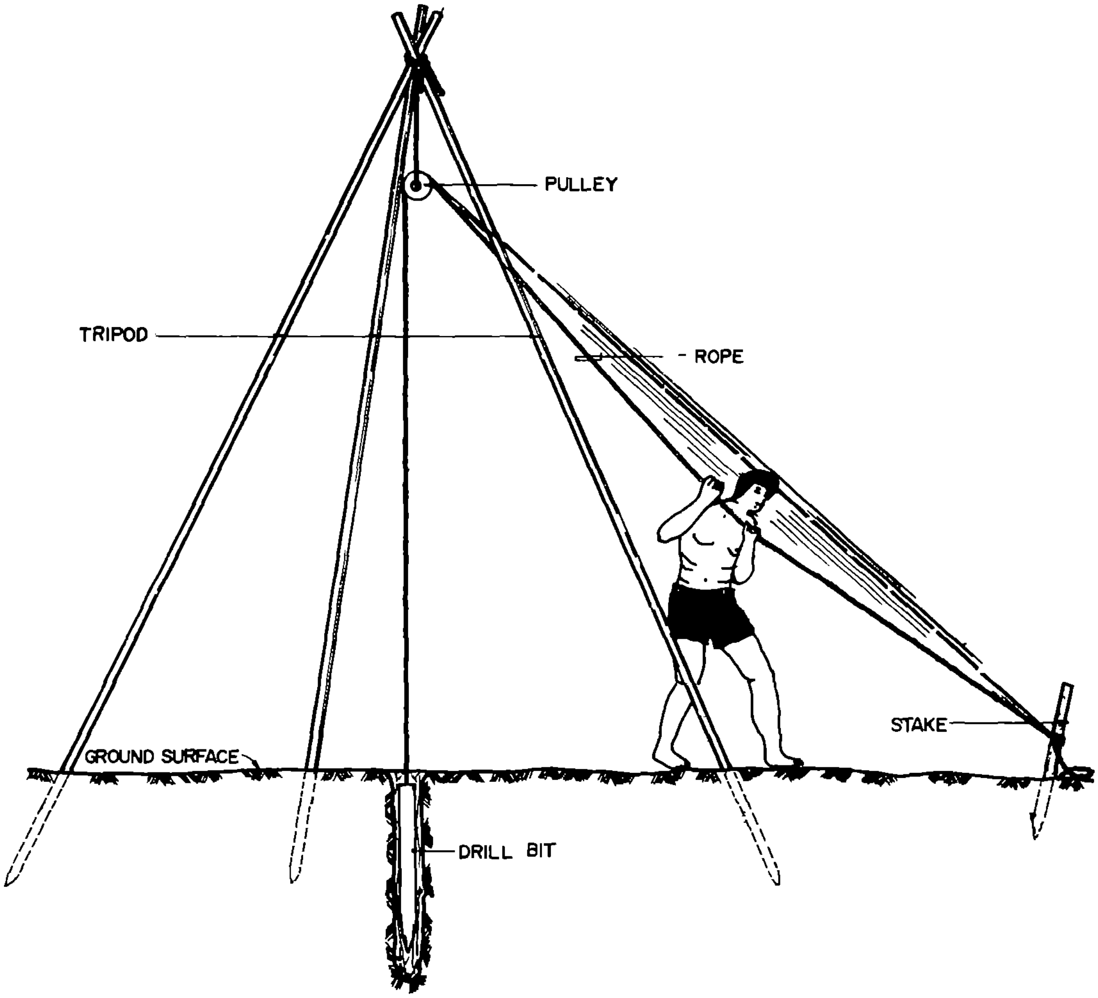


FIGURE 5.6

MANUAL PERCUSSION RIG

CHAPTER 6

DISINFECTION

Disinfection is primarily employed to control the spread of communicable waterborne diseases by killing pathogenic organisms found in drinking water. Disinfection is carried out through physical action, mechanical action or use of oxidizing agents.

6.01 MEANS OF DISINFECTION

1) **Physical action** — through direct application of force or energy. It includes boiling and exposure to the ultra-violet rays of the sun.
2) **Oxidizing Agents like Chlorine, Bromine and Ozone** — Chlorine is the most common and effective means of killing bacteria. The mechanism is discussed in detail in the next section.
3) **Mechanical Action** — this process includes the removal of bacteria by filtration, coagulation and sedimentation.

6.02 FACTORS AFFECTING CHLORINE DISINFECTION (*Chlorination*)

Chlorine (and its compounds) is the most widely used disinfectant for water supplies firstly because of its effectiveness and secondly because it is cheap and readily available.

The destruction of bacteria through chlorination consists of two processes: The penetration of the cell wall or covering (skin) of bacteria and the reaction with the body enzymes which cause the inactivation of the body cells and consequently results in the death of the microorganism.

The factors affecting the effectiveness of chlorination are:

a. time of contact
b. nature and concentration of pathogenic bacteria
c. chlorine dosage
d. the temperature of water to be disinfected

6.03 TERMINOLOGY AND DEFINITIONS

1) **Available Chlorine Content** — is the potential disinfecting power of chlorine compounds.
2) **Chlorine Demand** — is the total amount of chlorine used in destroying the bacteria completely. In case where organic matter, iron manganese, etc. are present, chlorine demand includes the amount of chlorine used in oxydizing these substances. To compute

chlorine demand, find the difference between the amount of chlorine added to water and the amount of residual chlorine remaining at the end of a specific contact period.

3) **Chlorine Residual** — is the total amount of chlorine (combined and free available chlorine) remaining in water at the end of a specific contact period following chlorination.

4) **Dosage of Chlorine** — is the quantity of chlorine applied to a specific quantity of water. Dosage is usually expressed in mg/1 of chlorine.

5) **Dosage Rate** — is the amount of chlorine applied per unit time. It is usually expressed in gm/day or kg/day.

6.04 CHLORINE AND CHLORINE COMPOUNDS USED IN DISINFECTION

1) **Chlorine** — Chlorine is a poisonous yellow-green gas with penetrating odor. In water, chlorine hydrolyses to form the hypochlorous acid and the hypochlorite ion (free available residual chlorine) which are very toxic to bacteria. Chlorine gas is available in cylinder tanks.

2) **Bleaching Powder or Chloride of Lime** — Bleaching powder losses strength rapidly whenever it is exposed to moist air so that it should be kept in closed containers.

3) **High-Test Hypochlorite (HTH)** — It is a more stable and stronger compound but is more costly than bleaching powder.

4) **Sodium Hypochlorite (NaOC1)** — it is manufactured by electrolysis of brine.

Shown in Table 6.1 is the per cent available chlorine of various chlorine compounds.

Table 6.1

Per Cent Available Chlorine of Various Chlorine Compounds	
Materials	Per Cent Available Chlorine
1) Chlorine, Cl_2	100
2) Calcium Hypochlorine (HTH)	70-74
3) Bleaching Powder	35-37
4) Sodium Hypochlorite	12-15

6.05 CHLORINE DOSAGES

1) For disinfection of water supplies

a. Dosage : 0.2 — 0.7 mg/l
b. Contact time : 15 — 30 minutes

2) For disinfection of newly constructed/repaired wells, storage tanks, pipelines, spring box, etc.

   a. Dosage : 50 mg/l
      Contact time : 24 hours
   b. Dosage : 300 mg/l
      Contact time : 1 hour

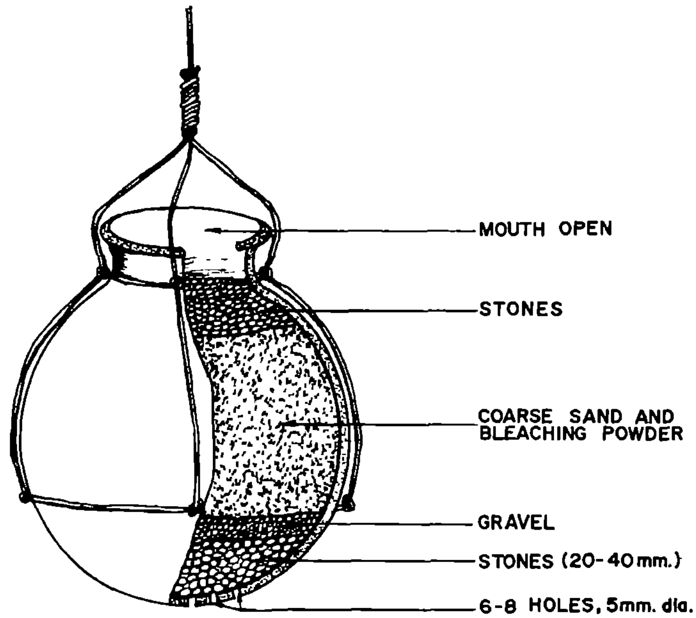
   Sample problems in computing chlorine dosages are presented in Appendix K.

6.06 EQUIPMENT USED IN CHLORINATION

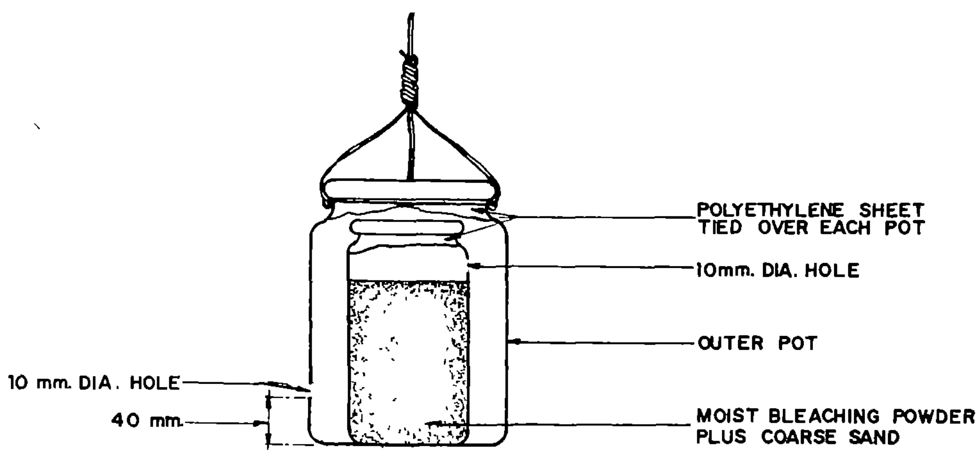
1) **Pot Chlorinator** — Shown in Figure 6.1 is the pot chlorinator. It is the simplest equipment used in disinfecting wells. The process consists of suspending a pot containing a mixture of coarse sand and bleaching powder or any chlorine containing powder into the well.

2) **Floating Bowl Chlorinator** — Shown in Figure 6.2 is the set-up of floating bowl chlorinator. The arrangement shows the bowl with a hole at the bottom which is fitted with a rubber or cork stopper. Passing through the stopper are two tubes. One tube is connected to the outlet and to the well or reservoir and the other is fixed with its top slightly below the liquid level so that the solution spurts up into the bowl and down through the other tube. As the liquid level drops, the bowl also drops always floating on the surface and maintaining a constant head in the discharge tube.

The taut nylon string as shown in the figure functions as stabilizer. The flow from the chlorinator can be controlled by adjusting the tube which conveys the solution into the bowl. The flow is reduced by moving the tube upward which results in the reduction of height between its tip and the liquid level in the tank (as shown in Figure 6.2) and therefore reduces water getting into the bowl.



SINGLE POT SYSTEM

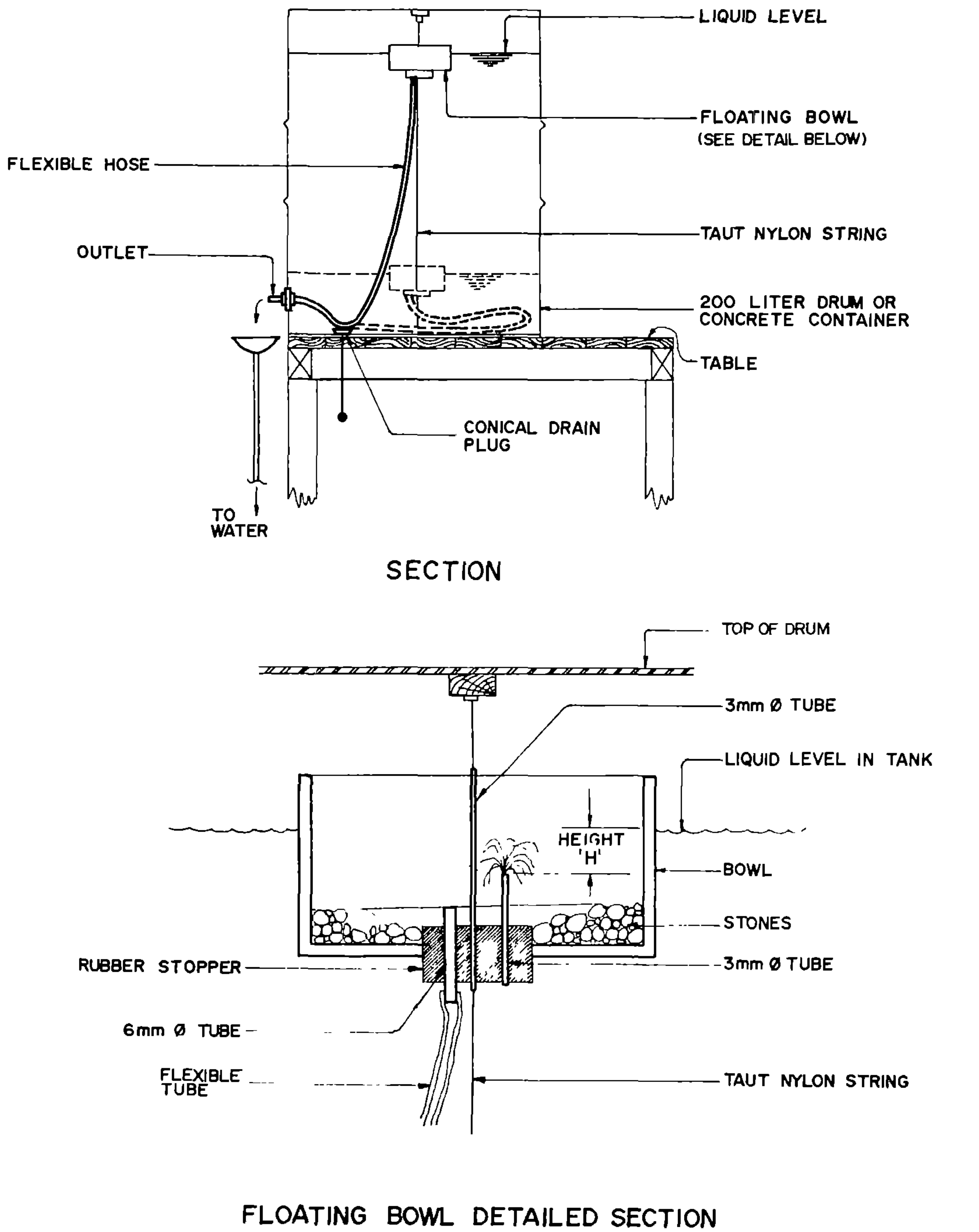


DOUBLE POT SYSTEM

SOURCE SMALL WATER SUPPLIES BY S CAIRNCROSS and R. FEACHEM

FIGURE 6.1

POT CHLORINATOR



SOURCE SMALL WATER SUPPLY
BY S. CAIRNCROSS and
R FEACHEM

FIGURE 6.2

FLOATING BOWL CHLORINATOR

CHAPTER 7

WATER TREATMENT

7.01 PRIMARY CONSIDERATIONS IN THE DESIGN OF WATER TREATMENT SYSTEMS FOR RURAL COMMUNITIES

In the design of water treatment systems, the financial capability and technical know-how of the people must be of prime consideration. Firstly, because these people will never spend a greater part of their income for water even though it is of first class quality. They will first satisfy their primary needs like clothing, food, etc. Secondly, in order for the project to be successful, the participation of the villagers in the operation of the water treatment system is vital.

Thus, the following factors should be taken into account when designing a low cost rural water supply system:

a. The operation of the water treatment plant must be simple.

b. The local materials, construction techniques, skills and others must be available locally.

c. Treatment must be avoided if there are other available sources of water.

7.02 SLOW SAND FILTRATION

Slow Sand Filtration is a cheap and simple method of purifying water. It is the method chosen for water purification in rural areas and in small communities in European countries. It has great advantage over other methods — it can use local skills and materials, it is less expensive and easier to operate. Shown in Figure 7.1 is a schematic diagram of a slow sand filter and filtered water reservoir.

A slow sand filter is composed of a large tank (filter box) containing a sand bed. Water is introduced at the top and it trickles down through the sand bed to the underdrain and goes to the storage tank. The impurities in the water are retained in the upper layers of the sand bed. Furthermore, in the uppermost layer, a slimy layer consisting of bacteria and microscopic plants grows. These layers remove the organic matter and most of the pathogenic microorganisms in water which might be smaller than the pores of the sand.

Usage and Limitations

a. To reduce bacterial count by 85% — 99% depending on the initial count.

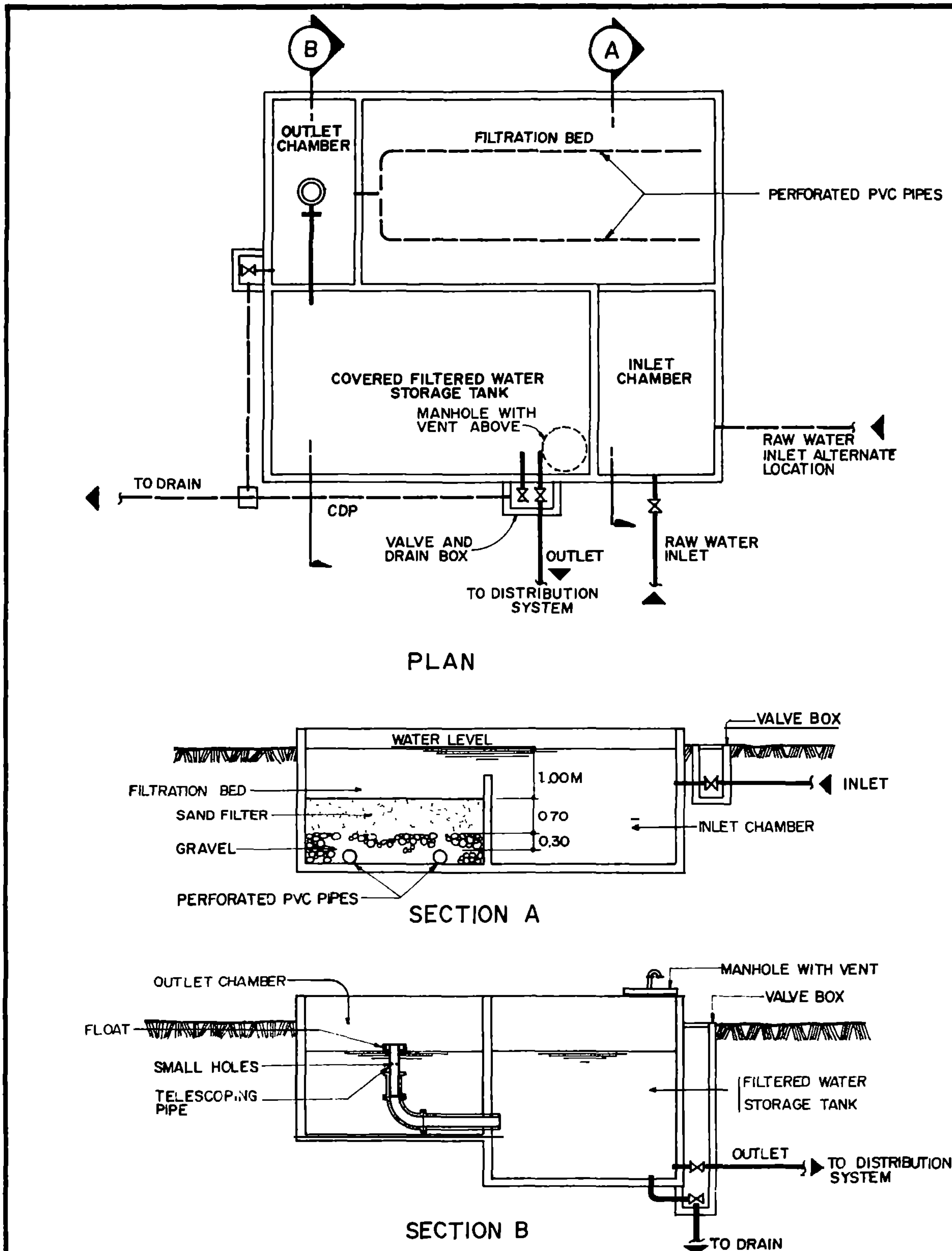


FIGURE 7.1

SCHEMATIC DIAGRAM OF SLOW SAND FILTER AND FILTERED WATER STORAGE TANK

b. To reduce turbidity from about 50mg/L (the maximum permissible level) to 5 mg/L or less of the raw water. Water with turbidity greater than 50 mg/L should be subjected to coarse infiltration or pre-sedimentation process before slow sand filtration. Otherwise, this will result in short filter runs.

c. To remove color. The degree of removal depends upon the size of sand grains and the rate of filtration.

7.03 AERATION

Aeration is a method of bringing water in intimate contact with air to improve the chemical and physical characteristics of the water. It is done by spraying water in well-ventilated tanks, by allowing water to flow in thin sheets over a series of steps or weirs, or by introducing fine bubbles of air in the water. There are four types of aerators, namely: gravity aerators, spray aerators, diffusers and mechanical aerators. Shown in Figure 7.2 is the spray gravity aerator.

Aeration is employed:

a. To remove taste and odors caused by dissolved gases like hydrogen sulfide.

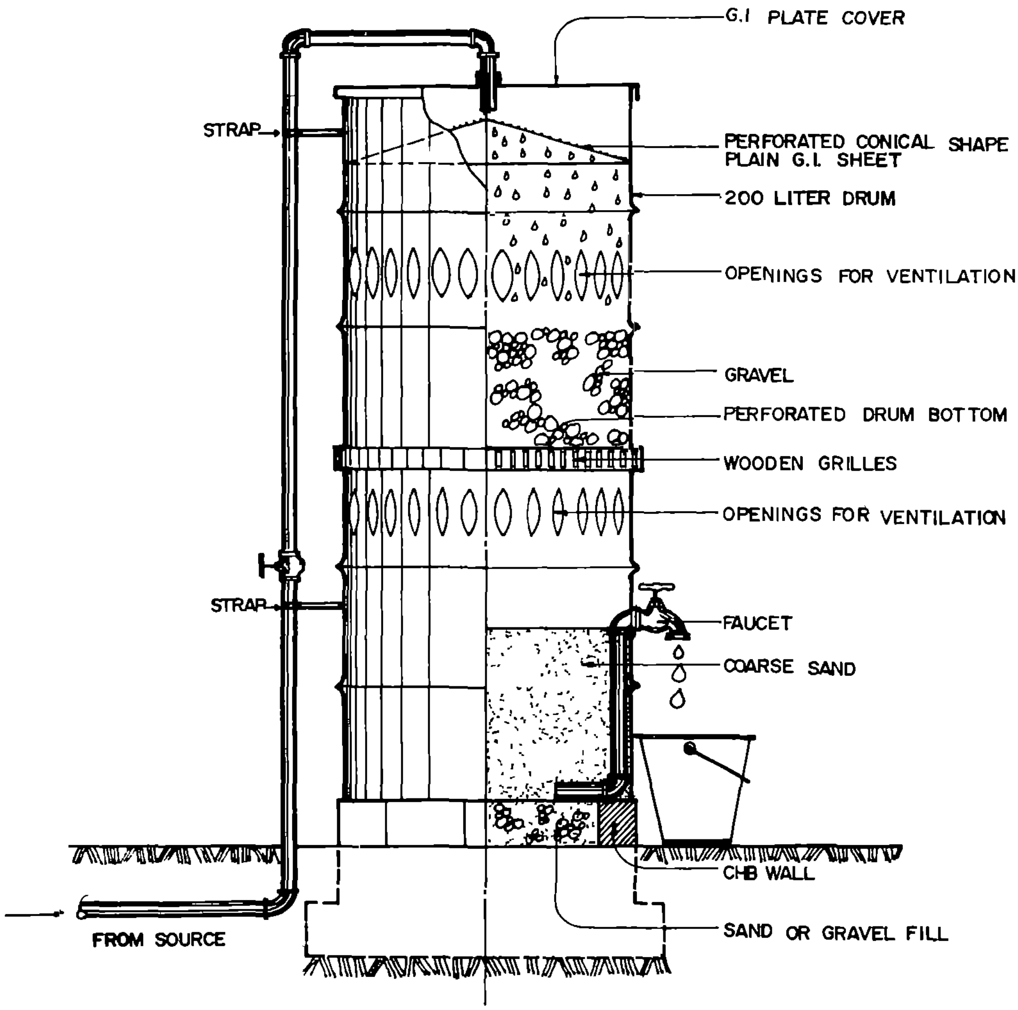
b. To remove iron and manganese through oxidation. Dissolved iron and manganese upon contact with free oxygen from air will form an insoluble precipitate which could be removed by subsequent filtration.

c. To expel carbon dioxide and other obnoxious gases like hydrogen sulfide (H_2S). Excessive amounts of carbon dioxide make water corrossive and dissolve iron in the piping system.

7.04 WATER SOFTENING

Water softening is the process of removing hardness from water supplies. Hardness is caused primarily by the presence of calcium and magnesium salts like calcium bicarbonate, magnesium bicarbonate, calcium and magnesium sulfate, and calcium and magnesium chloride.

By itself hardness is not harmful to man although in large quantities it necessitates the use of more soap when washing clothes, dishes, etc. Water softening is not recommended in rural water supply for it is expensive.



HALF ELEVATION / HALF SECTION

FIGURE 72
SCHEMATIC DIAGRAM OF SPRAY AERATOR SYSTEM FOR THE REMOVAL OF IRON AND MANGANESE

CHAPTER 8

WATER DEMAND

Knowledge of the quantity of water needed to satisfy the requirement of the community is necessary in the design of any water supply system. In rural areas, water is utilized mainly for domestic consumption. The factors affecting domestic consumption are:

1) Size of the community.
2) Standard of living of the consumer.
3) Quality and quantity of water available.
4) Cost of water to consumers.
5) Habits and manner of usage of the consumers.
6) Climate.
7) Livestock, poultry, hogs and other animals being raised by the residents.
8) Plants and gardens being maintained by the residents.

In addition to domestic consumption, allowance should be made for leakages and pilferages. Ideally, this should not be more than 15% of the total water sent to the distribution system.

8.01 TERMINOLOGY AND DEFINITIONS

1) **Water Consumption** — Amount of water consumed by all residents, institutions, etc. when provided with water service facilities.
2) **Water Demand** — The sum of water consumption and unaccounted for water.
3) **Unaccounted For Water** — The amount of water losses thru leakages and pilferages.
4) **Average Day Demand** — The Average Day Demand is the sum of the daily water demands in one year divided by the number of days of that year.
5) **Maximum Day Demand** — Largest one-day water demand. In the example cited the day with the highest water demand is the maximum day demand. Normally this occurs during dry season generally on a Monday.
6) **Maximum Hour (Peak Hour) Demand** — Any hour of the day when the water demand is at its maximum. In most places this occurs early morning at 7 or 8.

7) **Design Period** — The number of years in which the proposed system and its component structures and equipment are expected to serve the population adequately.

8) **Design Population** — the population of the area to be served within the design period.

8.02 DESIGN CRITERIA

The objectives of the design criteria are to establish goals such that if the criteria are met, consumers will receive water at reasonable quantities and cost. However, during the planning process, it may be necessary to modify the criteria to accommodate special requirements of the locality.

8.03 DEMAND FACTORS

In planning, it is always important to know the maximum or peak hour demand, maximum day demand, average day demand and the distribution of demand throughout the day. The maximum hour demand is the most critical factor in establishing pipe, pump and reservoir sizes.

8.04 DESIGN PERIOD

The effective life of the project is dependent upon the size and source of the water supply system, the life span of pumps, pipelines, and storage tanks, and the availability of funds to finance the project. For rural water supply systems, the design periods recommended for the following appurtenances are:

1) Pumps: 5.0 years
2) Wells, pipelines, and storage tanks: 5 years, but the life of the system may last up to 20 years.

8.05 DESIGN POPULATION

The design population is equal to the present population multiplied by 1.15. Stated mathematically:

$$Pp = 1.15*P$$

where: Pp = Projected population at the end of the design period
P = present population

*Based on 3% annual increase of population for the design period of 5 years (0.03 × 5 = 0.15)

8.06 WATER CONSUMPTION RATES STUDY ON PUBLIC FAUCET SYSTEM AND INDIVIDUAL HOUSEHOLD CONNECTION

A study was conducted to determine the water demands in rural areas. The description of the study area and the result of the investigation is presented in detail in Appendix J. Basing on the outcome of this study, the following figures are recommended:

1) Water Consumption Rates
   - Public Faucet System — 60 LPCD
   - Household Connection — 100 LPCD
2) Average Day Demand — Design Population × Water Consumption Rate
3) Maximum Day Demand — 1.30 × Average Day Demand
4) Maximum Hour Demand
   - Less than 100 HH or 600 persons — $\frac{3.0 \times \text{Average Day Demand}}{24}$
   - More than 100 HH or 600 persons — $\frac{2.5 \times \text{Average Day Demand}}{24}$

8.07 WATER CONSUMPTION FIGURES

Water consumption varies greatly depending upon its usage and the number of users. In rural areas, it is mainly utilized for domestic purposes, i.e., for drinking, cooking, bathing, and washing. Shown in Table 8.1 are the average water consumption rates obtained from different sources.

Table 8.1

WATER CONSUMPTION RATES
(in liters per capita per day, LPCD)

Use	Cairncross & Feachem	Wagner & Lanoix	Wright F.B.	DCCD*
1) Public Faucet	20	15	—	60
2) Individual Household Connection	200	250	208	100
3) Combined Public Faucets and some Household Connection	—	—	—	80

*Water losses included

Example 8.1 Sample Problem in Computation of Water Demand

Date:

Barrio	: Sinisian, East Lemery, Batangas
Population	: 703

Design Criteria:

Water Consumption Rate	: 60 LPCD
Peaking Factor	: 2.5 (population is more than 600 persons)

Analysis:

1) **Calculate the Design Population**

Pp = 1.15 P

= 1.15 (703) = 808

2) **Calculate the Average Day Demand**

Average Day Demand = Design Population × Water

= Consumption Rate

= 808 × 60

= 48,480 LPD

3) **Calculate the Maximum Day Demand**

Maximum Day Demand = 1.3 × Average Day Demand

= 1.3 × 48,480 LPD

= 63,024 LPD

4) **Calculate the Maximum Hour Demand (Peak Hour)**

Maximum Hour Demand= 2.5 × Average Day Demand

= 2.5 × 48,480 ÷ 24

= 5050LPH

5) **Significance of Various Water Demand Figures:**

a.

Average Day Demand

1) Used in the design of reservoir capacity.

b.

Maximum Day Demand

1) Used in determining the minimum pump capacity. (Except in Hydropneumatic Pressure System)

c.

Maximum Hour Demand

1) Used in estimating the diameter of transmission and distribution mains.
2) Used in estimating the minimum pump capacity in Hydropneumatic Pressure System.

CHAPTER 9

APPLIED HYDRAULICS

Hydraulics is concerned with the behavior of fluids both at rest and in motion. This chapter shall deal mainly on the hydraulics of water in closed conduits or pipes.

The principal factors that affect the flow of fluids in pipes are:

1) Cross sectional area of pipe.
2) Roughness of interior pipe surface.
3) Conditions of flow, i.e., full, steady, or varied flow.
4) Presence or absence of obstructions, bends, etc.
5) Specific gravity and viscosity of the liquid and other characteristics.
6) Available energy or head.

9.01 FACTORS THAT DESCRIBE AND DETERMINE THE RATE OF FLOW IN PIPES

1) **Hydraulic Grade Line.** The hydraulic gradeline, as shown in Figure 9.1 is a line connecting the points to which the liquid would rise in piezometer tubes if inserted at various places along any pipe. It is the measure of the pressure head available plus the elevation of the pipe at these various points.

2) **Energy Grade Line.** The energy gradeline is illustrated in figure 9.1. The total energy of flow in any section with reference to some datum is the sum of the elevation head (H) of the pipe, the pressure head (Hp), and the velocity head (Hv). Also shown in the figure is the head loss, (h_1) which is the loss of energy in transporting water from point 1 to 2.

3) **Slope.** The head loss per unit length of pipe.

4) **Equivalent Length.** Fittings, valves, etc. are reduced to an equivalent length of straight pipe of same diameter. This is especially useful in the computation of head losses in valves, fittings, etc. (Table 9.3).

9.02 WATER PRESSURE

1) **Basic Principles**

Pressure is defined as the force exerted per unit area.

$$P = \frac{\text{Force}}{\text{Area}} = \frac{F}{A}$$

Where: P = Pressure, kgf/cm^2
F = Force, Kgf
A = Area, cm^2

The force represents the weight of a column of water above a certain point. The weight then is equal to the volume of the column of water multiplied by the specific weight of water. Specific weight of water equals 1 kg_f/liter or 1000 kg_f/M^3

Example No. 9.1 Calculate the pressure at the bottom of a tank full of water having the following dimensions:

Date:

Shape of Tank	:	Square
Side Dimension	:	20 cm.
Height of Tank	:	40 cm.

Analysis:

1) Calculate the volume, V and Area of the Bottom, A.

$A = 20 \times 20 = 400 \text{ cm.}^2$

$V = AH = 400 \times 40 = 1600 \text{ cm.}^3$

2) Calculate the weight of water in the tank, W

$W = \text{Specific Weight} \times V$

$1 \text{ CUM } (M^3) = 1{,}000{,}000 \text{ cm.}^3$

$$W = \frac{1 \text{ Kgf}}{\text{liter}} \times 16{,}000 \text{ cm}^3 \times \frac{1 \text{ liter}}{1{,}000 \text{ CM}^3} \approx 16 \text{ Kgf}$$

3) Calculate the pressure:

$1 \text{ Kgf/cm}^2 = 10 \text{ meters head of water}$

$$P = \frac{F}{A} = \frac{16}{400} \; 3 \; 0.04 \text{ Kgf/cm}^2 = 0.4\text{M}$$

2) Static Water Pressure

Static water pressure is the pressure in the system when water is not flowing. It is an indication of the potential pressure available in the system. Static pressure can be produced by:

a. Placing the water at an elevation above the location of water use. Some examples are storing rainfall in elevated tanks, storing water in elevated reservoirs, etc.

b. Imparting energy to the water through a pump.

c. Air pressure in hydro-pneumatic tank.

Example No. 9.2 Determine the pressure at places of different elevations in the system shown in Figure 9.2.

At Point A, the static Pressure	=	0
At Point B, the static Pressure	=	6 M.
At Point C, the static Pressure	=	6 M.
At Point D, the static Pressure	=	9 M.
At Point E, the static Pressure	=	9 M.
At Point F, the static Pressure	=	8 M. (9-1)
At Point H, the static Pressure	=	8 M.
At Point G, the static Pressure	=	5 M. (6-1)

3) **Dynamic Water Pressure**

The dynamic water pressure is the pressure at any particular point with a given quantity of water flowing past that point. Dynamic pressure differs from static pressure in that it varies throughout the system due to the friction losses during the transport of water. In this manual, the dynamic and static pressure terms are expressed simply as pressure or head.

9.03 FRICTION LOSS

Friction loss is the loss of pressure caused by water flowing through the pipe in a system. Flow in pipes is usually turbulent and the roughness of the inside walls of pipes have a direct effect upon the amount of friction loss. Turbulence increases and consequently friction loss increases with the degree of roughness.

Friction loss is thus determined by the type, size and length of the pipe and the amount of water flowing through it.

Friction loss in plastic pipes and galvanized iron (G.I.) pipes can be estimated using Table 9.1 and Table 9.2, respectively. The information necessary to determine the pressure loss are the pipe size and the discharge rate, Q. Also, Tables 9.1 and 9.2 can be used to determine pipe sizes if the discharge rate and friction loss are given.

Furthermore, when water flows past valves, fittings and public faucets, there is a loss in energy due to friction. This loss of energy can be calculated by the use of Table 9.3 and 9.1 or 9.2. The pipe fittings, valves and public faucets are first reduced to an equivalent length of straight pipe using Table 9.3 and then the corresponding friction loss is determined using Table 9.1 or 9.2.

Example No. 9.3. A pipe 200 M in length and 19 mm in diameter carries water at the rate of 0.20 liters per second. How much head or pressure would be lost due to friction if PVC pipe is used? If G.I. pipe is used?

Given: Length of Pipe = 200 M
Q = 0.20 LPS

Required: Friction Loss
a. If PVC Pipe is Used.
b. If G.I. Pipe is Used.

Solution: A. The pipe material is PVC

1) Determine the friction loss per 100 M

Referring to Table 9.1 locate Q = 0.2 LPS and move horizontally until the column for 19 mm O is reached. Read the figure.

From the table, the friction loss is h_L = 3.8 M/100 M of pipe length.

2) Calculate the friction loss, h_f of 200 M length of PVC pipe, Hf = HL × L h_F = 3.8 M/100 × 200 M = 7.6 M.

HL × L h_F = 3.8 M 100 × 200 M = 7.6 M.

B. The Pipe Material is G.I.

The friction loss, h_1 for G.I. pipes is determined using Table 9.2, with Q = 0.2 LPS and D = 19 mm.

h_L = 7.6M/100 M (From Table 9.2)

$$h_f = \frac{7.6\ M}{100\ M} \times 200\ M = 15.2\ M$$

Example No. 9.4. A 240 M length of pipe will be used to convey water from a spring located at top of the hill to the barrio reservoir (Figure 9.3A) The elevation of the spring is 3.0 M higher than the maximum water surface elevation of the reservoir and therefore, the water can be transported through gravity flow. If the desired flow is 1.4 LPS, what size of pipe should be used if PVC pipe is used? If G.I. pipe is used?

Given: Length of pipe = 240 M
Pressure Head Available H_p = 3 M
Q = 1.4 LPS

Required: Pipe Size

a. If PVC Pipe is used.
b. If G.I. Pipe is used.

Solution: a. The pipe material is PVC

The minimum pipe size can be obtained when the available head or pressure will equal to friction losses when water is flowing at the desired Q = 1.4 LPS.

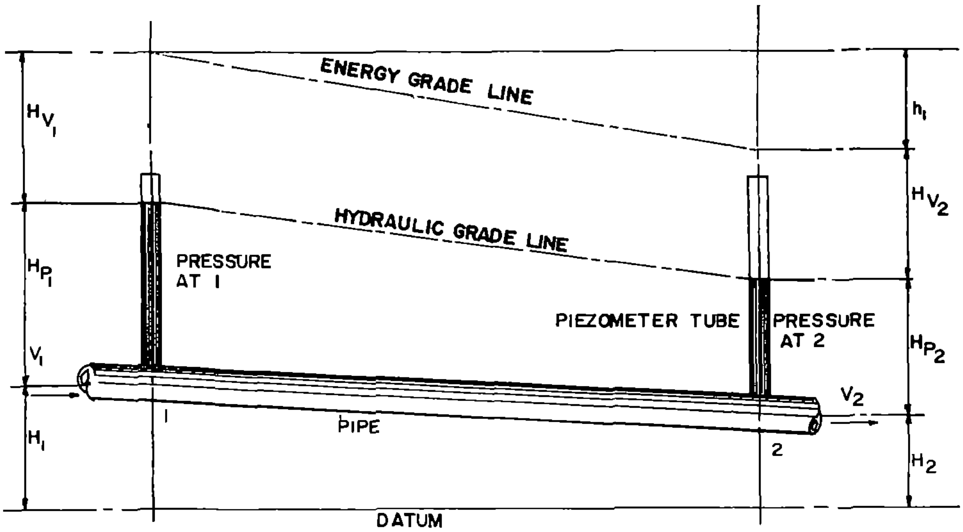
$h_f = H_p$

$h_f = h_L \times L$

$H_p = h_L/100\ M \times L$

$h_L = H_p/L \times 100 = 3/240 \times 100 = 1.25$

Referring to Table 9.1, locate Q = 1.4 LPS and move horizontally until h_1/100M = 1.25 is found in or any value found in Table 9.1 which is nearest to 1.25. Find the column of pipe size having this friction loss. From Table 9.1, the nearest value to 1.25 M is 1.20 which is found in the column of pipe size with the size of 50 mm. Therefore, a 50 mm PVC pipe can transport water from the spring to the reservoir.



LEGEND :

H_V = VELOCITY HEAD = $\frac{V^2}{2g}$

V = VELOCITY OF FLOW

g = ACCELERATION DUE TO GRAVITY

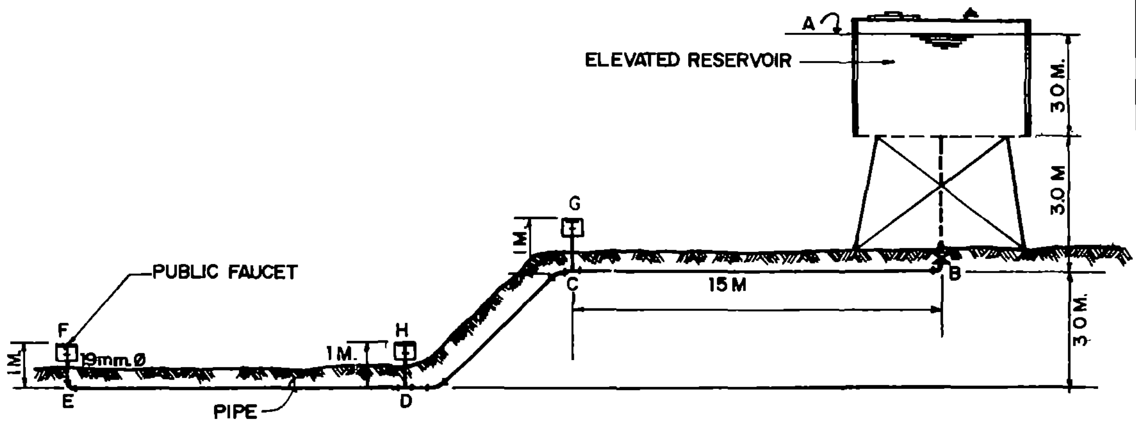
H_P = PRESSURE HEAD

H = ELEVATION OF PIPE

h_l = FRICTION LOSS

FIGURE 9.1

PIPE FLOW



EXAMPLE 2

FIGURE 9.2

ILLUSTRATION SHOWING ELEVATION PRESSURE EFFECTS

Q	PIPE SIZES (mm.)									
LPS	13	19	25	31	38	50	63	75	100	150
01	0.1									
02	0 4									
03	0 8	0 11								
04	1 4	0 19								
05	2 1	0 30								
06	3 0	0.41	0 10							
07	4 0	0.50	0 13							
08	5 0	0 65	0.17							
09	6.3	0.82	0 22							
.10	7 6	1 06	0 26							
11	9 1	1 18	0.31	0 11						
.12	10 7	1 50	0.36	0 13						
14		2 00	0 48	0.17						
15		2 10	0 55	0.18						
.16		2 50	0.62	0 22						
18		3 10	0 77	0.27	0 101					
.20		3 80	0 94	0.32	0 131					
25		5 80	1.42	0 48	0.20					
30			2.00	0 67	0 23					
40			3 40	1.15	0 47	0.12				
50			5 10	1.74	0 71	0 18				
60			7 20	2 40	1.00	0 25				
70				3 20	1 33	0 33	0.11			
.80				4.10	1.70	0 42	0 14			
1 00				6 30	2 60	0 64	0 21	0 089		
1 20				8 80	3 60	0 89	0 30	0.124		
1 40					4 40	1.20	0.40	0.165		
1 50					4 90	1 35	0.44	0 187		
1 60					5.50	1.52	0 51	0.211		
1 80					7.35	1 88	0 64	0 262		
2 00					8 40	2 30	0 77	0.320	0 079	
2.50						3 50	1 20	0.48	0 119	
3 00						4.95	1 65	0 68	0 166	
3.50						6 95	2 19	0 90	0 221	
4 00						9.20	3.00	1 15	0 184	
4.50						11.85	3 60	1 43	0.353	
5 00							4 50	1 74	0.429	0 06
6 00							6 20	2.44	0.60	0 09
7 00							8.60	3 20	0.80	0 11
8 00								4 15	1.20	0 14
10.00								6 50	1 55	0.21

FRICTION HEAD LOSS IN METERS PER 100 METERS
PLASTIC PIPE - PVC, PE, PB C = 150

TABLE 9.1

FRICTION HEAD LOSS IN PLASTIC PIPES

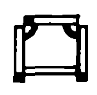
Q	PIPE SIZES (mm)									
LPS	13	19	25	31	38	50	63	75	100	150
0 01	0.20									
0 02	0.80									
0 03	1 60	0.22								
0 04	2 80	0.38								
0.05	4 20	0 60								
0 06	6 00	0 82	0 20							
0.07	8 0	1 00	0.26							
0 08	10 00	1.30	0 34							
0 09	12 60	1 64	0 44	0.15						
0.10	15.20	2.12	0 52	0 18						
0 11	18 20	2.36	0 62	0 22						
0 12	21.40	3 00	0.72	0.26						
0 14		4 00	0 96	0.34	0 13					
0 15		4 20	1 10	0 36	0 15					
0.16		5.00	1 24	0 44	0 16					
0.18		6.20	1 54	0 54	0 202					
0.20		7 60	1 88	0 64	0.262	0 70				
0 25		11 60	2.84	0 96	0 400	0.10				
0 30			4 00	1.34	0.46	0 14				
0.40			6 80	2 30	0.94	0.24				
0 50			10 20	3 48	1 42	0.36	0 12			
0 60			14 40	4 80	2 00	0.50	0 17	0 70		
0.70				6 40	2 66	0 66	0 22	0.91		
0 80				8 20	3 40	0 84	0 28	0.117		
1.00				12.60	5.20	1 28	0 42	0.177		
1 20				17.60	7 20	1.78	0 60	0 248		
1 40					8 80	2.40	0 80	0 330		
1 50					9.80	2 70	0 88	0 374		
1 60					11 00	3.04	1 02	0 422	0 104	
1.80					14 70	3.76	1 28	0.524	0 '129	
2 00					16.80	4 60	1 54	0 640	0 157	
2.50						7.00	2 40	0 96	0.238	
3 00						9 90	3 30	1 36	0 332	
3.50						13 90	4.38	1 80	0.442	
4.00						18 40	6.00	2 30	0.368	
4 50						23 70	7.20	2.86	0 706	
5.00							9 00	3.48	0.858	0 12
6.00							12.40	4.88	1 200	0 17
7 00							17.20	6 40	1 60	0 22
8 00								8.30	2 40	0.28
10.00								13 00	3.10	0 42

FRICTION HEAD LOSS IN METERS PER 100 METERS
GALVANIZED IRON PIPE (GIP)

TABLE 9.2

FRICTION HEAD LOSS IN G.I. PIPES

RESISTANCE OF VALVE AND FITTINGS*

NOMINAL DIA. IN. MILLI-METERS	90° ELBOW	45° ELBOW	STAND. T	GATE VALVE FULLY OPEN	GLOBE VALVE FULLY OPEN	ANGLE VALVE FULLY OPEN	FAUCET FULLY OPEN	FOOT VALVE FULLY OPEN	STRAINER	CHECK VALVE FULLY OPEN
										
	EQUIVALENT LENGTH STRAIGHT PIPE, METERS									
13	0.55	0.24	1.04	0.11	4.88	2.56	4.88	1.22	3.05	1.16
19	0.69	0.30	1.37	0.14	6.40	3.66	6.40	1.52	3.66	1.58
25	0.84	0.41	1.77	0.18	8.23	4.57		1.83	4.27	1.98
32	1 14	0.52	2.29	0.24	11.28	5.49		2.13	4.88	2.74
38	1.36	0.61	2.74	0.29	13.71	6.71		2.44	5.49	3.35
50	1.62	0.76	3.66	0.38	16.76	8.54		2.74	6.10	4.27
63	1.98	0.91	4.27	0.43	19.81	10.06		3.05	6.71	5.18
75	2.50	1.16	4.88	0 53	25.90	12.80		3.66	7.62	5.79
100	3.35	1.52	6.71	0.70	33.54	12.80		4.57	9.15	7.62
150	5.03	2.04	9.76	1.01	48.78	24.39		6.42	12.21	11.59

* WHEN THE LENGTH OF PIPE IS GREATER THAN 1000 TIMES IT'S DIAMETER, THE LOSS OF HEAD DUE TO VALVES AND FITTING MAY BE DISREGARDED.

TABLE 9.3

EQUIVALENT LENGTH OF PIPE FITTINGS, VALVES, ETC.

b. The pipe material is G.I. Pipe.

$h_1/100$ M = 1.25, Q = 1.4 LPS

Referring to Table 9.2 locate Q = 1.4 LPS and move horizontally until $h_1/100$ M = 1.25 is found or any value found in Table 9.2 which is nearest to 1.25. Find the column of pipe size having this friction loss. From Table 9.2, the nearest value of 1.25 is 0.8 which is found in the column of pipe size with the size of 63 mm. A 63 mm G.I. pipe is then suitable.

Example No. 9.5. A gravity storage tank shown in Figure 9.3B is located on a hill. The minimum water surface elevation of 9 meters above the faucet and requires 100 meters of pipe, two 90° elbows, a gave valve, and a 13 mm faucet. The desired flow at the faucet is 0.12 liters per second. What size pipe should be used if a minimum residual pressure of 3 M is to be attained at the faucet?

Given:
H = 9 M of storage tank
L = 100 M
No. of 90° elbows = 2
No. of gate valves = 1
No. of faucet = 1, Dia = 13 mm
Q = 0.12 LPS

Required: Pipe Diameter

Solution:

a. Using PVC pipes, calculate the diameter

1) Calculate $h_1/100$ M disregarding the headloss in fittings and valves

$$h_1/100\ M = H - 3/L \times 100$$
$$= 9 - 3/100 \times 100$$
$$= 6\ M$$

2) Using Table 9.1, calculate the pipe diameter when

Q = 0.12 LPS
$h_1/100$ M = 6M
D = 13 mm

b. Check whether the friction losses in pipes, fittings and valves is equal or less than 6 M.

1) Calculate the equivalent length (EQL) of pipes fittings, valves, etc. using Table 9.3 with D = 13 mm

Material	Diameter	No. of Pieces	EQL/Fitting	EQL
Elbow, 90°	13 mm	3	0.55	1.65
Gate Valve	13 mm	1	0.11	0.22
Faucet	13 mm	1	4.88	4.88
		Total Equivalent Length		6.75 M

2) Calculate the total length. The total length is the sum of the straight pipe and the equivalent length of valves, fittings, etc.

Total Length = 100 + 6.75 = 106.75 M

3) Calculate the friction loss using Table 9.1

When: Q = 0.12 LPS
D = 13 mm

$$\frac{h_1}{100\ M} = 10.7\ M \quad h_1/100\ M = 10.7M$$

Total Headloss, h_f = 10.7/100 × 106.75
= 11.4 M.

Conclusion:
h_f = 11.4 is very much greater than the available head which is 6 M, therefore the pipe size should be increased to the next size which is 19 mm.

4) Check the total head loss using the 19 mm PVC pipe.

a. Determine the equivalent length using Table 9.3

Material	**Diameter**	**No. of Pieces**	**EQL/Fitting**	**EQL**
Elbow, 90°	10 mm	3	0.69	2.07
Gate Valve	19 mm	2	0.14	0.28
Faucet	13 mm	1	4.88	4.88

b. Calculate the total length of Pipe

1) For 19 mm Pipe

Total Length = 100 + 2.07 + 0.28
= 102.35 M

2) For 13 mm Pipe (for Faucet)

Total length = 4.88 M

c. Calculate the total headloss using Table 9.1

1) For 19 mm Pipe with Q = 0.12 and D = 19 mm

h_1/100M = 1.5 M

headloss h_f = 1.5/100 × 102.35
= 1.53 M

2) For 13 mm Pipe with Q = 0.12 LPS and D = 13 mm

$h_1/100\ M = 10.7\ M$

headloss $h_f = 10.7/100 \times 4.88 = 0.52$

3) Calculate the total headloss. The total headloss is the sum of the headloss in pipes 19 mm and 13 mm in diameter.

Total headloss, $h_f = 0.52 + 1.53 = 2.05\ M$

19m Ø pipe was found to be satisfactory because the headloss (2.05 M) incurred is smaller than the available head (6 M.)

Summary of Design	**Length/Number**	**Diameter**
Straight Pipe	100 M	19 mm
Elbow, 90°	3 M	19 mm
Gate Valve	2 M	19 mm
Faucet	1 M	13 mm

CHAPTER 10

MEASUREMENTS

Knowledge of the amount of water a source is capable of producing is important in planning a water supply system. An estimate of the water production will permit the planner to decide for or against the development of water sources like wells and springs. For these sources to be acceptable, they must at least satisfy the maximum day demand of the area to be served.

10.01 TERMINOLOGY AND DEFINITIONS

1) *Static Water Level* — (See Figure 10.1) The vertical distance from the center line of the discharge to the water surface in the well when there is no pumping.
2) *Pumping Water Level* — The vertical distance from the center line of the discharge to the water surface in the well while pumping. During the pumping test, pumping water level is the depth of water surface when the amount of water withdrawn from the well and the amount of replenishment of water to the well is equal.
3) *Drawdown* — The difference between the static water level and the pumping water level.
4) *Yield of Well* — The volume of water per unit time that could be pumped from the well as determined by test pumping.
5) *Yield of Spring* — The volume of water per unit time discharged by the spring.

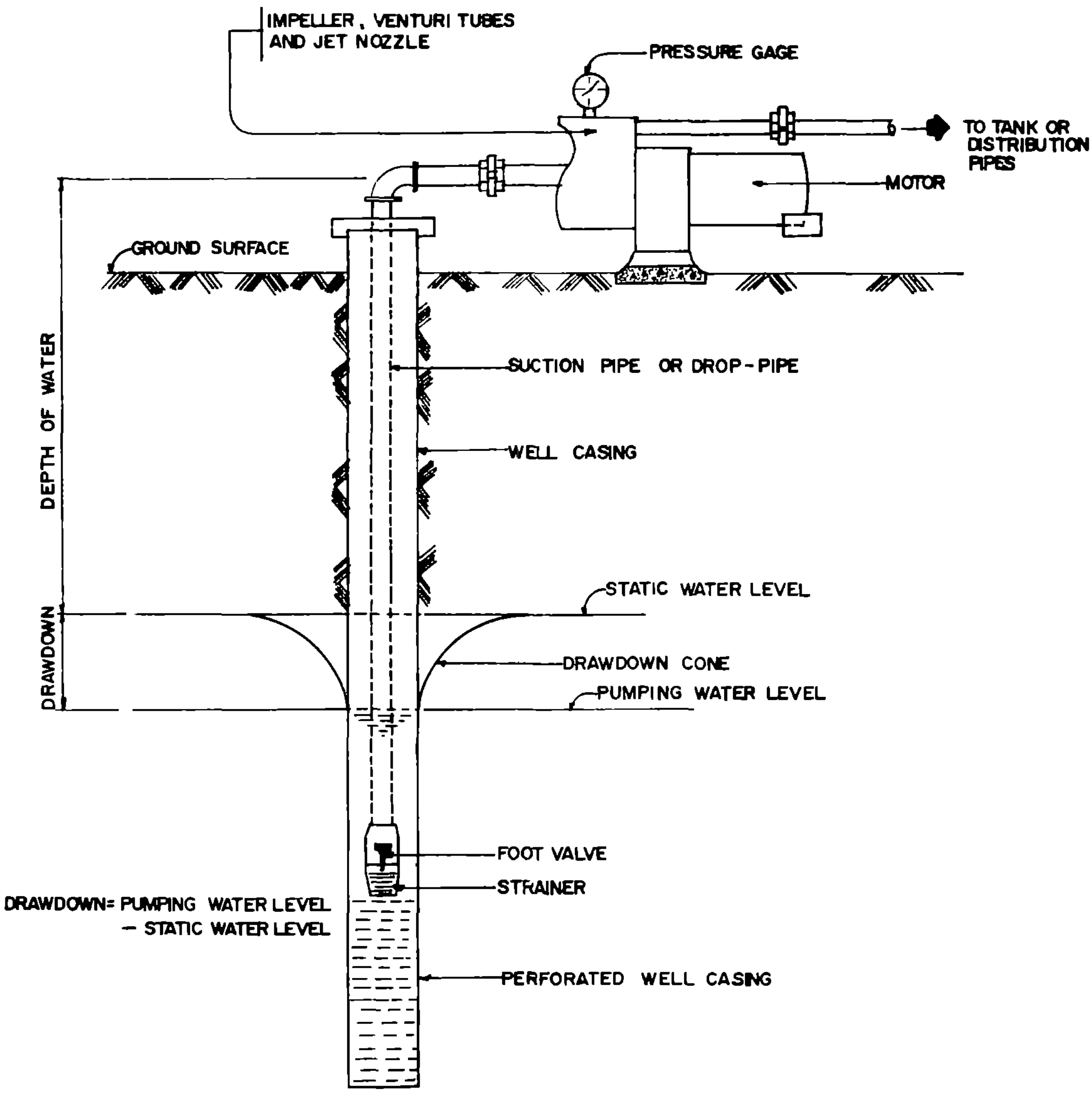
10.02 MEASUREMENT OF DISCHARGE

1) *Volumetric Method* — Flows can be determined by volume measurement. The equipment necessary are a wrist watch or timer and a bucket or oil drum of known volume. The method consists of noting down the time required to fill the bucket. For more accurate results, several trial measurements should be done, and the average of these trials is taken.

Example 10.1: Determine the yield of the well using the volumetric method.

Data:

Volume of oil drum used	:	200 liters
Number of drums used	:	1
Time to fill the drums	:	2 minutes



SHALLOW - WELL JET PUMP

FIGURE 10.1

WELL FEATURES

Solution:

a) Calculate the total volume of water collected, V

V = Volume of oil drum used
= 200 liters

b) Calculate the yield of well, Y

Y = Volume of water collected per unit time
= 200/2 = 100 liters per minute
= 1.67 LPS

2) *V-Notch Weir Method* — A weir is an overflow structure built across an open channel for the purpose of measuring the rate of flow of water. Weirs may be rectangular, trapezoidal or triangular in shape. The Triangular or V-Notch Wier is a flow measuring device particularly suited for small flows. The V-Notch Weir usually used in flow measurements is the 90° V-Notch shown in Figure 10.2.

A 90° V-Notch Weir can be cut from a thin sheet of metal or plywood and is placed in the middle of the channel and water is allowed to flow over it. The water level in the channel is then measured using a gauging rod as shown in Figure 10.2. The zero point in the rod should be level with the bottom of the notch. For a known height of water above the zero point in the rod, the flow in LPS can be obtained by using Figure 10.2 Table A or using the formula;

$$Q = 4.4\ H^{2\ 48}$$

Where:

Q = Discharge rate, liters per second
H = Height of water level on the weir, decimeters.

Example 10.2: Water from the spring is discharged into an open channel and is metered using the V-Notch Weir Method.

Data:
Height of water on the weir measured using the gauging rod = 100 mm

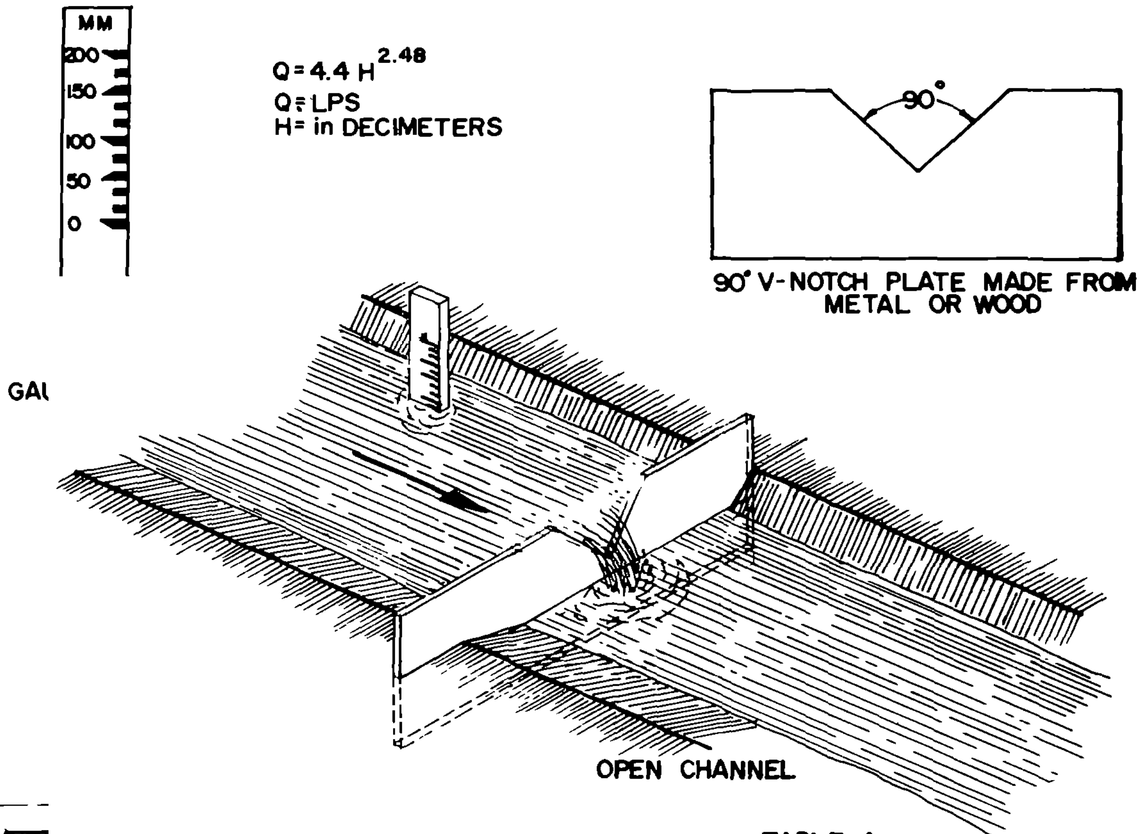
Required:
Water yield of spring.

Solution:

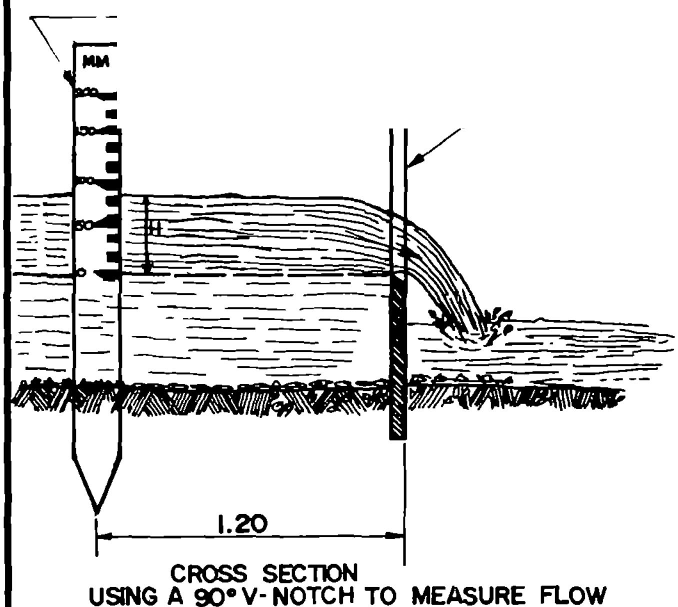
a) Calculate the yield of spring using Figure 10.2 Table A.

Locate under the column "Height of Water" the value H = 100 mm and draw a horizontal line to intersect in the column "Flow". The reading in column "Flow" is,

Q = 4.4 LPS



90° V-NOTCH PLATE MADE FROM METAL OR WOOD



CROSS SECTION
USING A 90° V-NOTCH TO MEASURE FLOW

TABLE A
FLOW OVER A 90° V-NOTCH

OF WATER H (mm)	FLOW (LITERS/SEC.)
50	0 8
60	1.2
70	1 8
80	2 5
90	3.4
100	4 4
110	5.6
120	7.0
130	8 4
140	10.1
150	12.0
160	14.1
170	16.4
180	18.9
190	21.6
200	24.5

FROM: SMALL WATER SUPPLIES, THE ROSS INSTITUTE

FIGURE 10.2

METHOD OF MEASURING FLOW USING A V-NOTCH WEIR

b) Calculate the yield of spring using the formula,
$Q = 4.4\ H^{2.48}$

$H = 100\ mm = 1\ decimeter\ (dm)$
$Q = 4.4\ (1)^{2.48} = 4.4\ LPS$

10.03 MEASUREMENT OF WATER LEVELS IN WELLS

The measurements of static and pumping water levels can be done electrically and manually. These measurements will provide the necessary data which reflect the condition of a well. These data could be interpreted as follows:

Case No.	Static Water Level	Drawdown	Interpretation
1	Dropping	Unchanged	The water table is falling. This means that the acquifer is being depleted faster than it can recharge itself.
2	Unchanged	Increased	The screen or strainer may be clogged and water is not freely flowing into the well.
3	Unchanged	Decreased	There is a loss in the efficiency of the pump.

The usual methods employed on making water level measurements are the electric sounder, the wetted tape and the splashing methods.

1) *Electric Sounder or Electrical Depth Gauge* — An electrode suspended by a pair of insulated wires is lowered into the well (Figure 10.3). When the electrode touches the water surface, closed circuit is produced and flow of current occurs. This is indicated by the attached ammeter. A bulb and flashlight batteries may be used instead of an ammeter. The bulb lights up as the electrode touches the water surface. To improve the accuracy of readings, the electrode and cable should be left hanging in the well for a series of readings. This eliminates any error from kinks or bends in the wires which may change the length slightly when the device is pulled up and let down.

Example 10.3 Determine the Static Water Level, Pumping Water Level and Drawdown of Wells

Data:

Measuring Device	: Electric Depth Gauge
Indicator	: A closed circuit indicates that the lowered cord with attached electrodes reaches the water surface. Closed circuit is indicated by the lighted bulb.

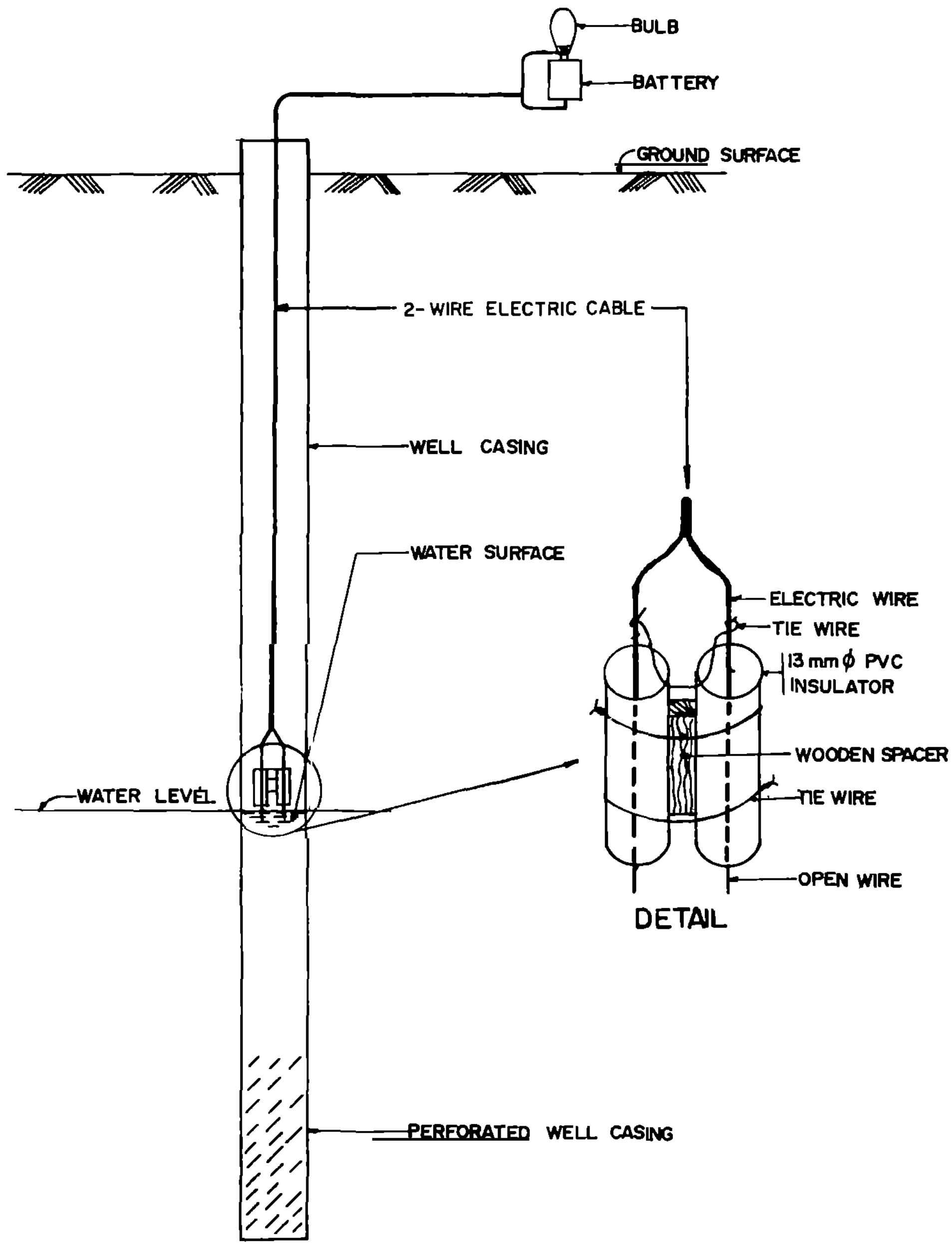


FIGURE 10.3

ELECTRICAL DEPTH GAUGE FOR MEASURING WATER LEVEL

Before Pumping Operation	: Length of cord lowered into the well when the bulb lighted = 12 M
While Pumping Water table is stable	: Length of cord lowered into the well when the bulb lighted = 14M

Required:

a) Static Water Level, SWL
b) Pumping Water Level, PWL
c) Drawdown

Solution:

a) Calculate the static water level

The SWL is the depth of water table from the ground surface before pumping,

SWL = 12 M

b) Calculate the pumping water level

The PWL is the depth of water table from the ground surface during pumping operation when water table is stable.

PWL = 14 M

c) Calculate the drawdown

D = PWL − SWL
D = 14 − 12 = 2 M

2) *Wetted Tape Method* — The wetted tape method is an accurate method of measuring depth of water and can be readily used for depths up to 25 M. First, a lead weight is attached to a steel measuring tape. The lower 60 to 90 cm of the tape is wiped dry and coated with carpenter's chalk or keel before making measurement. The tape is then lowered into the well until a part of the chalked section is below the water surface while the foot mark is held exactly at the top of the casing or at some other measuring point that may have been selected. The tape is then pulled up. The wetted line on tape can be read to a fraction of an inch on the chalk section. The actual depth of the water level is then determined by finding the difference of the reading in the chalk section and the foot mark.

The disadvantage of this method is that the approximate depth of water must be known so that a portion of the chalked section will be submerged each time to produce a wetted line. Where the depth of water is more than 25 meters, the tape is difficult to handle.

Example 10.4 Determine the static water level, pumping water level, and drawdown of wells.

Data:

Measuring Device: Wetted Tape

Before Pumping :

Length of cord from the foot mark to lead weight,

FM_1 = 12.5 M

Length of wetted cord below water surface,

CW_1 = 0.5 M

During Pumping operation when water table is stable:

Length of cord from the foot mark to lead weight,

FM_2 = 14.3 M

Length of wetted cord below water surface,

CW_2 = 0.3 M

Required:

a. Static Water Level, SWL
b. Pumping Water Level, PWL
c. Drawdown, D

Solution:

a. Calculate the static water level

$$SWL = FM_1 - DW_1$$
$$= 12.5 - 0.5 = 12 \text{ M}$$

b. Calculate the pumping water level

$$PWL = FM_2 - CW_2$$
$$= 14.3 - 0.3 = 14 \text{ M}$$

c. Calculate the drawdown

$$D = PWL - SWL$$
$$= 14 - 12 = 2 \text{ M}$$

3) *Splashing Method* — In the splashing method of measuring water levels in wells, a cord or rope with a weight can be lowered into the well until the weight is heard splashing on the water surface. The string is held or marked at the ground surface and then withdrawn. The length of lowered when splashing is heard is the depth of water level in well.

CHAPTER 11

TRANSMISSION AND DISTRIBUTION MAINS

The primary function of transmission lines is to convey water from the source to the distribution mains. From the distribution main, water is distributed to the consumers.

In the selection of the type of distribution system, the water demand and the financial capabilities of the consumers, and the funds available should be the primary considerations. Presently, there are two widely used water distribution systems for household service. They are the household connection system and the public faucet system. The household connection system usually needs a high capital outlay and operational cost, hence, will cost the consumers higher water bills. Because of this factor, public faucets are generally used for water distribution in rural areas.

11.01 THREE GENERAL TYPES OF DISTRIBUTION SYSTEM

1) **Gravity** — Water is distributed to consumers by gravity. This takes place when the water source originates from a higher elevation (usually springs). In gravity systems, the operational cost is very low.
2) **Pumping with Storage** — Water is either pumped to the consumers and storage tanks or to the storage tank then to the consumers. The maintenance of this system is higher than the first.
3) **Pumping Direct to Distribution System** — This is the least desirable of the three alternatives. In this system, water is pumped directly from the source to the consumers. Power failure in this system means complete breakdown of service.

11.02 DISTRIBUTION SYSTEM LAYOUT

In the Philippines, water distribution mains are usually located in the North or East side of the road. This standardization is necessary for ease of locating the pipes for maintenance and repair purposes. The south and west sides of the road are normally allocated to drainage systems.

1) **Dead-end System** — In Figure 11.1A is the dead-end system of distribution. The size of the main line decreases as its distance from the source increases. This is due to the decrease in the amount of water that the pipe has to carry.
2) **Looped System** — Shown in Figure 11.1 B is the looped system of distribution. The pipe size and pressure in this system is fairly uniform.

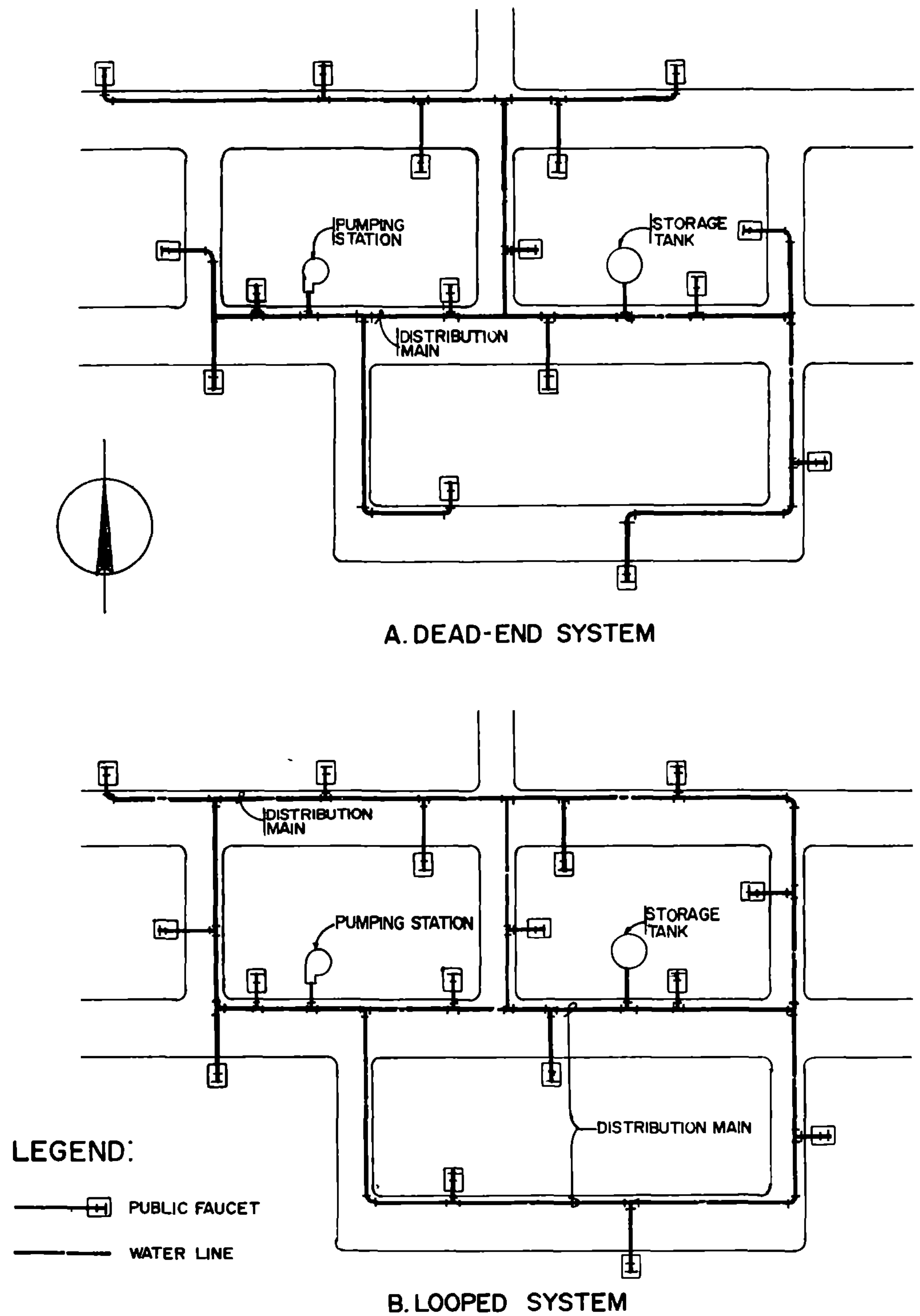


FIGURE III

DISTRIBUTION SYSTEM LAYOUT

11.03 PROTECTIVE MEASURES TO PRESERVE THE QUALITY OF WATER IN THE DISTRIBUTION SYSTEM

Contamination of water supplies sometimes occur in the transmission and distribution lines. This is usually due to infiltration of polluted surface water into the pipes when for some reason the service is cut off and a partial vacuum is created inside the pipe thus contamination gains entrance through leaks in pipe joints. The growth of bacteria inside pipes may be also the cause of contamination. To maintain the quality of water all the way to the consumers' tap, the following measures should be followed:

1) Transmission and distribution pipes should be constructed away from excreta and wastewater disposal systems like latrines and drainage canals.
2) In cases where the pipelines are laid under bodies of water, enough positive pressure should be kept in pipes to prevent infiltration and the system must be operated 24 hours/day.
3) Leaks in pipes should be promptly repaired to keep dirty water from coming in when pressure in the pipe is reduced.
4) Effective circulation of water in the pipelines should be maintained to prevent the deposition of sediments and minimize the growth of bacteria.
5) Cross connections should be avoided.
6) A residual chlorine of 0.2 mg/L should be maintained in the remotest part of the distribution system.

11.04 PIPELINE DESIGN CRITERIA

1) The pipelines must be designed to handle the maximum hour demand of the area to be served.
2) Minimum Pressure at the remotest end of the system — 3 M (approx. 4.26 psi).
3) Maximum velocity of flow in pipes
   a. Main pipes . . . . 3.0 meters per second
   b. Distribution Pipes 1.5 meters per second

11.05 PIPELINE MATERIALS SELECTION

1) **Factors in Selecting Pipeline Materials**
   a. **Flow Characteristics** — The friction head loss is dependent on the flow characteristics of pipe. Friction loss is a power loss and thus may affect the operating costs of the system if a pump is used.
   b. **Strength of Pipe** — Select the pipe with working pressure and bursting pressure rating adequate to meet the operating con-

dition of the system. In low pressure rural water supply systems, any standard water pipe is satisfactory.

c. **Durability** — Select the type of pipe with good life expectancy under the operating conditions and in the soil conditions of the system. It should have an expected life of 30 years or higher. Plastic pipe is best.

d. **Type of Soil** — Select the type of pipe that is suited to the type of soil in the area under consideration. For instance, acidic soil could easily corrode G.I. pipes and very rocky soil can damage plastic pipes unless properly bedded in sand or other types of material.

e. **Availability** — Select locally manufactured and/or fabricated pipe whenever it is available.

f. **Cost of Installing Pipes** — Beside initial cost of pipe, also consider the cost of installation. This is affected by type of joint, such as screwed, solvent weld, slip joint, etc., weight of pipe for ease of handling, depth of bury required and width of trench and depth of cover required.

g. **Cost** — Calculate the cost of pipe plus installation cost. Select the type of acceptable pipe which has the lowest investment cost.

2) **Pipe Materials**

1) Galvanized Iron (G.I.) Pipes

It is available in sizes of 13, 19, 25, 31, 38, 50 63 and 75 mm and in lengths of 6M. It is joined by means of threaded couplings. Discussed below are the advantages and disadvantages of the use of G.I. Pipes.

a. **Advantages of G.I. Pipes**

1) Strong against internal and external pressure.
2) Can be laid below or above the ground.
3) People in rural areas know how to install it.

b. **Disadvantages of G.I. Pipes**

1) G.I. Pipes can easily be corroded, thus the service life is short.
2) These have rougher internal surface compared to plastic pipes, hence, have higher friction head losses.

2) Plastic Pipes

Polyvinyl Chloride (PVC), Polyethylene (PE) and Polybutylene (PB) are commercial plastic pipes. They are available in sizes of 13, 19, 25, 31, 38, 50, 63, 75 and

100 mm. PVC is supplied in lengths of 3 M and 6 M while PE and PB are available in rolls.

PE Pipes are joined by butt welding while PB Pipes are joined by flaring and with special fittings. In case of PVC pipes they can be joined through solvent cement welding or through the use of special sockets with rubber rings.

a. **Advantages of Plastic Pipes**

1) It has a smooth internal surface.
2) Plastic pipes are resistant to corrosion.
3) It is extremely light and easy to handle.

b. **Disadvantages of Plastic Pipes**

1) It losses strength at high temperatures (50°C +).
2) It is not suitable for laying above the ground.
3) It can deform during storage.
4) It requires good and careful bedding materials.

Tabulated in Table 11.1 are the characteristics of different types of pipes.

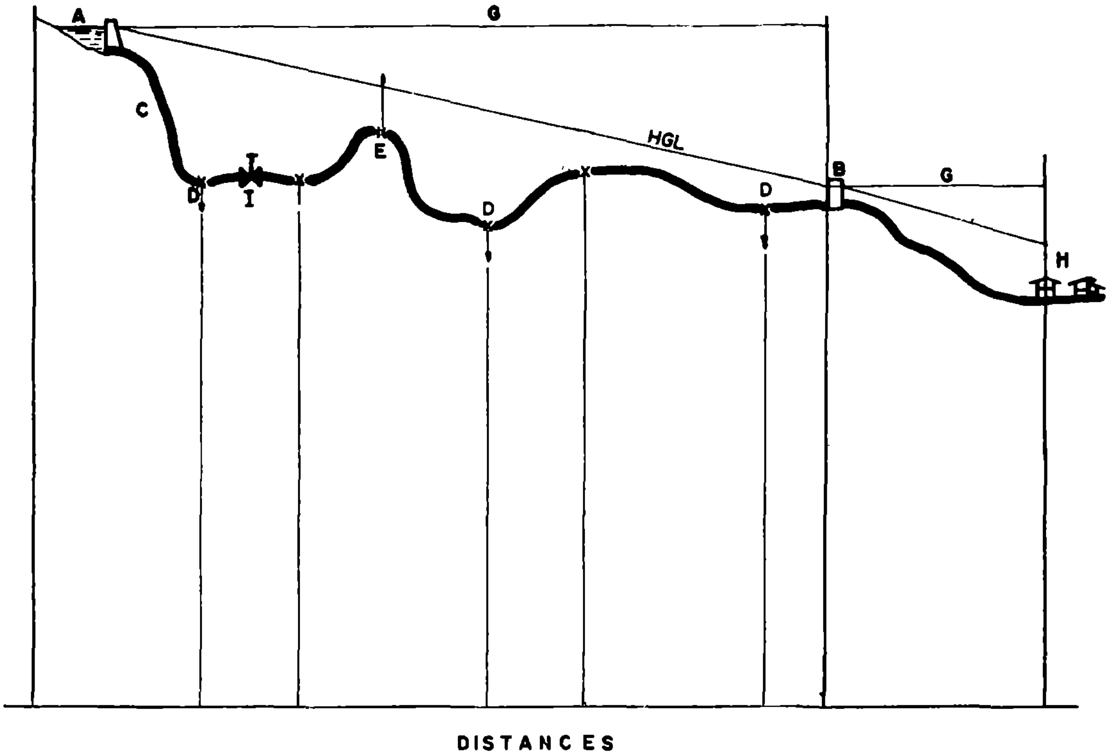
Table 11.1

CHARACTERISTICS OF DIFFERENT PIPE MATERIALS

	PARAMETERS	G.I.	PVC	PE	PB
1)	Crushing strength versus superimposed loads in trench	Excellent	Fair	Poor	Poor
2)	Bursting strength versus internal pressure	Excellent	Good	Good	Good
3)	Durability	Fair	Excellent	Excellent	Excellent
4)	Resistance to corrosion	Poor	Excellent	Excellent	Excellent
5)	Flow capacity	Fair	Excellent	Excellent	Excellent
6)	Resistance to external mechanical injury	Excellent	Fair	Poor	Fair
7)	Ease of installation	Easy	Must be handled gently and must be buried.		
8)	Pipe cost	High	Low	Low	Low
9)	Cost per fitting	Low	High	High	High
10)	Number of fittings	High	High	Low	Low

Legend:

G I. — Galvanized Iron Pipe
PVC — Polyvinyl Chloride Pipe
PE — Polyethylene Pipe
PB — Polybutylene Pipe



NOT TO SCALE

A = INTAKE STRUCTURE (RESERVOIR, POND, ETC.)

B = STORAGE RESERVOIR

C = PIPELINE

D = BLOW-OFF VALVES

E = AIR VALVES

HGL = HYDRAULIC GRADE LINE

G = STATIC HEAD

H = RURAL TOWN OR VILLAGE

I = SECTIONING VALVES (EVERY 1.5 KM.)

FIGURE 11.2 PROFILE OF TRANSMISSION PIPELINE FROM SOURCE TO DISTRIBUTION SYSTEM

11.06 APPURTENANCES FOR TRANSMISSION AND DISTRIBUTION MAINS

1) **Valves**

Shown in Figure 11.2 is the profile of a transmission pipeline from source to distribution system. The figure shows the location of the different components of the water supply system like the valves, storage tank, etc.

a. **Gate and Globe Valves** — used for controlling the flow of water. Gate valves are placed at various points in the distribution network to permit the isolation of areas for repair work. Globe valves are cheaper than gate valves and most adaptable for rural water systems.

b. **Check Valves** — allow water to flow in one direction and prevent it from flowing back. They are usually used on all pipelines, after the pumps, in order to prevent water from running back when pumps are stopped.

c. **Air Valves** — are usually installed at major summits of transmission mains to automatically permit the escape of air during pipeline filling and to admit air into the pipeline replacing water which rushes out in the event of a main break or planned shut down.

d. **Blow-Off Valves** — are usually placed at low points to drain the line and remove the sediments.

2) **Fittings**

Fittings are installed in the pipelines for the following purposes:

a. To connect the same kind and size of pipe.

   1) **Union** — Unions are provided in the pipeline for ease of repair. Union are usually installed at 60-meter intervals on straight pipelines.

   2) **Coupling** — used in jointing 2 pipes of the same diameter. It is cheaper than unions.

b. To connect two pipes of different sizes

   1) **Reducers** — Reducers are used when there is a reduction of pipe size and include bushings and street elbows for GIP. Also available are reducing elbows, tees and crosses.

c. To change the direction of flow

   1) Elbow — to change the direction of flow.
   2) Tees — to divide the flow into two.
   3) Crosses — to divide the flow into three.

d. To stop the flow — the fittings to stop the flow are caps, plugs and blind flanges.

3) **Thrust Blocks**

Thrust blocks are reaction or thrust devices placed at elbows, dead-end mains, tees, reducers, and at crosses having one or more plugged openings.

CHAPTER 12

RESERVOIRS AND STORAGE TANKS

Reservoirs or storage tanks are employed in the distribution system to meet peak demands, to equalize pressure and to store water.

12.01 TERMINOLOGY AND DEFINITIONS

1) **Minimum Water Level** — is the lowest water level in the tank sufficient to give the minimum residual pressure at the remotest end of the system.
2) **Maximum Water Level** — is the highest water level in the tank.
3) **Working Pressure** — the minimum pressure at which the system will operate.
4) **Safe Working Pressure** — is the working pressure multiplied by a factor of safety.

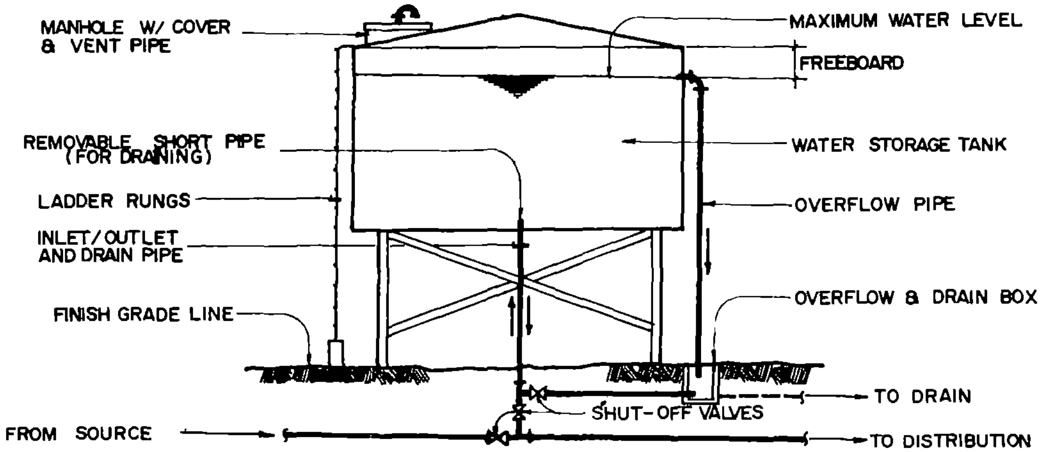
12.02 IMPORTANCE OF DISTRIBUTION RESERVOIRS

In rural distribution systems, whether water is obtained by gravity or by pumping, the construction of distribution reservoirs is usually necessary for the following reasons:

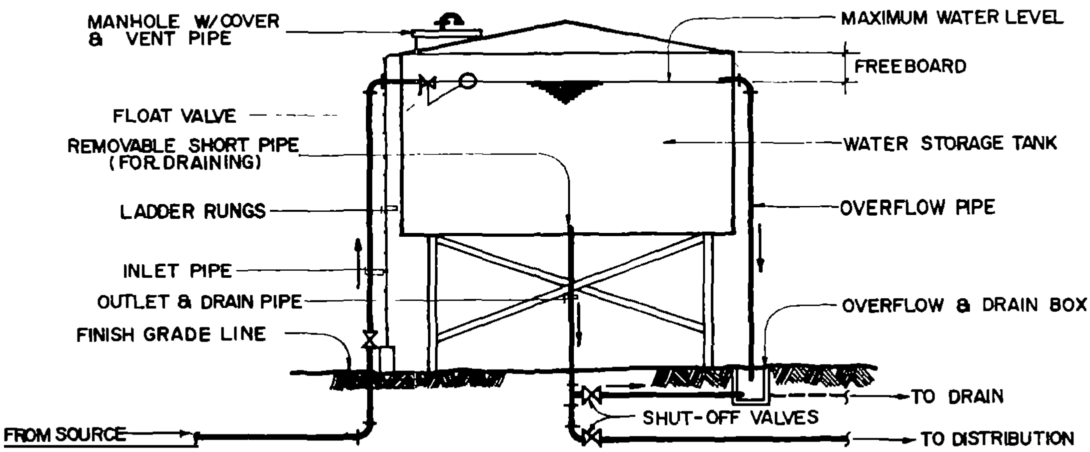
1) To balance the supply and demand in the system. In small distribution systems, such variations may be three times or more than the average hourly consumption.
2) To maintain adequate and fairly uniform pressure throughout the distribution system.
3) To avoid the total interruption of the water service when repairing pipes between the source of supply and reservoir.
4) When water is pumped directly to the reservoir, pumps can be operated uniformly throughout the day. Such pumps may be much smaller than would be required otherwise.

12.03 DESIGN OF RESERVOIRS

1) **Capacity** — To a great extent depends upon the water demand. Also, provision should be made to cover the demand during normal breakdown or maintenance. As a rule of thumb, the storage tank volume (except in a hydropneumatic pressure system) should be at least equal to one-fourth of daily water demand of the community.



A. FLOATING-ON-THE LINE



B. FILL- AND-DRAW

FIGURE 12.1

SCHEMATIC DIAGRAM OF ELEVATED STORAGE TANKS

2) **Site of the Storage Tank** — In the selection of the site of storage tanks, natural elevated places should be given the first priority.

   If the elevated storage tank is to be constructed in flat areas, it may be built central to the distribution system or opposite the source. This is to avoid long and consequently large diameter service mains.

3) **Structural Design** — The structural design of reservoirs must meet the standards set by the National Structural Code of the Philippines. The reservoirs must be strong enough to withstand all loads such as hydrostatic pressure, earth pressure, wind loads, seismic loads and other dead or live loads.

12.04 TYPES OF RESERVOIRS

Reservoirs may be classified according to their function, relative position with respect to the earth's surface, manner of operation and as to type of material of construction.

1) **Elevated Reservoirs** — Elevated reservoirs could be constructed in elevated or hilly areas or in case of flat areas, a supporting frame is installed to support the storage tank. Elevated reservoirs may be operated on the following basis:

   a. **The Floating-On-The-Line System** — In this system, water is pumped both into the reservoir and to the consumers; water goes up to the tank when the water demand is low or if there is a residual water supply, and water is withdrawn from the tank during peak demand. This system requires fairly continuous pumping at low pumping capacity. (See Figure 12.1 A).

   b. **Fill-And-Draw System** — In this system, water is pumped directly into the reservoir and from the reservoir, water supply is distributed to the consumers through gravity flow. The tank is usually installed near the water source to minimize head losses due to friction and hence, pumping cost. In the fill-and-draw system, Figure 12.1B, however, water is conveyed to the storage tank at high pumping capacity at shorter time duration, and always against the maximum head.

2) **Hydropneumatic Pressure System** — The hydropneumatic pressure system includes a sealed water tank filled partially with air. A water pump and éssential control devices are installed for making the system operate automatically with the least amount of attendance, (Figures 12.2 A & B). The pump is employed to supply the required amount of water into the pressure tank. The tank acts as a storage vessel. The proper ratios of water and air are maintained by the control devices. The air is compressed on top of the water and thereby provides the necessary pressure for servicing the water demand of the area. The expansion of air under reducing pressure regulates the amount of water withdrawn

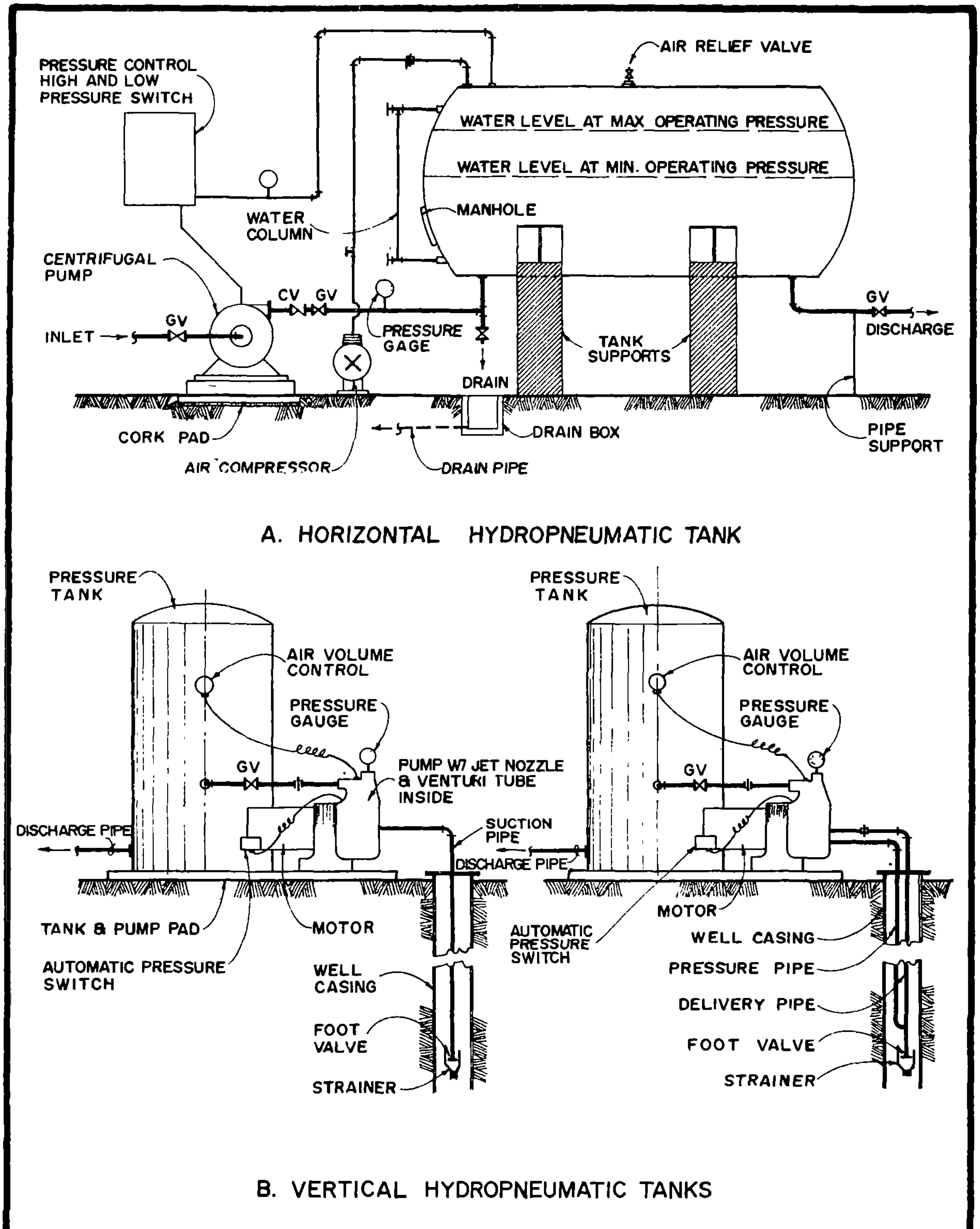
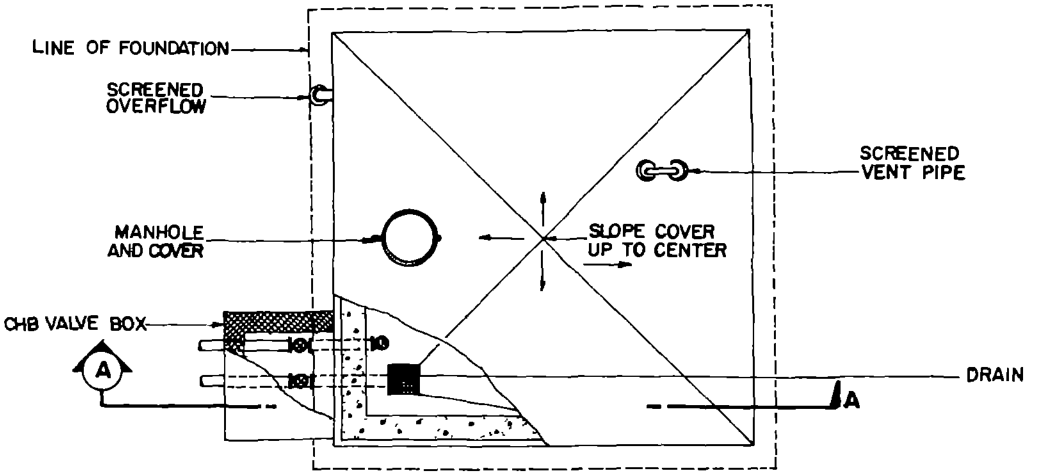
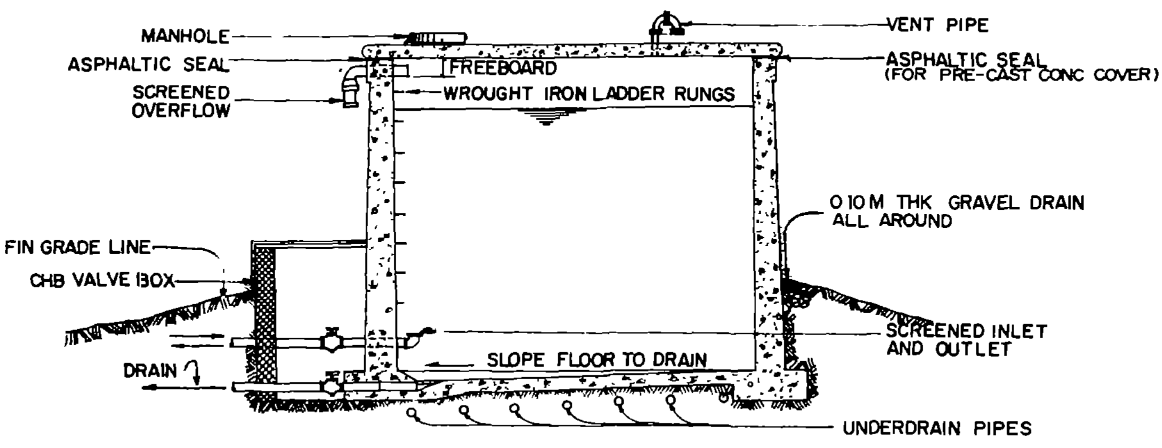


FIGURE 12.2

SCHEMATIC DIAGRAM OF HYDROPNEUMATIC STORAGE TANKS



PLAN



SECTION "A"-"A"

FIGURE 12.3A

GROUND LEVEL CONCRETE RESERVOIR

before the pump turns on to replenish the reserve capacity that is desired to be maintained in the tank.

Design of Hydropneumatic Pressure System

a. Calculate the tank volume

V = 10* x Population to be served

where V = Volume of tank, liters

b. Compute the pressure requirements (working pressure). Working pressure is the sum of the following pressures:

1) Minimum pressure at the remotest end of the system 3M
2) Friction head loss through the pipeline.
3) Differential operating pressure 5M (7.10 psi)
4) Static head

c. Compute the safe working pressure of the tank.

Safe Working Pressure = 1.5 x Working Pressure

3) **Ground Level Reservoirs** — Ground level reservoirs may be made of reinforced concrete pipe, fiber glass, concrete hollow blocks, steel or ferrocement. These may be single ground level tanks (Figure 12.3 A and B) or multiple type tanks (Figure 12.4 A nd B). One form of multiple ground level reservoirs is the standpipe. Standpipes are reservoirs whose height is generally greater than its diameter.

Design Criteria for Standpipe

a. Minimum Pressure at the intake pipe — 3 M
b. Tank Capacity (Minimum) — 827 liters good for 5 households

12.05 RESERVOIR APPURTENANCES

1) **Inlet Line** — The size of the inlet line shall be determined by the supply and demand requirements. The inlet line on all reservoirs must have a shut-off valve located adjacent to the reservoir.

2) **Outlet Line** — Like the inlet line, the size of the outlet line is determined by the supply and demand requirements.

The upstream-end of the outlet pipe is usually installed at least 5 cm. above the floor of the reservoir creating a dead volume of water. This dead volume of water at the bottom of the reservoir acts as settling zone, where particles are allowed to settle, and prevents bottom sediments from entering the water distribution line. The outlet line must also have a shut-off valve located adjacent to the reservoir.

In floating-on-the line reservoirs, there is only one inlet and outlet line.

*See appendix M for the derivation

3) **Drain Line** — A drain line is provided for draining and cleaning of the reservoir. Draining could be through the inlet-outlet by shutting off the value controlling the flow in the main line and opening the drain valve. To facilitate cleaning, the floor or base of the reservoir is sloped to the drain.

4) **Air Vents** — Air vents are provided in reservoirs to allow to escape fast enough before pressures can build up inside the reservoir during filling. Air vents also allow air to enter the reservoir to replace water being drawn out so that a vacuum in the reservoir may not occur which may result in damaging or collapsing of the reservoir. The air vents should be designed to prevent rain or surface water from entering, and to minimize the risk of dust getting into the reservoir. Also, the air vents must be screened with fine mesh wire to keep out bats, birds, mosquitoes and other insects.

5) **Overflow Line** — Reservoirs should be provided with an overflow line big enough to allow the maximum anticipated overflow. The end of the overflow pipe should be properly screened to prevent the entry of insects, animals or other possible pollutants.

6) **Manholes and Covers** — Manholes and cover hatches are installed in reservoirs to serve as entrance during repair, cleaning and mainenance. To prevent the entry of surface weater which may contain pollutants, manholes should be installed slightly raised above the roof level and must be equipped with an overlaying cover. Also, the cover is needed to prevent the sun's rays from filtering into the tank and thus promote algal growth.

7) **Water Level Indicators** — These are used to indicate the water level inside the reservoir. Depth gauges using a float and wire are normally used.

8) **Control Valves** — The use of reservoir control valves will depend on the type of controls and means of operation to be employed for the system. The flow into the reservoir may be stopped manually or automatically by a float valve or a pressure switch or equivalent device.

Example 12.1 Design a reservoir considering that the area under consideration is relatively flat.

Data:

Barrio : Daraitan, Tanay, Rizal
Population : 630
Design Population: 1.15 × 630 = 724
Water Consumption Rate: 60 LPCD
Average Day Demand: 724 × 60 = 43,440 LPD
Friction Head loss in Pipeline from tank to the remotest

PF = 3 M

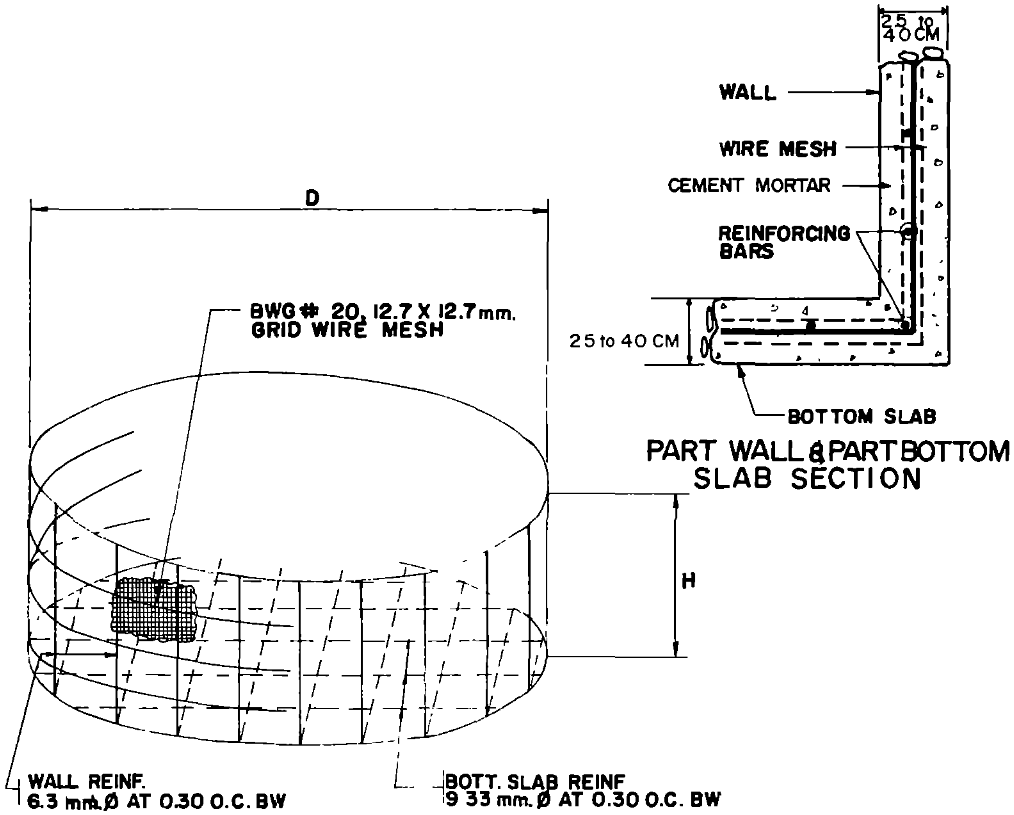


TABLE OF DIMENSIONS

VOLUME CU. M.	DIMENSIONS IN METERS		THICKNESSES IN mm.		NO. OF WIREMESH LAYER	
	D	H	BOTTOM SLAB	WALL	BOTTOM SLAB	WALL
2	1.60	1.20	38.1	19.05	3	2
3	2.00	1.20	38.1	19.05	3	3
4	2.00	1.50	50.0	25 4	3	3
5	2.25	1.50	50.0	25.4	3	4

NOTES:

1 WIRE MESH SHALL BE BWG # 20 (0 889 MM. DIA.) WITH 12.7 X 12.7 SQUARE GRID
2. REINFORCEMENT FOR BOTTOM SLAB SHALL BE 9 53 mm Ø AT 0.30 O.C BW AND 6.3 mm.Ø AT 0.30 O.C. BW FOR WALLS.
3 PROVIDE SPACER BETWEEN WIRE MESH.
4 PROVIDE GAGE #16 G I SHEET WITH MANHOLE AND VENT FOR TANK COVER
5 PIPING, VALVES, FITTINGS AND APPURTENANCES SIMILAR TO FIGURE 12 3A

FIGURE 12.3B

DETAILS & SCHEDULE OF FERROCEMENT STORAGE TANK

Required:

a. Using elevated tanks, calculate the capacity and height of the minimum water level.

b. Using hydro-pneumatic pressure system, calculate the tank volume and safe working pressure.

c. Using standpipes, calculate the tank capacity and the number of standpipes.

Analysis:

a. Using Elevated Tanks

1) Design Criteria

Minimum Pressure at the remotest PF = 3M
Capacity of Tank = 1/4 of average Day Demand

2) Calculate the Capacity

Capacity = 1/4 × 43440 = 10,860 liters
say 11,000 liters
Shape of reservoir = Cylindrical
Height = 3 M
From Figure 12.5, D = 2 M*

*The diameter was determined using Figure 12.5. Locate the height = 3M in the figure and move horizontally to intersect V = 11,000 and then move downward to the abscissa to find the diameter, D = 2.09 M. Use D = 2.0 M

3) Calculate the Height of Minimum Water Level, H

H = Minimum Pressure at the remotest PF + Friction head loss in pipeline from tank to remotest PF.
H = 3 + 3 = 6 M

b. Using Hydropneumatic Pressure Systems

1) Design Criteria

Minimum Pressure at the remotest Faucet	= 3 M
Differential Operating Pressure	= 5 M
Safe Working Pressure	= 1.5 × Working Pressure
Tank Volume	= 10 × population

2) Calculate the Tank Volume

Tank Volume = 10 × 630 = 6,300 liters
Shape of tank = cylindrical
Height = 1.20 M; Diameter = 4.20 M

3) Calculate the Safe Working Pressure

a. Estimate the Working Pressure

1) Minimum Pressure at the remotest end of the system . . . . 3 M
2) Friction Head loss through the pipeline . . . . 3 M

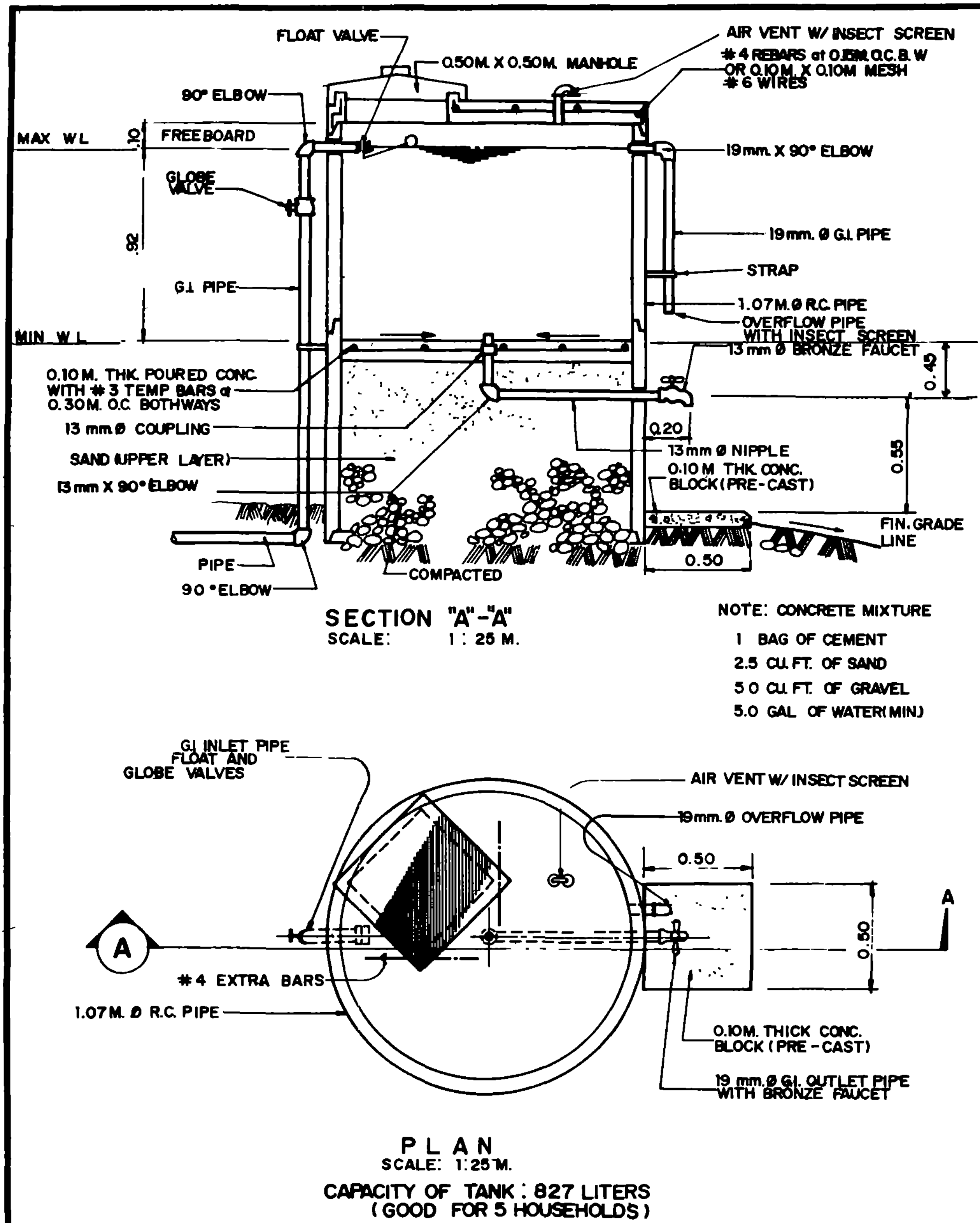


FIGURE 12.4A

DETAILS OF PRECAST REINFORCED CONCRETE GROUND LEVEL STORAGE TANK

3) Differential Operating Pressure
Working Pressure . . . . 5 M
11 M

b. Estimate the Safe Working Pressure

Safe Working Pressure = 1.5×11 = 16.5 M

c. Using Standpipes (Multiple Storage Tank)

1) Design Criteria

Tank Capacity = 5 Households (HH)

2) Calculate the Tank Capacity

Tank Capacity = $(5 \times 6 \times 60)/2$
= 900 liters

3) Calculate the Number of Standpipes

No. of standpipe = 630 people x 1 HH/6 people x 1 standpipe/5 HH
= 21standpipes

4) Tank Features — See Figure 12.4A.

Example 12.2 Design a reservoir for the area shown in Figure 12.6

Data:

Barrio	:	Bontoc, Ifugao
Population	:	435
Design Population	:	435 x 1.15 = 500
Average Day Demand	:	500 x 60 = 30,000 LPD

PF, found at the remotest of the system

Friction Head loss in Pipeline, F_1 = 4 M
Elevation of PF_1 E_1 = 2 M

PF_2, found 40 M from the storage tank

Friction Headloss in pipeline, F_2 = 2 M
Elevation of PF_2, E_2 = 5 M

Elevation of the location of Storage Tank, E_3 = 6 M

Required:

a. Using elevated tanks, calculate the capacity and height of the minimum water level.

b. Using hydropneumatic pressure system, calculate the tank volume and safe working pressure.

Analysis:

a. Using Elevated Storage Tank

1) Design Criteria

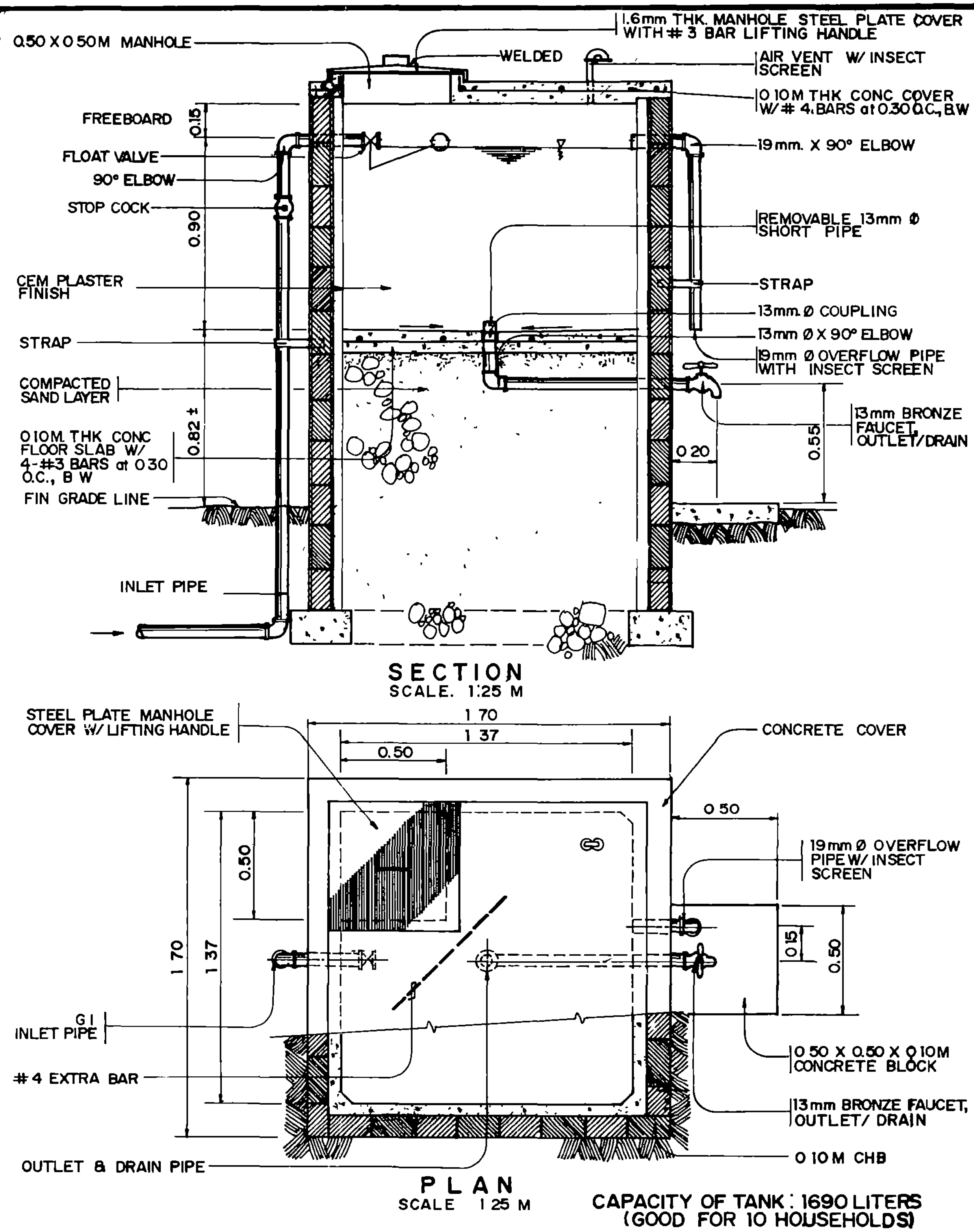


FIGURE 12.4B

DETAILS OF CONCRETE HOLLOW BLOCKS (CHB) GROUND LEVEL STORAGE TANK

Minimum Pressure in the system . . . . 3 M
Capacity = 1/4 of the average day demand

2) Calculate the tank Capacity

Capacity = 1/4 × 30,000 = 7,500 liters
Height = 2.5 M
Shape of bottom and top surface = square
From Figure 12.5, L = W = 1.75 M*

*The length was determined Table 12.5. Locate the height = 2.5 M in the figure and move horizontally to intersect V = 7,500 and then move upward to the abscissa to find the length and width, L = W = 1.75 M

3) Calculate the Height of the Minimum Water Level, H

Case A. Use the remotest PF, as the basis in the computation of H.

Find the sum of the Minimum Pressure, Friction headloss and Elevation :

Minimum Pressure	= 3M
Friction Headloss, F_1	= 4 M
Elevation of PF_1, E_1	= 2 M
Pressure to be supplied by H of tank, P_1	= 9 M

Case B. Use the PF_2 located 40 M from the Storage Tank as the basis of the computation of H.

Find the sum of the minimum pressure, friction headloss and elevation:

Minimum Pressure	= 3 M
Friction Headloss, F_2	= 2 M
Elevation of PF_2, E_2	= 5 M
Pressure to be supplied by H of tank, P_2	10 M $>$ P_1 = 9 M

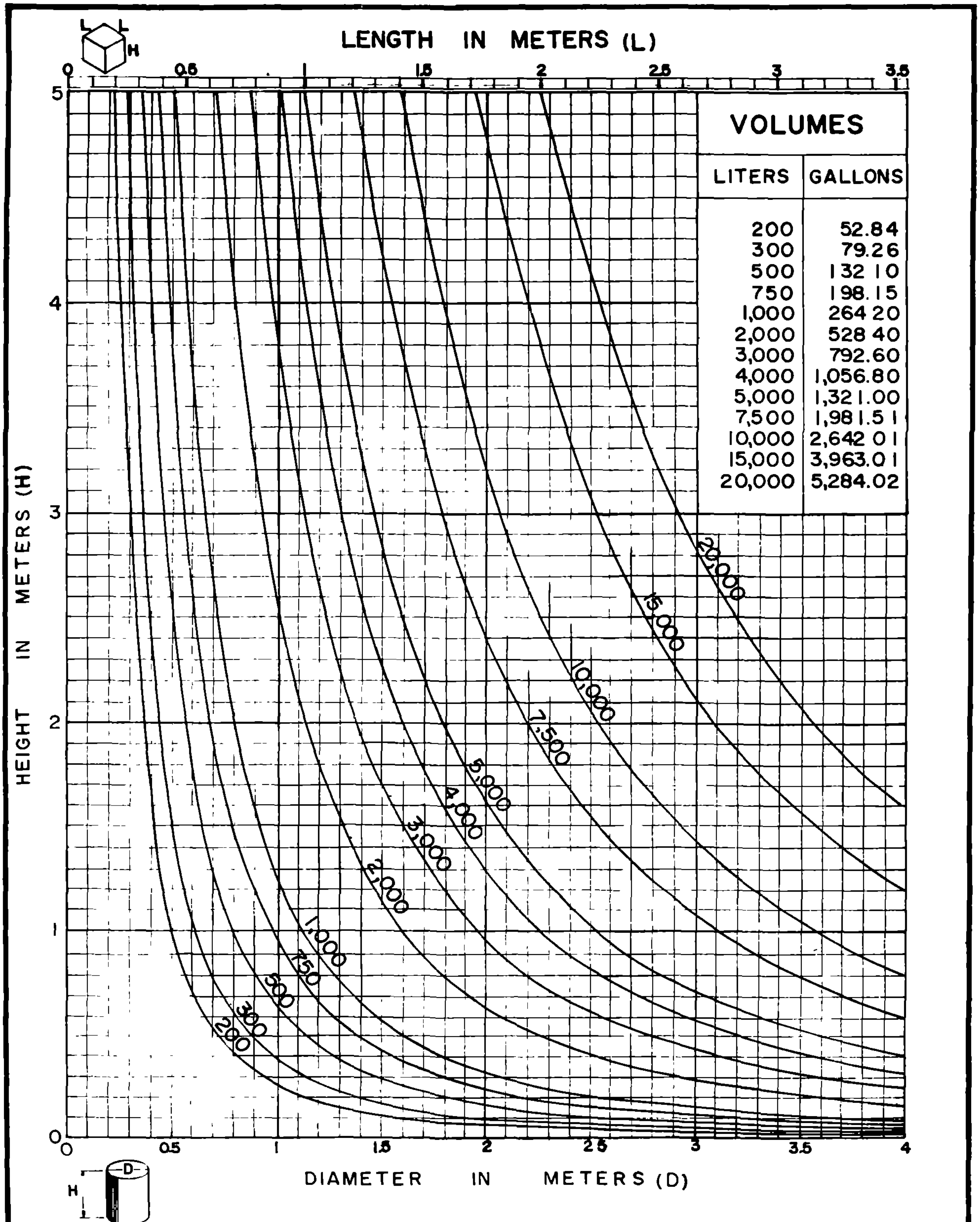
Conclusion: Select P_2 in the computation of Height, H of Tank.

Rationale: Using P_1 as the basis will result to no water or the minimum pressure in the system of 3 M will not be attained in PF_2 located 40 M from the Storage Tank for the pressure requirement in PF_1 is less than in PF_2.

Calculate the Height of the Minimum Water Level of Storage Tank

The height of the minimum water level of storage tank is equal to the difference of P_2 and the ground elevation of location of tank, E_3.

$$H = P_2 - E_3 = 10 - 6 = 4 \text{ M}$$



VOLUMES	
LITERS	GALLONS
200	52.84
300	79.26
500	132 10
750	198.15
1,000	264 20
2,000	528 40
3,000	792.60
4,000	1,056.80
5,000	1,321.00
7,500	1,981.51
10,000	2,642 01
15,000	3,963.01
20,000	5,284.02

FIGURE 12.5

VOLUME OF PRISMATIC TANKS

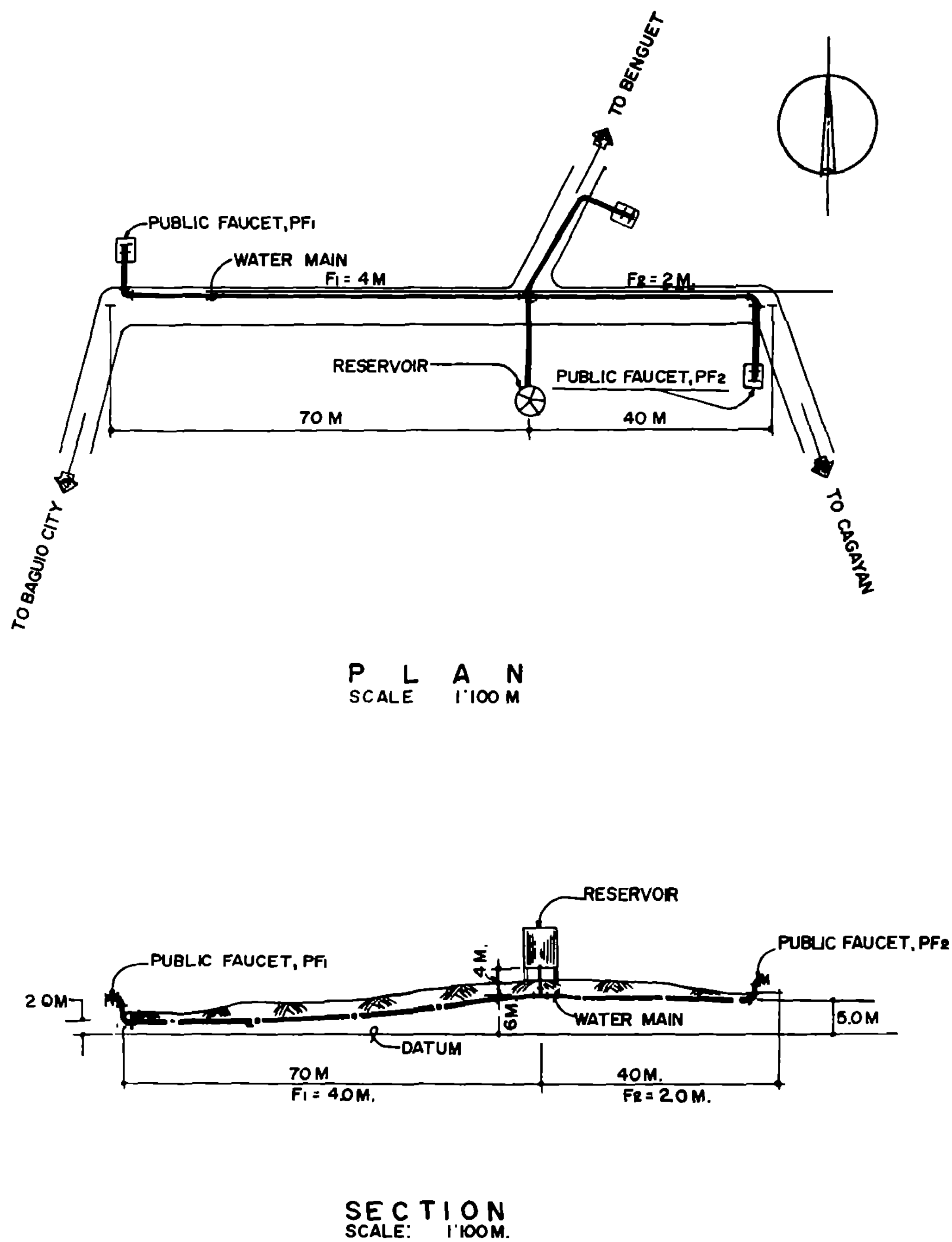


FIGURE 12.6

LAYOUT OF WATER SYSTEM OF BONTOC, IFUGAO

b. Using Hydropneumatic Pressure Systems

1) Design Criteria

Minimum Pressure .... 3 M
Differential Operating Pressure . . 5 M
Safe Working Pressure = 1.5 x working Pressure
Tank Volume = 10 x population

2) Calculate the Tank Volume

Tank volume = 10 x 435 = 4,350 liters
Shape of tank = Cylindrical
Height = 1.20 M; Diameter = 3.00M

3) Calculate the Safe Working Pressure of Tank

a. Estimate the Maximum Working Pressure of Tank.

Case A. Use the remotest PF_1 as the basis for calculating the working pressure, P_1

Minimum Pressure	3 M
Differential Operating Pressure	5 M
Friction Headloss, F_1	4 M
Elevation of PF_1, E_1	2 M
	14 M
Subtract the ground elevation of the location of Tank, E_3	6 M
Working Pressure, P_1	8 M

Case B. Use the PF_2 located 40 M from the storage tank as the basis of computation of H. Calculate the working Pressure, P_2.

Minimum Pressure	3 M
Differential Operating Pressure	5 M
Friction Headloss, F_2	2 M
Elevation of PF_2, E_2	5 M
	15 M
Subtract the elevation of the site of storage tank, E_3	6 M
Working Pressure, P_2	9 M

Select working pressure, P_2 in the design

Rationale: Using P_1 as the basis will result in no water; or the minimum pressure (3M) will not be attained in PF_2 located 40 M from the storage tank.

b. Calculate the Safe Working Pressure

Safe Working Pressure $= 1.5 \times P_2$
$= 1.5 \times 9$
$= 13.5$ M

CHAPTER 13

PUMPING FACILITIES

Pumps are devices used in transferring water or other liquids from one place to another through pipes. The transfer is effected by the addition of energy. An understanding of the different types of pumps, their applications, their design differences, and procedures to operate and maintain them is important in planning a water supply system.

13.01 TERMINOLOGY AND DEFINITIONS

1) **Total Dynamic Head (TDH)** — The total dynamic head is the sum of static head, pipe friction and velocity head at the point of discharge.

   a. **Static Head** — the total change in elevation of water from suction level to the discharge level (Figure 13.1).

   b. **Pipe Friction** — head loss due to friction in the suction and discharge lines, elbows and valves, and suction entrance loss.

   c. **Velocity Head** — change in kinetic energy of water from source to the discharge point. Velocity head is equal to the square of the velocity divided by twice the acceleration of gravity

   $$H_v = V^2/2g$$

   Where: H_v = Velocity head, meters
   V = Velocity of water, meters/second
   g = 9.8 meters/sec^2

2) **Water horsepower (output horsepower)** — is the energy transferred by pump to the water. Water horsepower (W.H.P.) is normally expressed as

   $$W.H.P. = Q \times H/75$$

   Where: Q = Pump discharge, LPS
   H = Total head, M

3) **Brake horsepower (input horsepower)** — is the horsepower or energy supplied to the prime mover of an installed pump. Because of losses due to friction, impeller slippage, etc., the brake horsepower is always greater than the water horsepower. Brake horsepower can be calculated by the following formula:

   $$B.H.P. = Q \times H/(75 \times e) = W.H.P./e.$$

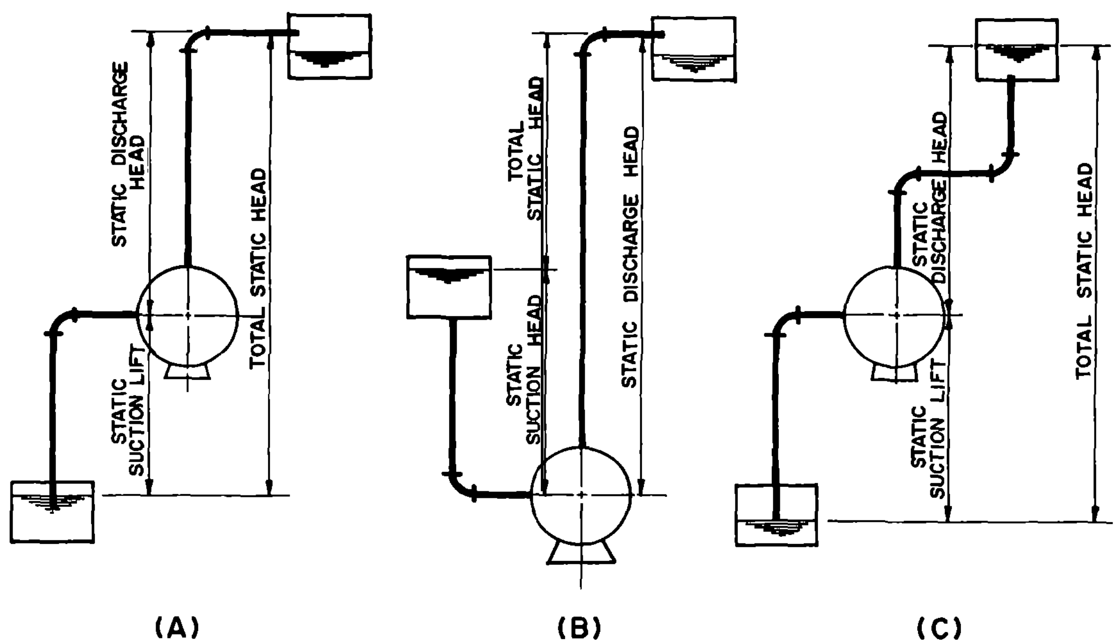


FIGURE 13 1

HEAD TERMS USED IN PUMPING

Where:

Q = Pump discharge, LPS
H = Total head, M
e = Pump efficiency

Pump efficiency is the measurement of pump's ability to convert brake horsepower to water horsepower.

13.02 DESIGN OF PUMPS

1) **Data needed to purchase pumps**

a) Pump discharge, Q
b) Total dynamic head, TDH

2) **Pump Discharge or Capacity of Pump**

a. If the pump is used directly to supply water, the capacity must be equal to the maximum hour demand.

b. If the water distribution system has a reservoir, the pump capacity must be equal to the maximum day demand.

3) **Pump Selection**

a. In the absence of electric power and in cases of isolated small population, hand pumps are recommended because of higher capital, maintenance and operating costs of diesel or gasoline engine driven pumps.

b. If the well water depth is 6 meters or less, use centrifugal pump (maximum suction lift = 6 M)

c. If the well water depth is 6-20 M, use jet pumps.

d. If the well water depth is more than 20 M, use submersible pumps or vertical line shaft turbine pumps.

4) **Pump operating time** = at least 8-12 hours.

13.03 CLASSIFICATION OF PUMPS

Pumps can be classified into several groups as shown in Figure 13.2. The pumps discussed under this section are the most commonly used in rural areas.

1) **Hand Pumps** — Hand pumps are most suitable to install for isolated small population and/or where there is an absence of electric power. Hand pumps are normally installed over dug wells or tube wells.

There are two basic types of hand pumps. The shallow well pump with the pump cylinder above ground, and the deep well pump with the pump cylinder below ground (normally below water level).

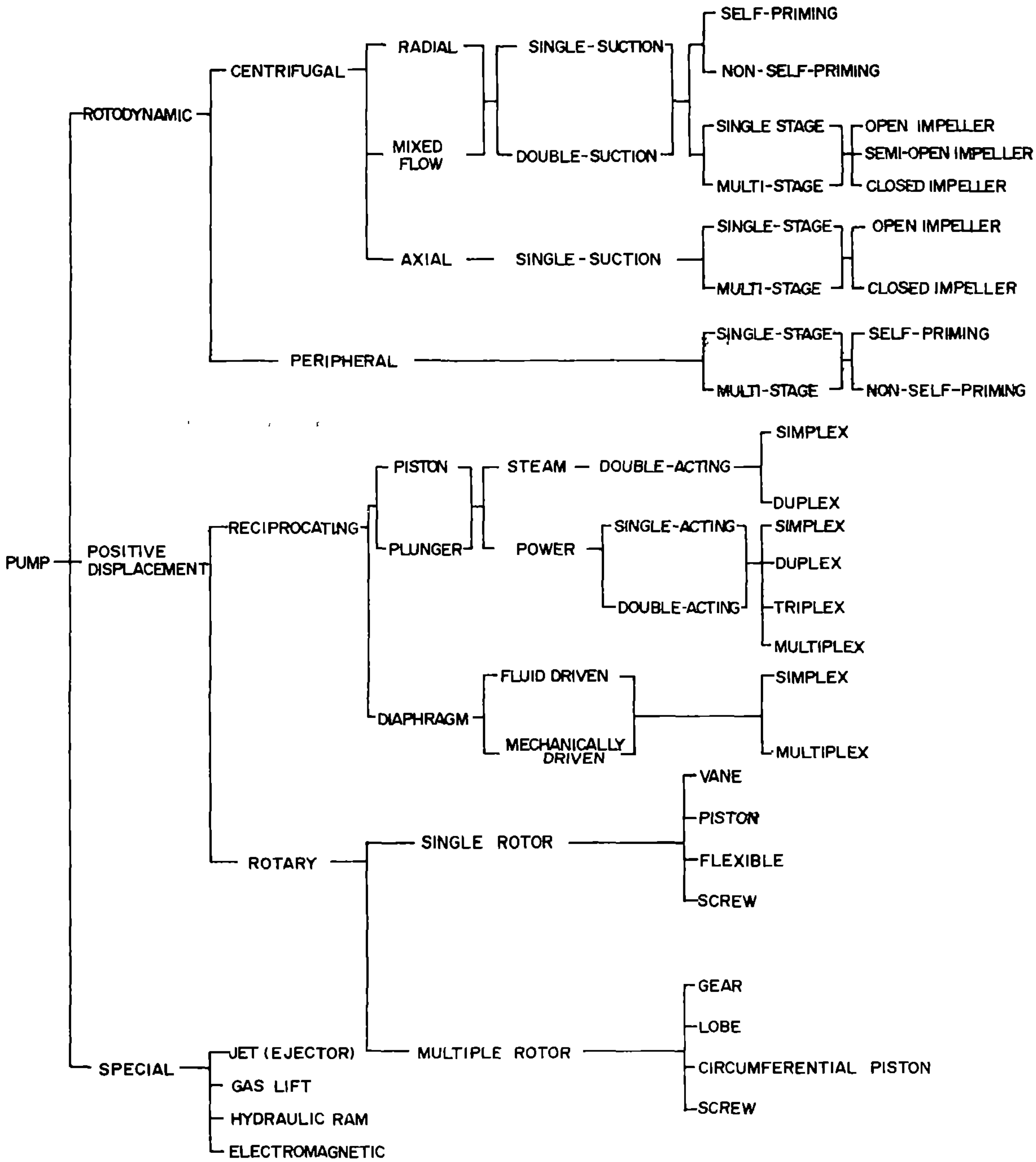


FIGURE 13.2

CLASSIFICATION OF PUMPS

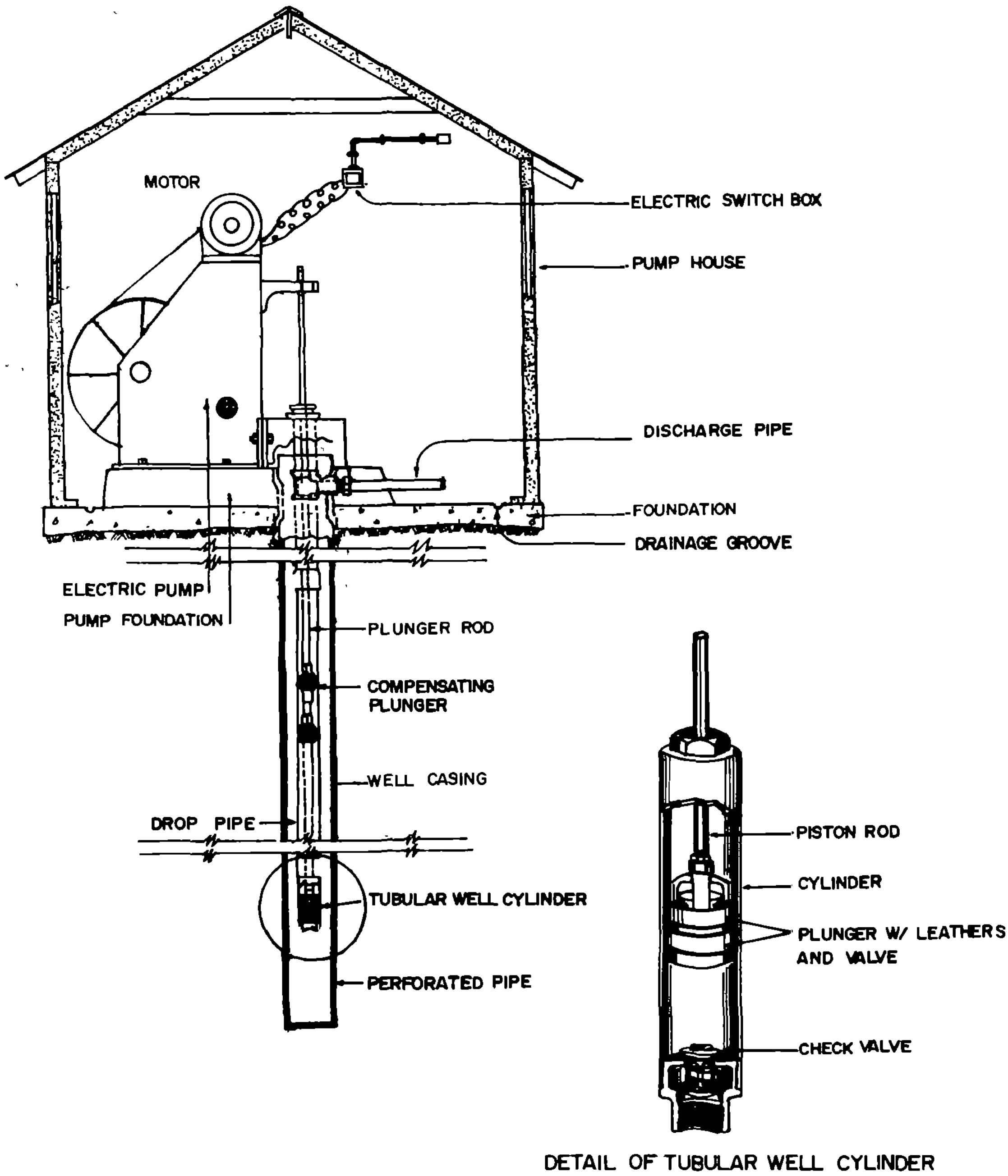


FIGURE 13.3

RECIPROCATING PUMP

2) **Positive Displacement Pumps**

Positive displacement pumps are divided into reciprocating and rotary types. Reciprocating pumps (Figure 13.3) include piston pumps which operate by creating a vacuum in a cylinder. After water is drawn into cylinder by the downward movement of the piston which creates a vacuum, the water is then forced out of the discharge outlet by the return stroke of the piston. When the piston acts on both ends of the cylinder, it is a double action pump or a duplex pump. Triplex and quadraplex designs are also possible and produce a smoother flow than the single action model.

The plunger pump is a reciprocating pump with a plunger that enters and withdraws from the cylinder through the packing glands. When the plunger is raised, a vacuum is created below it allowing water to flow through a check valve to fill the void. When the plunger is lowered, the check valve closes and water is trapped in the pump and forced up in the plunger. The water is then lifted further on the next upward stroke of the plunger.

Diaphragm pumps contain a diaphragm made of a flexible material such as rubber and is connected to the edges of a cylinder. When the diaphragm moves in one direction, a vacuum is created which draws the water into the cylinder through a check valve. When the diaphragm moves in the other direction, the water is forced from the cylinder through a discharge valve.

Reciprocating displacement pumps are self-priming. Their flow rates may be adjusted by adjusting the strokes of the moving element of the pump. Rotary type displacement pumps consist essentially of elements rotating in a pump case in which they closely fit, such as, gears, screws, cams, lobs, or rollers. The movement of the element is such that water is constantly being drawn into the pump through an inlet and then discharged. Rotary pumps act with neither suction nor discharge valves. The movement of the elements causes the water to flow in one direction only.

3) **Centrifugal Pumps**

Centrifugal pumps (Figure 13.4) raise liquids by centrifugal force created by a wheel, called an impeller, rotating within a pump case. Water enters at the center of the impeller. When the impeller is rotated, water in the pump is forced out by centrifugal force. This causes a vacuum condition at the center of eye which provides the necessary force to move or lift the water. Water is continuously drawn toward the vacuum and at the same time being discharged by the centrifugal force of the impeller, thereby providing a smooth and continuous flow of water.

Centrifugal pumps come in many different designs, arrangements and types, although they all operate on the same operating principles. The volute-design centrifugal pump has an impeller which discharges into a progressively expanding spiral casing. The proportions of the casing are designed to produce equal velocity of the water all around its circumference. The velocity of the water is gradually reduced as if flows from the impeller to the discharge pipe resulting in the energy of the pump being converted from a velocity head to a pressure head.

Turbine pumps are also considered a type of centrifugal pump. This pump does not rely solely upon centrifugal action to do the necessary pumping. In turbine pumps the water does not flow freely from the impeller vanes but is held in the pump until the water has rotated about the pump. The water, when released at the discharge, has a higher pressure than the common centrifugal pump.

Mixed-flow pumps are a type of centrifugal pump which produce the necessary water pressure by a combination of centrifugal force and the lift of vanes on the impeller. Axial-flow or propeller pumps may or may not be considered centrifugal pumps since they rely almost solely upon the lift of the impeller vanes to produce the flow of water.

Centrifugal pumps may have a single suction inlet, where water is admitted on one side of the impeller, or a double suction inlet if water is admitted on both sides of the impeller. A centrifugal pump cannot operate unless the pump casing is full of water. For the pump to begin developing a suction at the eye of the pump, the case will have to be filled with water, or "primed".

4) **Hydraulic Rams**

Hydraulic rams (Figure 13.5) use the energy of falling water to raise a smaller quantity of water to greater heights. This pump operates by taking advantage of the same forces that create water hammering in a system. Because of this, the hydraulic ram is often called an impulse pump. To operate correctly, this pump must have a constant supply of water available at the correct pressure, which is normally accomplished by having a reservoir feeding the ram. The quantity of water discharged by a hydraulic ram depends upon the working fall, the quantity of water flowing to the ram, and the total head or pressure against the ram.

5) **Jet Pumps**

A jet pump (Figure 13.6) consists of a nozzle which discharges the water into a constricted throat much like a venturi. This throat leads from a suction pipe. This arrangement permits energy of a high pressure fluid to be converted into a high velocity fluid.

Jet pumps are usually selected when the suction lift required is greater than that of centrifugal pumps and the volume of water needed is relatively small. Jet pumps are suitable for 50 mm diameter wells. Jet pumps are easy to maintain and repair for its moving parts are installed above the ground. However, its distinct

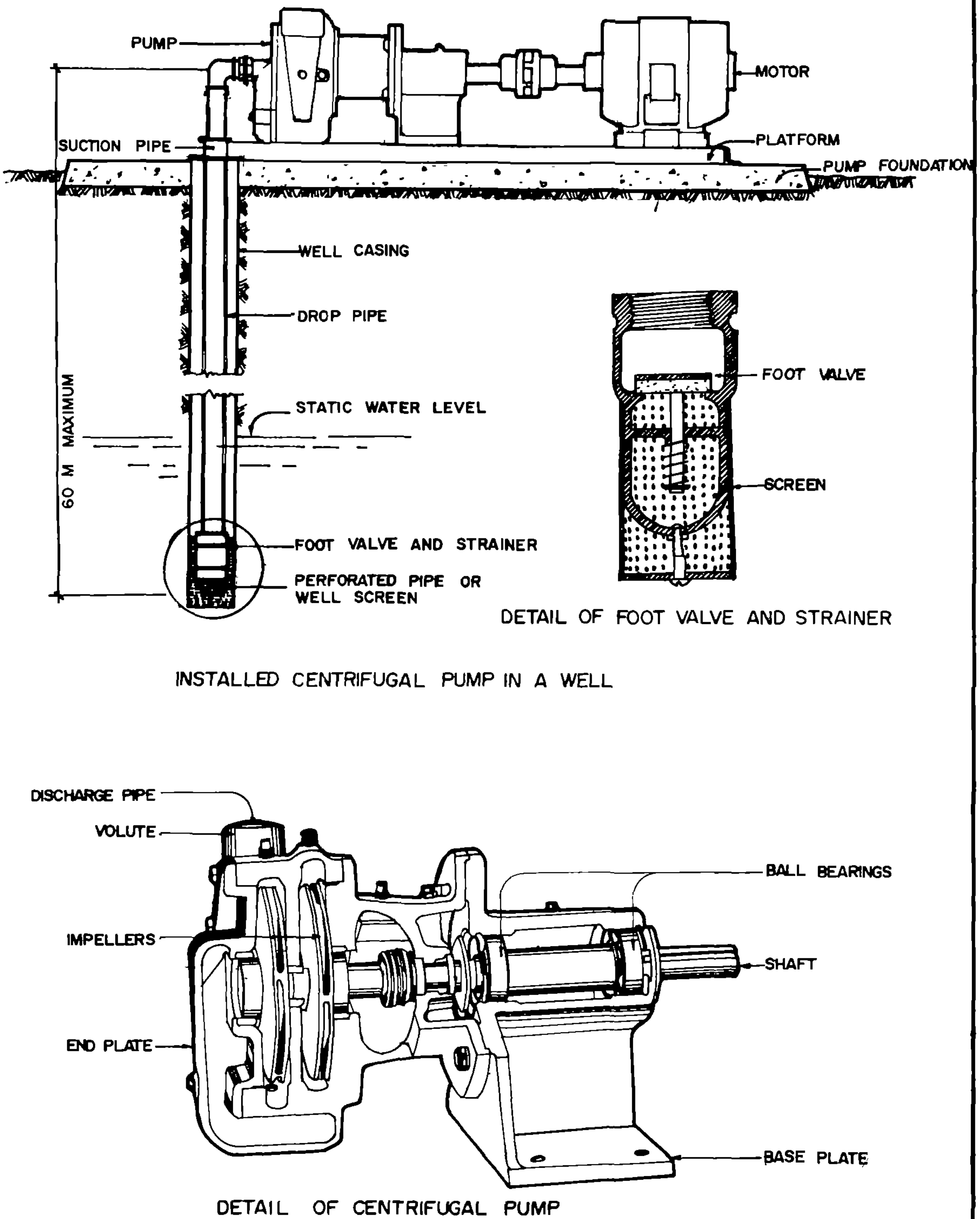
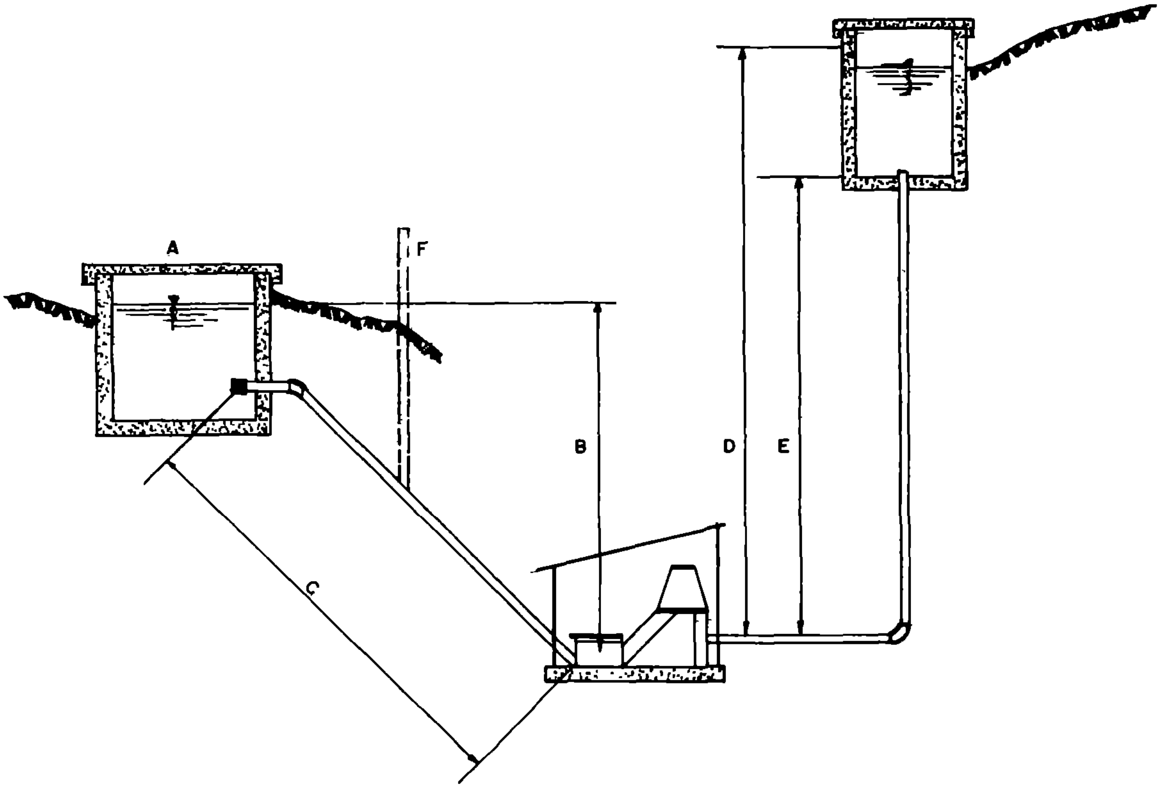


FIGURE 13.4

CENTRIFUGAL PUMP



A – SUPPLY— LITRES / MINUTE
B – DIFFERENCE IN ELEVATION BETWEEN RAM AND SUPPLY-POWER HEAD
C – LENGTH OF DRIVE PIPE
D – DIFFERENCE IN ELEVATION BETWEEN RAM AND HIGHEST POINT TO WHICH WATER IS TO BE ELEVATED– PUMPING HEAD
E – TOTAL LENGTH OF SUPPLY PIPE
F – STAND-PIPE, NECESSARY IN CASE OF EXCEEDINGLY LONG DRIVE PIPE

SOURCE WATER SUPPLY FOR RURAL AREAS
AND SMALL COMMUNITIES
BY: E.G. WAGNER and J.N. LANOIX

FIGURE 13.5

HYDRAULIC RAM

disadvantage is that there is an appreciable reduction in its capacity as depth down to water level increases.

Jet pumps are oftentimes employed in shallow and deep wells. The maximum depth down to water level to which it can operate is normally 30.5-36.5 meters with a corresponding discharge of about 0.21 liters per second.

Jet pump units are usually run by electric motors.

6) **Submersible Pumps**

Submersible pumps (Figure 13.7) are suitable for deepwells where the required discharge exceeds the capability of jet pumps. These pumps are usually powered by an electric motor installed below the water level, directly coupled to the pump.

13.04 PUMP APPLICATIONS

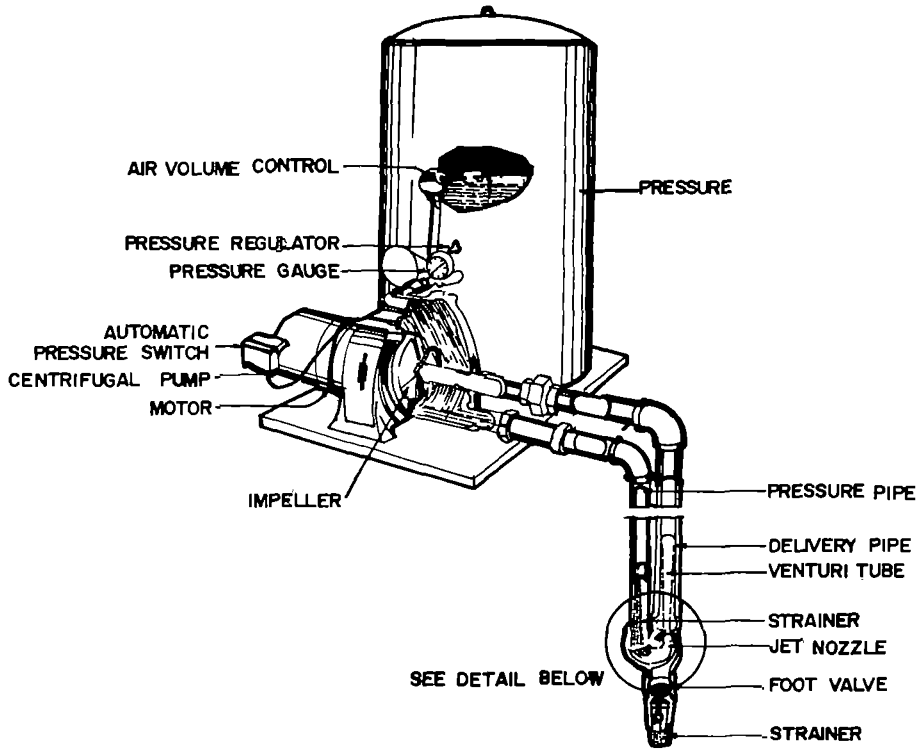
Pumps are often classified by their service application. These classifications include low lift, high lift, well, booster and standby.

Low lift service pumps are normally used in pumping raw untreated water from the source of supply to the treatment plant. High lift service pumps are used in pumping water into the distribution system.

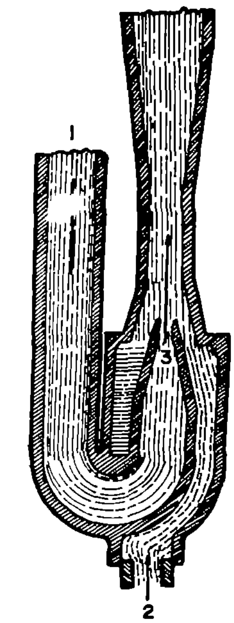
Well service pumps are used in pumping water from a well. Booster pumps are used for increasing the pressure in the distribution system and to lift water to the storage tank. Booster pumps are commonly used in outlying areas of the distribution system to avoid having low pressure areas or to serve higher elevations. Standby pumps are pumps that are made available during period of high water demand or emergencies.

13.05 PUMP PERFORMANCE CURVES

The characteristic curves of a pump describes the factors that affect its performance. They are usually expressed graphically with the rate of discharge Q as abscissa and the other factors plotted as ordinates, such as the head H, and the net positive suction head (NPSH). All pump manufacturers supply performance characteristic curves for their pumps which indicate how the pump capacity varies with discharge pressure or suction pressure. Typical pump performance curves and recommended efficiency are shown in Figure 13.8. From the diagram, one will note that as the pump discharge increases, the total head against which the pump is pumping, decreases. It is also indicated in the curve that as the pump capacity increases, the power required to drive the pump also increase. However, the pump efficiency behaves both proportionately and inversely with the capacity of the pump much like a parabolic curve. The pump efficiency increases as the capacity is increased up to a certain point. The efficiency then decreases from that point even as the capacity continues to increase.



A PRESSURE SYSTEM WITH A DEEP WELL JET PUMP



1 = WATER BEING RETURNED FROM PUMP ABOVE
2 = WATER FROM WELL BEING SUCKED UP INTO THROAT (4) BY HIGH VELOCITY DISCHARGE
3 = RISING WATER

B. DETAIL OF JET NOZZLE

FIGURE 13.6

JET PUMP

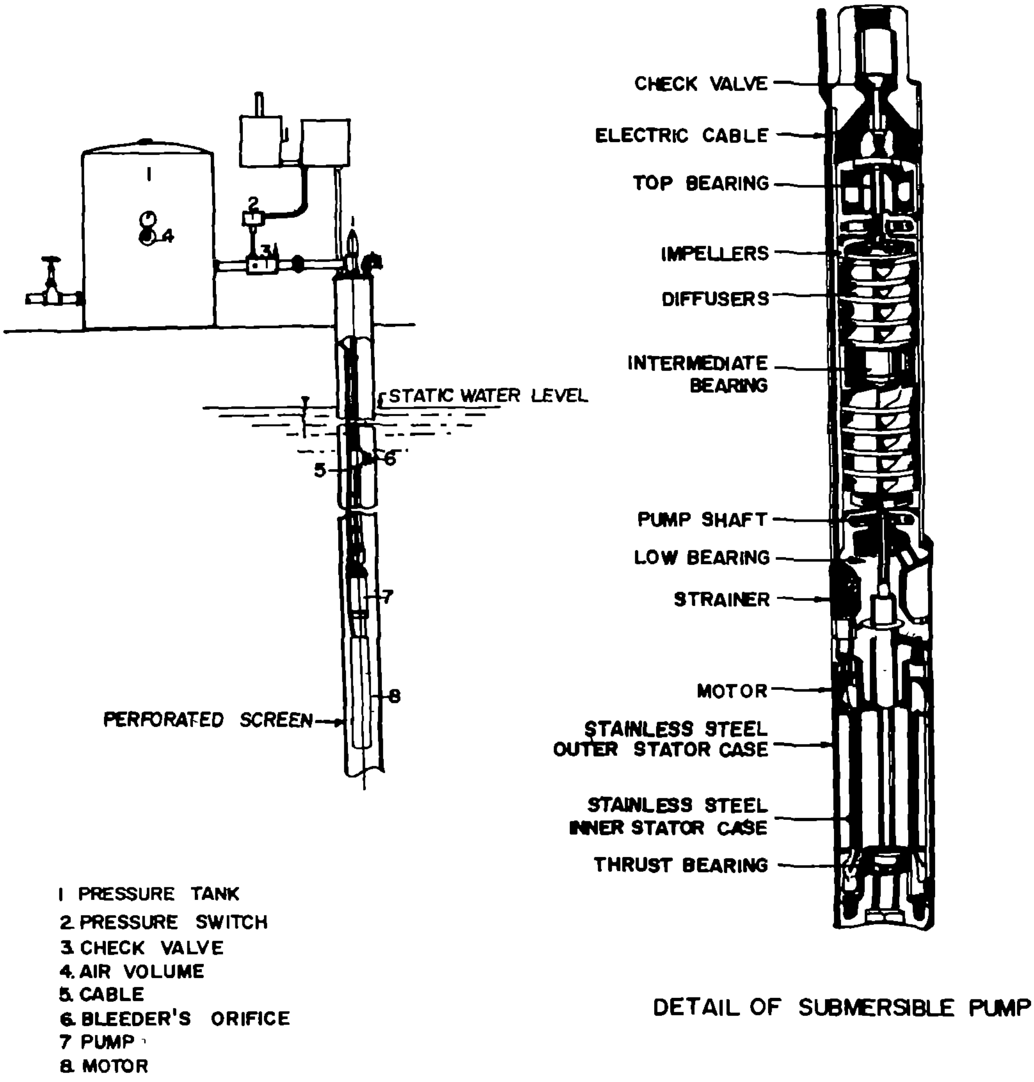


FIGURE T3.7

SUBMERSIBLE PUMP

Recommended Pump Efficiency

Pump Efficiency Overall - 70%
Motor Efficiency Overall - 90% } 0.70 X 0.90 = 0.63 = 63%

1 Centrifugal.

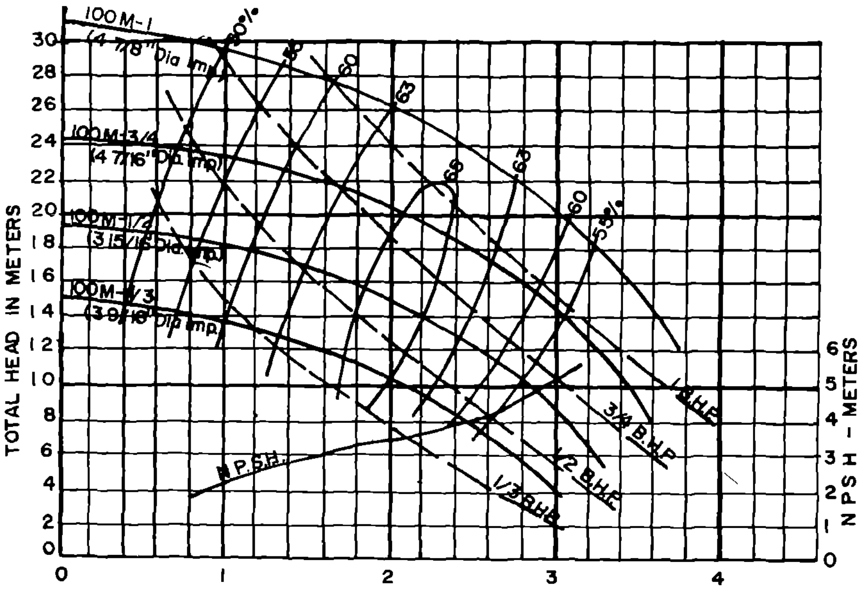
a. Good installation would be - 60%
b. Fair installation would be - 50% } Up to 4M lift
c. Over 4M suction lift - 40% - 4.0 to 5M

2 Jet Pump

a. 10 M lift - 30%
b. 15 M lift - 20%

Consult manufacturer's recommendation for pump efficiency

PUMP PERFORMANCE CURVES*



Net positive suction head (NPSH) is the absolute pressure above the vapor pressure of the fluid pumped available at the entrance or eye of an impeller to move and accelerate the fluid entering the eye

* FROM. MYERS CENTRI-THRIFT PUMPS
32 mm SUCTION - 25mm DISCHARGE
1/3 - 1 HP - 3450 RPM - 60 HZ

FIGURE 13.8 RECOMMENDED PUMP EFFICIENCIES & PUMP PERFORMANCE CURVES

13.06 PRIME MOVERS

Electric, gasoline or diesel engines are commonly used as source of power for operation of pumps. The electric motor was however the most favored source of power to drive the pumps because of the relatively low cost of electricity and reliability of electrical motors. For rural water supply systems where small pumps are usually required, electric motors should be single phase.

Furthermore, electric motors should be protected by heat sensors installed in the windings during manufacture. These sensors will shut the motor off in case of low voltage or change in phase before damage can be done.

13.07 PUMP INSTALLATION

1) **Pumps Connected in Series**

When one pump is connected behind the other, the installation is called series connection. Series connection will yield discharge equivalent to one pump and the head is approximately equal to the sum of the individual heads of the pumps in the system.

2) **Pumps Connected in Parallel**

If we place pumps in parallel, that is, one pump beside the other, they will both be working against the same external head, and will yield identical manometric heads. The capacity of two pumps working in parallel is found by adding their separate discharges together.

13.08 PUMP CONTROL

Pump controls can be manual or automatic. For small systems manual controls can work very well. the operators start the pump in the morning and they can soon tell how long it will take to satisfy the morning peak demand and to fill the tank. When the tank is full, the pump is shut off. The pump is again started when the water level in tank decreases to the minimum water level. On the other hand, in automatic control, the start and stop of pump is actuated either by a float or by pressure.

Example 13.1

Data:

Barrio	:	Pakiad, Oton, Iloilo
Water Consumption Rate	:	60 LPCD
Population	:	611
Design Population	:	1.15 x 611 = 703
Average Day Demand	:	60 x 703 = 42,180 LPD
Maximum Day Demand	:	1.3 x 42,180 = 54,834 LPD
Type of Water Source	:	Well

Static Water Level . . . . 4 M
Pumping Water Level . . . . 6 M
Reservoir Height (Maximum Water Level, M.W.L.) . . . . 8 M
Friction loss in suction and discharge pipe . . . . 2 M
The installation of the system is shown in Figure 13.9

Required:

a. Capacity
b. TDH
c. Water horsepower
d. Brake horsepower
e. Type of Pump

Analysis:

a. Calculate the pump capacity, Q
Design Criteria

Q = Maximum day demand

Q = 54,834 liters/day x 1 day/12 hours x 1 hour/3600 sec.

Q = 1.27 LPS Say 1.30 LPS

b. Calculate the pump TDH

The pump TDH is the sum of pumping water level, fric tion headloss and M.W.L. of reservoir

(See Figure 13.9 for illustration)

Pumping Water Level . . . . 6 M
Friction Headloss . . . . 2 M
M.W.L. of Reservoir . . . . 8 M

T D H . . . . 16 M

c. Calculate the Water Horsepower (W.H.P.)

W.H.P. = Q x H/75
= (1.3) (16)/75 = 0.28 HP

d. Calculate the Brake Horsepower (B.H.P.)

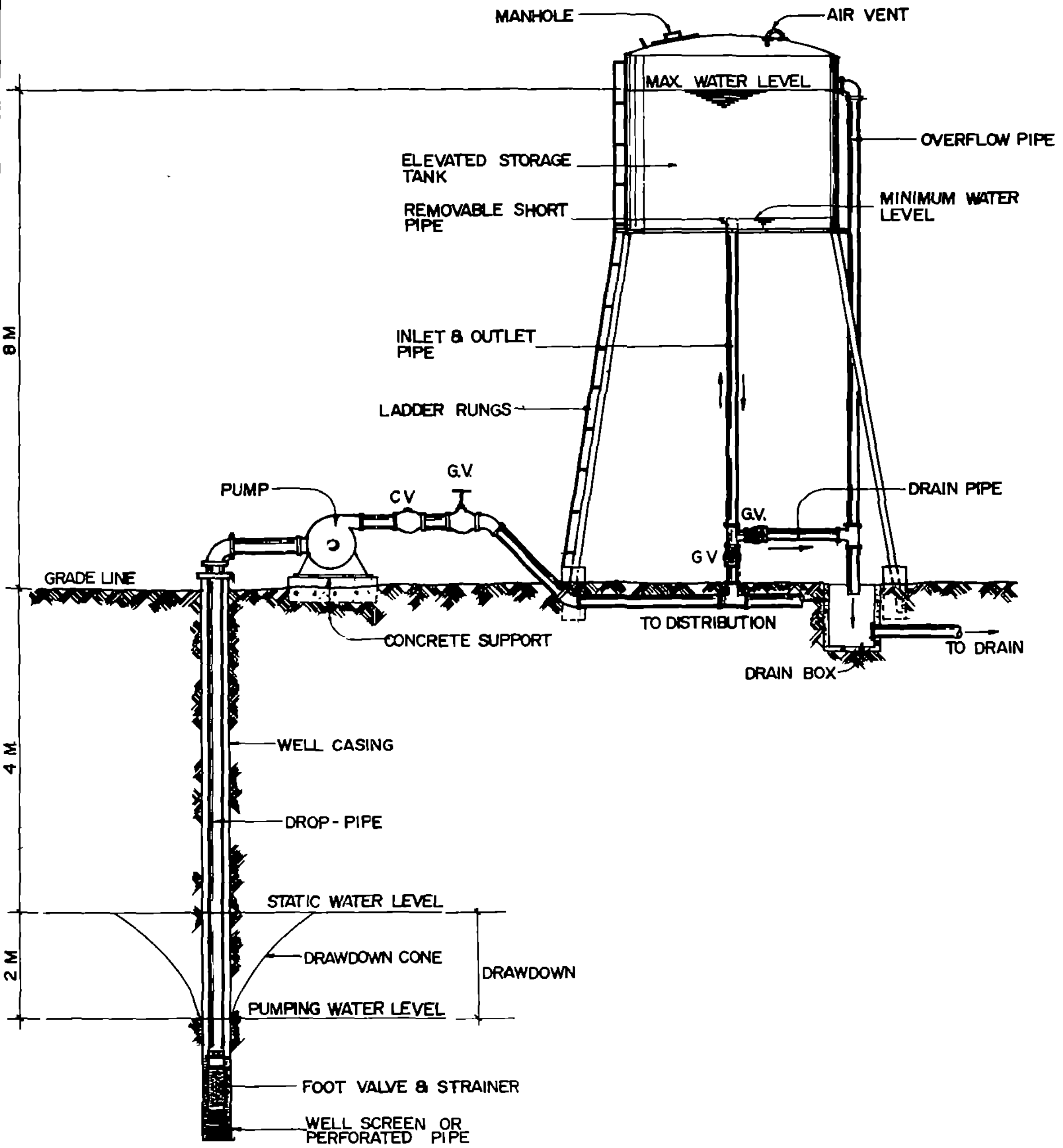
Assumed Pump Efficiency = 40% (Centrifugal Pump)

B.H.P. = W.H.P./e = 0.28/0.4 = 0.70 HP
say 3/4 HP

e. Determine the type of pump

Inasmuch as the pumping level is only 6 M, the most appropriate type of pump to be used is centrifugal pumps with the following characteristics:

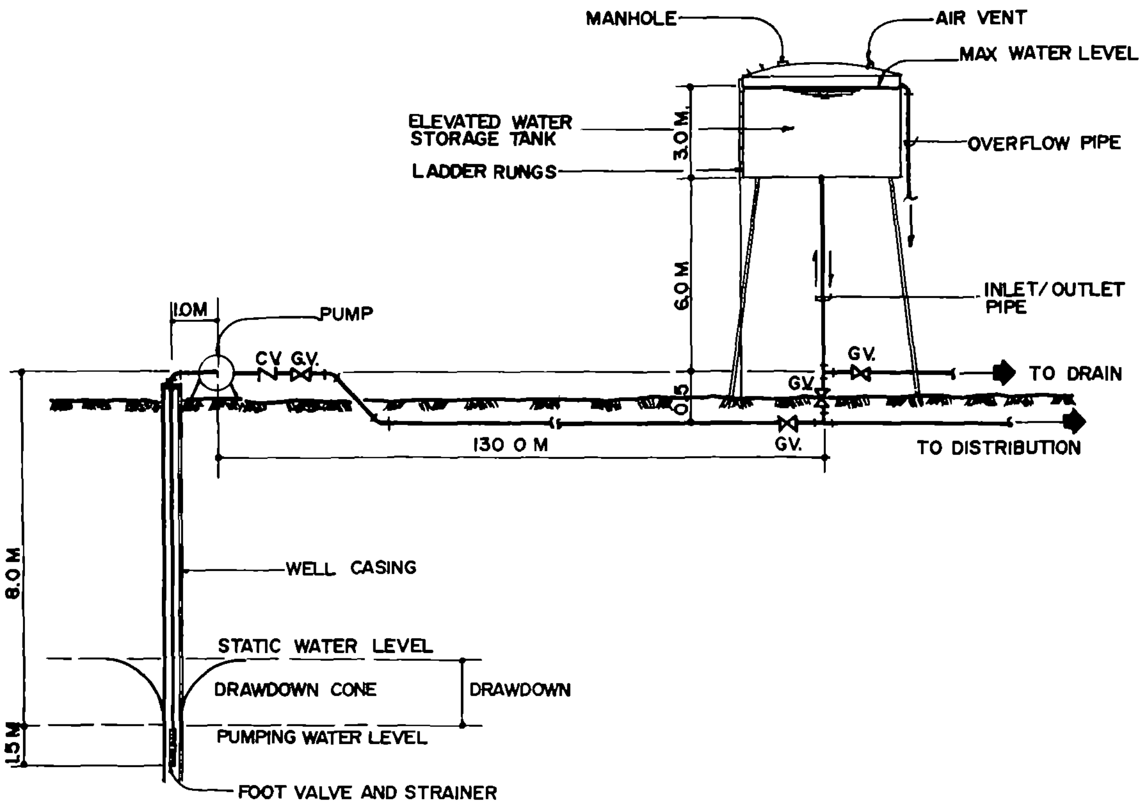
Q = 1.3LPS
TDH = 16 M
BHP = 3/4 H.P.



PIPES CONNECTING THE WATER SOURCE AND ELEVATED RESERVOIR

FIGURE 13.9

ILLUSTRATION OF EXAMPLE NO. 13.1



SECTION

PIPES CONNECTING THE WATER SOURCE AND ELEVATED RESERVOIR

FIGURE 13.10

ILLUSTRATION OF EXAMPLE NO. 13.2

Example 13.2

Determine the pump total dynamic head (TDH) and the pipe sizes in the water supply system shown in Figure 13.10. The pump capacity is 0.6 LPS. As a general rule, the suction pipe should not be smaller than the tapped intake opening of the pump.

Given: From Figure 13.10

Reservoir:

Maximum Water Level = 9 M

Pump:

Q = 0.6 LPS

Pipes:

Length = 1.5 + 8.0 + 1.0 + 130.00 +0.5 + 6.0
= 147.0 M

Fittings and Valves:

1 — foot valve
1 — strainer
1 — 90° Elbow
2 — 45° Elbow
2 — Tees
1 — Check Valve
3 — Globe Valve

Required:

a. Determine the pipe sizes
b. Determine the Pump TDH

Analysis:

1) **Alternate 1.** Use PVC Pipes

a. Determine the Pipe Size

From Appendix O, the recommended pipe size for Q = 0.60 LPS is 38 mm Ø

b. Determine the friction loss:

1) Determine the equivalent length of straight pipe for the valves, fittings, etc. using Table 9.3,

Appurtenances	**Dia. (mm)**	**No.**	**Equivalent Length Per Fitting (M)**	**EQL(M)**
Strainer	38	1	5.49	5.49
Foot Valve	38	1	2.44	2.44
Elbow, 90°	38	1	1.36	1.36
Elbow, 45°	38	2	0.61	1.22
Tees	38	2	2.74	5.48
Check Valve	38	1	3.35	3.35
Globe Valve	38	3	13.71	41.13
Total Equivalent Length				60.47

2) Determine the total Headloss

Determine Headloss per 100 M using Table 9.1.

With Q = 0.60 LPS and 38 mm Ø

$h_f/100$ M = 1.00 M

Calculate the total length of pipe. The total length of pipe is the sum of the equivalent length and the straight pipe.

Total Length = 60.47 + 147.00 = 207.47 M

Calculate the total headloss

h_f = 1.00/100 x 207.47 = 2.07 M

c. Determine the Pump TDH

1) Pump Capacity = 0.60 LPS
2) Determine the pump TDH

TDH is the sum of the height of the maximum water level of storage tank, depth of pumping level and headloss in pipes and fittings.

Height of the Maximum Water Level . . 9.00 M
Depth of Pumping Level . . . . 8.00 M
Friction Loss . . . . 2.07 M

TDH . . . . 19.07 M
say . . . . 19.00 M

3) Calculate the Water Horsepower, WHP

W.H.P. = Q x H/75 = 0.60 x 19/75 = 0.152 HP

4) Calculate the Brake Horsepower. Assume Pump efficiency is 30% (Jet Pump)

B.H.P. = W.H.P./e = 0.15/0.30 = 0.50 HP

Use 1/2 HP which is available in the market.

5) Type of Pump

Since the suction lift is 8 M (beyond the capacity of centrifugal pumps) a jet pumps is selected (Recommended in systems with suction lift of 6-20 M)

2) **Alternate 2.** Use G.I.

a. Determine the pipe size

From Table 9.2, for Q = 0.60 LPS and with pipe size of 38 mm Ø, $h_1/100$ M = 2.00 M

b. Determine the friction loss

1) Determine the equivalent length of valves, fittings, etc. using Table 9.3.

Total Equivalent Length of straight pipe for valves, fittings, etc. = 60.47 M (See Alternate 1)

2) Calculate the total length of pipe

Total length = 60.47 + 147.00 = 207.47 M

Calculate the total headloss

h_f = 2.00/100 M x 207.47 = 4.15 M

c. Pump Selection

1) Pump Capacity = 0.60 LPS

2) Estimate the pump TDH

Height of the Maximum Water Level . 9.00 M
Depth of Pumping Water Level . . . . . 8.00 M
Friction Loss . . . . 4.15 M

TDH. . . . . .21.15 M
say . . . . .22.00 M

3) Estimate the W.H.P.

W.H.P. = Q x H/75 = 0.6 x 22/75 = 0.176 HP

4) Calculate the B.H.P. Assume Pump efficiency is 30% (Jet Pump)

B.H.P. = W.H.P./e = 0.176/0.3 = 0.59 HP

Use 3/4 HP.

3) Conclusion

Pipe Material	Diameter	Discharged	Pump TDH	B.H.P
PVC	38 mm	0.6 LPS	19 M	1/2
G.I.	38 MM	0.6 LPS	22 M	3/4

The use of PVC pipes requires a smaller pump unit and lower electric power consumption as compared to when using G.I. Pipes.

CHAPTER 14

DESIGN OF A DISTRIBUTION NETWORK FOR RURAL WATER SUPPLY SYSTEM

This chapter illustrates the procedure for designing the distribution network and other related facilities for a low cost small water supply system. The following alternative schemes have been considered:

1) Floating-on-the-Line Elevated Reservoir System
2) Multiple Storage Tanks System
3) Fill-and-Draw Elevated Reservoir System
4) Hydropneumatic Pressure System

SAMPLE PROBLEM

Rural Area Z has no existing water supply system. Figure 14.1 shows the scaled layout of the barrio, the population distribution and the location of the water source.

Data:

Present Population:	240
Scale Plan:	Figure 14.1 shows the proposed well site and location of houses.

Required:

The design of the distribution network and other related facilities. Factors such as pump capacity, reservoir volume, number of public faucets, etc., are important as bases for the financial analysis of the rural water supply system for Area Z.

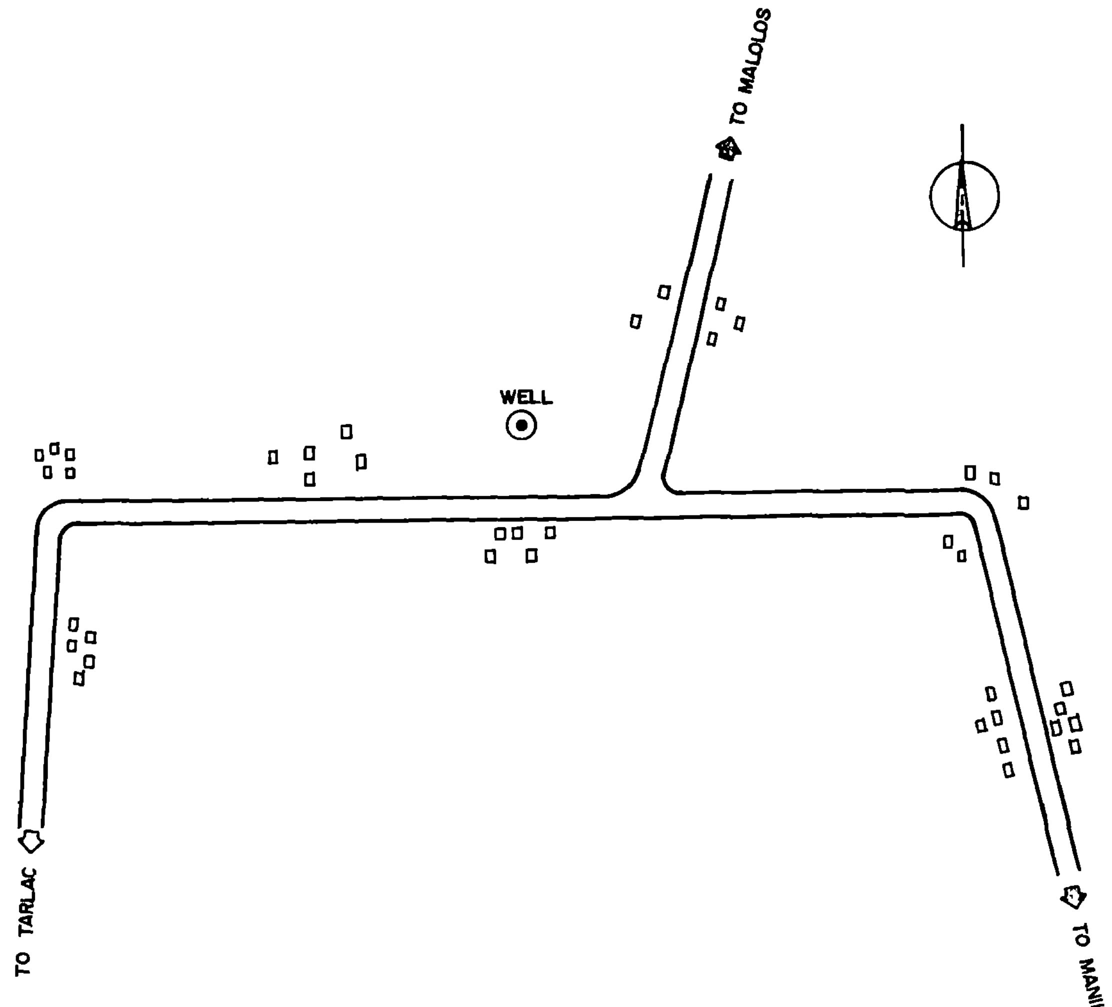
ALTERNATIVE ONE: USE OF A FLOATING-ON-THE-LINE ELEVATED RESERVOIR SYSTEM

PROCEDURE FOR DESIGN:

I. WATER DEMAND

A. Design Criteria

1) Design Period = 5 years
2) Average No. of Persons per Household = 6
3) Design Population = 1.15 P
4) Water Consumption Rate = 60 LPCD
5) Average Day Demand = Design Population × Water Consumption Rate
6) Maximum Day Demand = 1.3 × Average Day Demand
7) Maximum Hour Demand = 3 × Average Day Demand (for Population less than 600)



POPULATION : 240

NO OF HOUSEHOLDS 40

SOURCE OF WATER SUPPLY : SHALLOW WELL AT SAFE YIELD
PUMPING LEVEL 6 M
STATIC WATER LEVEL . 4 M

TERRAIN RELATIVELY FLAT

SOURCE OF POWER ELECTRICITY

LEGEND:

- □ HOUSEHOLD
- ⊙ WATER SOURCE

SCALE: 1 : 2500 M

FIGURE: 14.1

PLAN OF RURAL AREA Z

B. Calculate the Design Population, P_p

$$P_p = 1.15\,P = 1.15 \times 240 = 276$$

C. Calculate the Average Day Demand

Average Day Demand = 276 × 60
= 16,560 LPD
= 0.19 LPS

D. Calculate the Maximum Day Demand

Maximum Day Demand = 1.3 × 16,560
= 21,528 LPD
= 0.25 LPS

E. Calculate the Maximum Hour Demand

Maximum Hour Demand = 3 × 16,560 ÷ 24
= 2070 LPH

II. PUBLIC FAUCETS (PF)

A. Design Criteria

1) No. of households per public faucet (PF) = 5 HH
2) Minimum pipe size = 13 mm
3) Location should be equidistant to the 5 HH it will serve.

B. Determine the Number of Public Faucets to be Installed.

1) To be installed at present

Number of HH = 240/6 = 40
Number of PF = 40/5 = 8

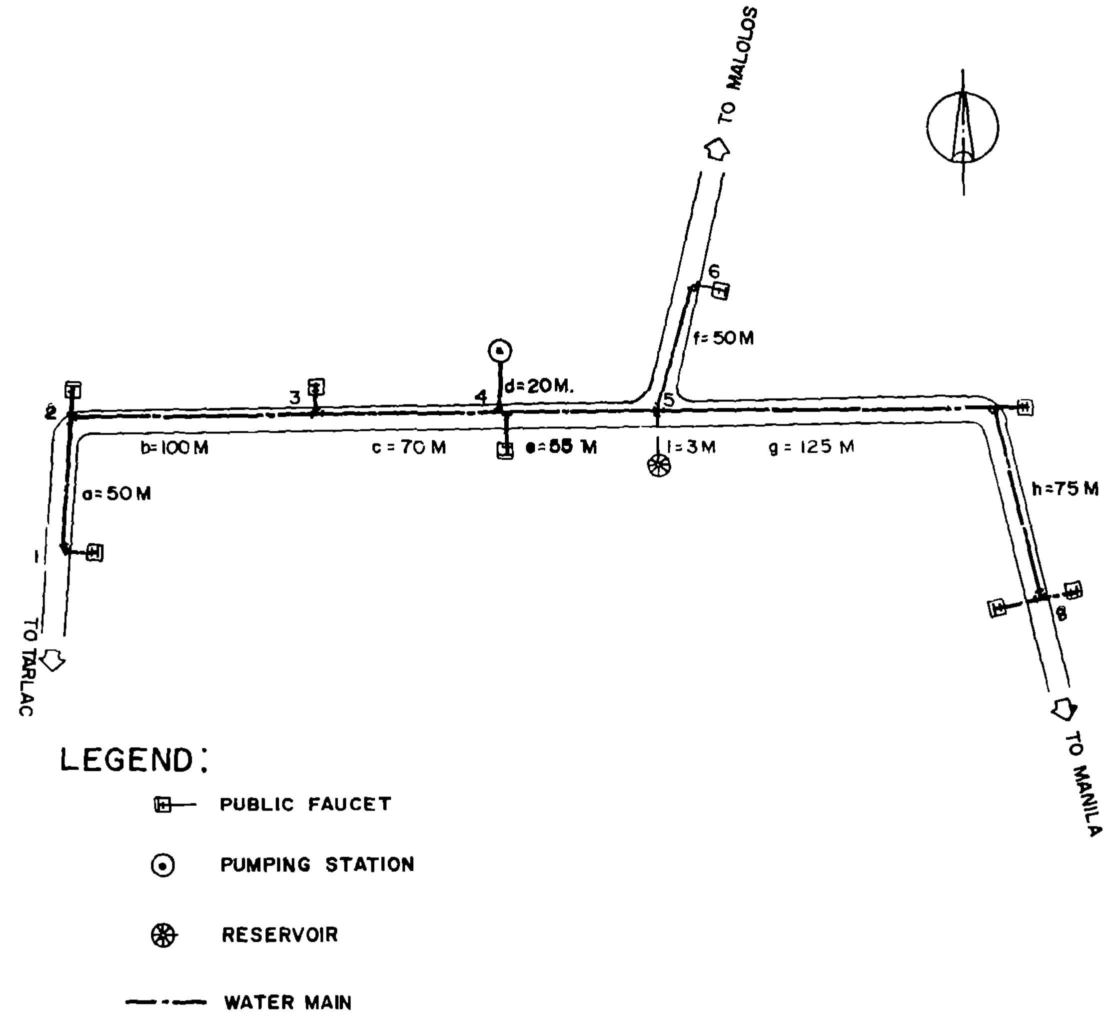
2) Total number of Public Faucets needed for ultimate development.

Number of HH = 276/6 = 46
Number of PF = 46 ÷ 5 = 9.2 say 10 PF

C. Decide on the location of Public Faucet. Figure 14.2 shows the locations of the Public Faucets (PF).

Recommended Locations (Figure 14.2)

Location	**Number of Public Faucets**
1	1
2	1
3	1
4	1
5	0
6	1
7	1
8	2



LOCATION OF PUBLIC FAUCETS, RESERVOIR AND WATER MAINS

FIGURE 14.2

FLOATING-ON-THE-LINE RESERVOIR SYSTEM

D. Calculate the Maximum Hour Demand per Public Faucet. Assume that water will be drawn simultaneously by users.

1) Q_1 = Maximum Hour Demand at location number (1)

Q_1 = Population served in location number (1) × 1.15 × 60 × 3

= 5 × 6 × 1.15 × 60 × 3 = 6210 LPD = 258.8 LPH

= 6210 × day/24 hr. × 1 hr. /60 min. × 1 min./60 sec. min./60 sec.

= 0.07 LPS

A short cut in determining the flow rates of the other PF's is through ratio and proportion. For example,

$Q_2 = HH_2/HH_1 \times Q_1$

HH_2 = number of households at location number (2)

HH_1 = number of households at location number (1)

2) $Q_2 = HH_2/HH_1 \times Q_1 = 5/5 \times 0.07 = 0.07$ LPS

3) $Q_3 = HH_3/HH_1 \times Q_1 = 5/5 \times 0.07 = 0.07$ LPS

4) $Q_4 = HH_4/HH_1 = Q_1 = 5/5 \times 0.07 = 0.07$ LPS

5) $Q_5 = HH_5/HH_1 \times Q_1 = 0$ LPS ($HH_5 = 0$)

6) $Q_6 = HH_6/HH_1 \times Q_1 = 5/5 \times 0.07 = 0.07$ LPS

7) $Q_7 = HH_7/HH_1 \times Q_1 = 5/5 \times 0.07 = 0.07$ LPS

8) $Q_8 = HH_8/HH_1 \times Q_1 = 10/5 \times 0.07 = 0.14$ LPS

III. TRANSMISSION AND DISTRIBUTION MAINS

CASE 1. Water is Supplied from Reservoir, Pump not operating (See Figure 14.3)

A. Determine the flow rates in the pipes

$Q_a = Q_1 = 0.07$ LPS

$Q_b = Q_a + Q_2 = 0.07 + 0.07 = 0.14$ LPS

$Q_c = Q_b + Q_3 = 0.14 + 0.07 = 0.21$ LPS

$Q_d = 0$

$Q_e = Q_c + Q_4 = 0.21 + 0.07 = 0.28$ LPS

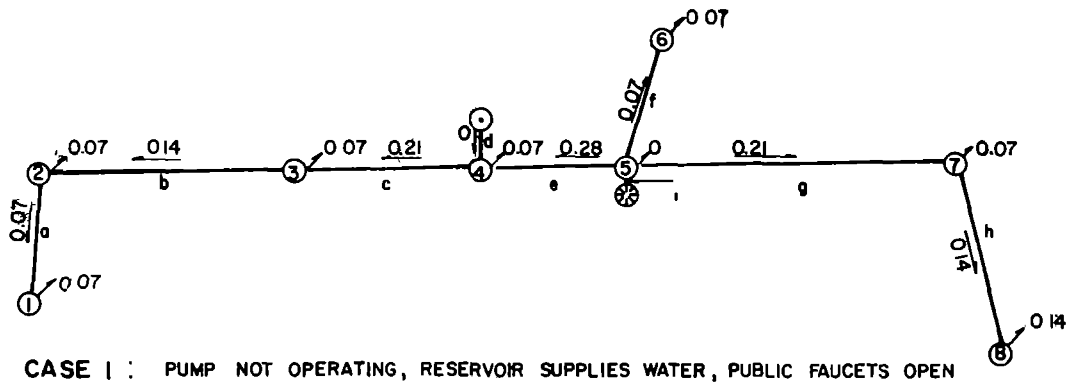
$Q_f = Q_6 = 0.07$ LPS

$Q_h = Q_8 = 0.14$ LPS

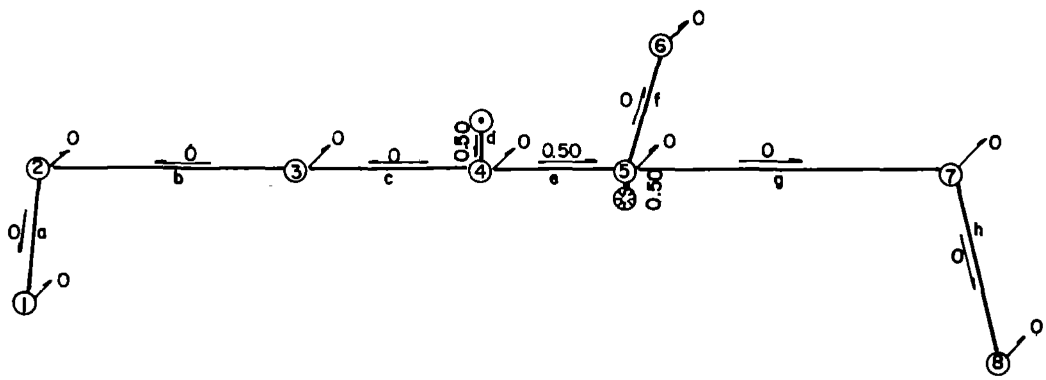
$Q_g = Q_h + Q_7 = 0.14 + 0.07 = 0.21$ LPS

$Q_I = Q_e + Q_f + Q_g = 0.28 + 0.07 + 0.21 = 0.56$ LPS

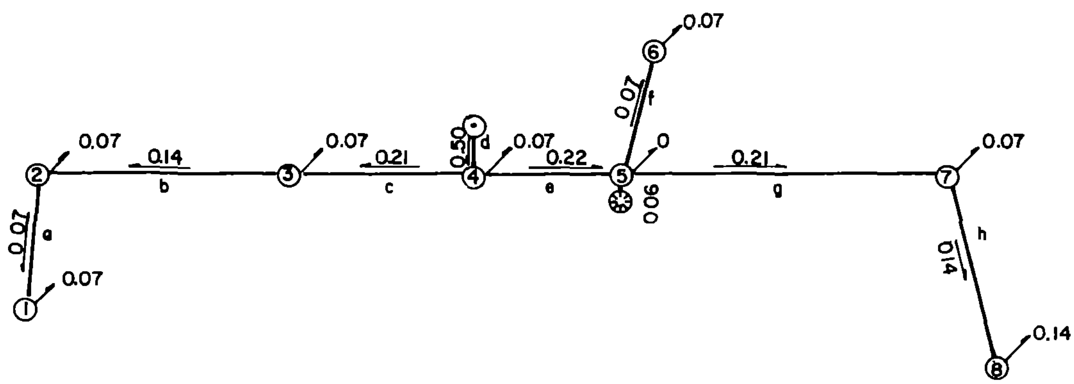
B. Select the longest route of pipes taking the reservoir as the base point, and determine their diameters approximately us-



CASE 1: PUMP NOT OPERATING, RESERVOIR SUPPLIES WATER, PUBLIC FAUCETS OPEN



CASE 2: PUMP OPERATING, RESERVOIR EMPTY, PUBLIC FAUCETS CLOSED



CASE 3: PUMP AND RESERVOIR SUPPLYING WATER AT THE SAME TIME, PUBLIC FAUCETS OPEN

FIGURE. 14.3

FLOATING-ON-THE LINE RESERVOIR
DIFFERENT CASES OF OPERATION

ing Appendix O. The longest network is composed of pipes a, b, c, e and i.

Pipe	Length (M)	No. of HH Served	Pipe Diameter (mm)
a	50	5	25
b	100	10	25
c	70	15	25
d	55	20	31
i	3	40	38

C. Calculate the friction loss using Table 9.1,

Pipe	Q(LPS)	Dia. (mm)	h_1/100M	Length(M)	h_f(M)
a	0.07	25	0.13	50	0.07
b	0.14	25	0.48	100	0.48
c	0.21	25	0.94	70	0.66
e	0.28	31	0.67	55	0.37
i	0.56	38	1.00	3	0.03
	Total Friction Loss.				1.61 M

D. Calculate the Minimum Water Level Elevation of Reservoir. The minimum water level is the sum of the friction loss in the longest route and the minimum pressure in the farthest PF.

Friction loss	1.61 M
Minimum Pressure in Water Main	3.00 M
Minimum Water Level Above the Water Main	4.61 M
	say 5.00 M

E. Check the pipe diameter in the longest route and estimate the diameter of pipes f, g and h.

1) Available head to operate the system = minimum water level of reservoir = 5.0 M

2) Determine the diameter of pipes included in the longest route (Pipes a, b, c, e, i)

a) Find h_1/100 M of the longest route

$$\frac{h_1}{100M} = \frac{\text{Available Head} - \text{Minimum Pressure}}{\text{Total Length of Pipe}} \times 100$$

Total Length $= L_a + L_b + L_c + L_e + L_i$
(See Fig. 14.4)
$= 50 + 100 + 70 + 55 + 3$
$= 278$ M

$$\frac{h_1}{100\ M} = \frac{5-3}{278} \times 100 = 0.72$$

b) Determine the pipe diameters using Table 9.1

Pipe	Q(LPS)	$h_1/100$(M)	Dia. (mm) (Table 9.1)
a	0.07	0.72	19
b	0.14	0.72	25
c	0.21	0.72	25
e	0.28	0.72	31
i	0.56	0.72	38

3) Determine the diameter of pipes g and h

$$\frac{h_1}{100\text{ M}} = \frac{\text{Available Head at point 5} - \text{Minimum Pressure}}{\text{Total Length of Pipes g and h}}$$

Available Head at point 5 = 5 − friction loss in pipe i

Friction loss in pipe i can be obtained using Table 9.1 with $Q_i = 0.56$ and $D_i = 38$ mm

$h_L = 1.00$ M/100 M

$h_{fi} = h_L \times$ length of pipe i

$= 1.00/100 \times 3 = 0.03$ M

Available Head at Point 5 = 5 − 0.03 = 4.97 M

$h_1/100\text{ M} = (4.97 - 3)/200 \times 100 = 0.99$

Find the diameter of pipes g and h using Table 9.1

Pipe	Q(LPS)	$h_1/100$ (M)	Dia. (mm) (Table 9.1)
g	0.19	0.99	25
h	0.13	0.99	25

4) Determine the diameter of pipe f.

$$\frac{h_1}{100\text{ M}} = \frac{\text{available head at point 5} - \text{minimum pressure}}{\text{Length of pipe f}} \times 100$$

$$= \frac{4.97 - 3}{50} \times 100 = 3.94$$

Pipe	Q(LPS)	$h_1/100$ (M)	Dia. (mm) (Table 9.1)
f	0.07	3.94	13

CASE 2. All Public Faucets are Closed, Pump is Utilized to Fill up the Reservoir (Figure 14.3)

A. Determine the Pump Capacity

1) Design Criteria

a. The pump capacity should at least be enough to supply the maximum day demand of the area to be served.

b. Pump operating time — 12 Hours/day

2) Estimate the Pump Capacity

Pump Capacity = Maximum Day Demand/Operating Time
= 21,528 1/d × 1d/12 hrs × 1hr/3600 sec.
= 0.50 LPS

B. Determine the diameter of the pipes connecting the well and reservoir. If the distance between nodes is not greater than 150 M, Appendix O could be reliably used in approximating the diameters.

Pipe	Length (M)	Capacity (LPS)	Diameter (mm)*
d	20.5	0.50	38
e	55.0	0.50	38
i	8.0	0.50	38
Suction	7.0	0.50	38

*The column for flow rate, Q in Appendix O of public faucet system is located and then a horizontal line is drawn intersecting the column for PVC pipe sizes public faucet. For example, Q = 0 50 LPS. Since Q = 0.50 LPS is not in the Table, Q = 0 58 LPS (the nearest value in the table) is taken and a horizontal line is drawn until it intersects the column for pipe sizes The value found is, D = 38 mm

CASE 3. The Pump and Reservoir are Supplying Water at the Same Time.

Inasmuch as Case 1 and Case 2 are the extreme cases for pipe flows, pipe diameters which are obtained in Case 3 will be smaller than those obtained in Cases 1 and 2.

SUMMARY

Selection of Pipe Size (see Figure 14.4)

		Diameter (mm)			
Pipe	Length (M)	Case 1	Case 2	Selected	Recommended*
a	50	19	—	19	25
b	100	25	—	25	25
c	70	25	—	25	25
d	20.5	—	38	38	38
e	55	31	38	38	38
f	50	13	—	13	25
g	125	25	—	25	25
h	75	25	—	25	25
i	8	38	38	38	38
Suction	7	—	38	38	38

*Recommended pipe sizes to minimize different types of fittings and for fewer sizes of pipes to be stocked

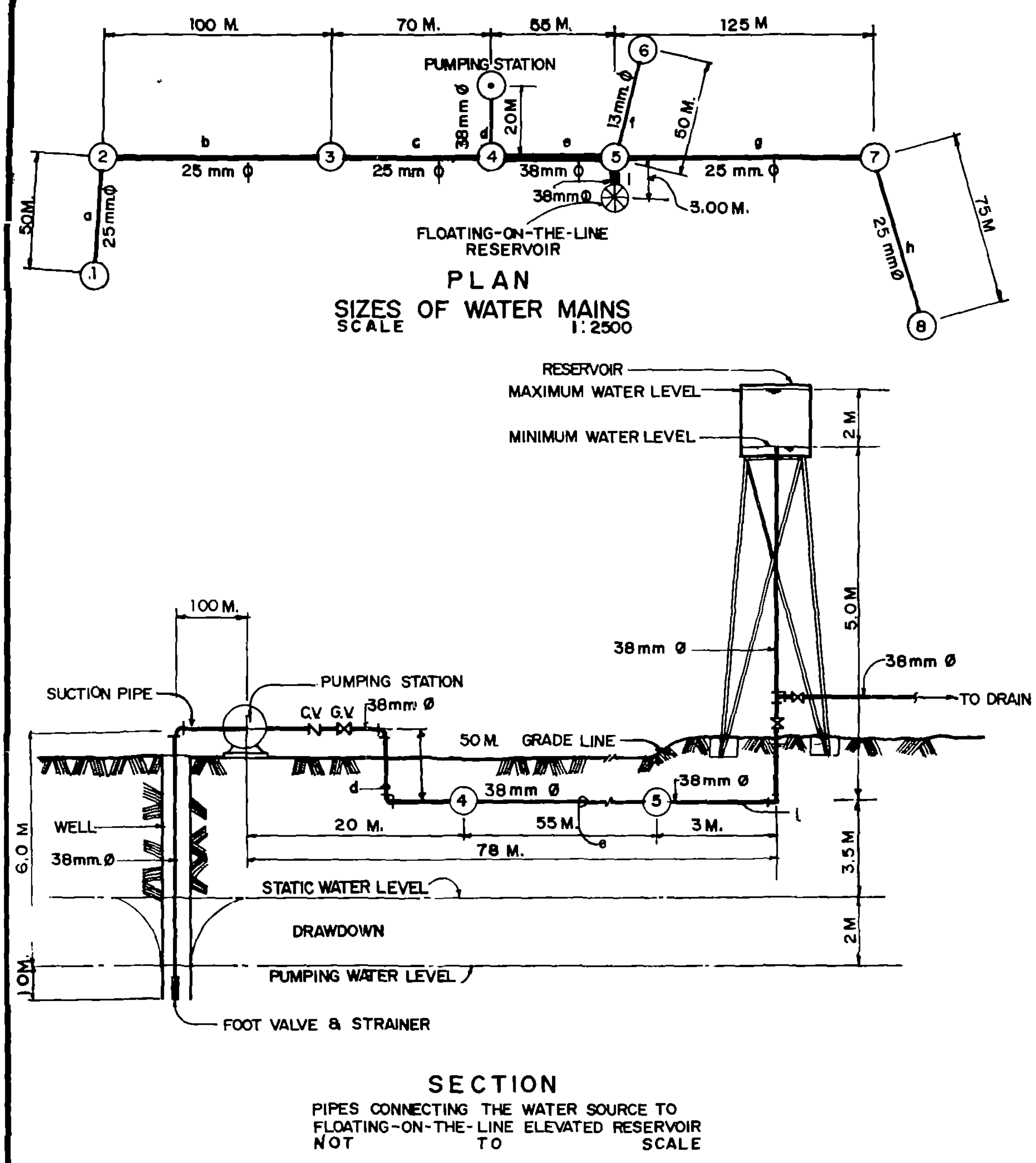


FIGURE 14 4

FLOATING-ON-THE LINE RESERVOIR
SIZES OF WATER MAINS

IV. DESIGN OF RESERVOIR AND PUMP

CASE 1. Reservoir Capacity is Equivalent to one-quarter of the Average Day Demand.

A. Design of Reservoir

1. Determine the Reservoir Capacity

Criterion for Capacity = 1/4 × Average Day Demand
Capacity = 1/4 × 16,560
= 4142 say 4000 liters

Shape of Reservoir = Cylindrical
Height of Water Level = 2.00m
From Fig. 12.5, Diameter = 1.6 M
Height of Reservoir = Height of Water Level + Freeboard
= 2.00 + 0.15
= 2.15 M.

2. Estimate the Minimum Water Level

Minimum Water Level = 5.0 M above the water main (see Section III D, page 14.06 for Calculation)

3. Estimate the Maximum Water Level

Minimum Water Level = 5.0 M
Depth of Water = 2.0 M
Maximum Water Level = 7.0 M above water main

B. Design of Pump

1. Determine the Pump Capacity

Capacity = 0.50 LPS
(see Section III Case 2)

$$\text{Frequency of Filling the Reservoir} = \frac{\text{Maximum Day Demand}}{\text{Volume of Reservoir}} = \frac{21{,}528}{40{,}000} = 5.4 \text{ times per day}$$

$$\text{Reservoir Filling Time} = \frac{\text{Volume of Reservoir}}{\text{Capacity of Pump}}$$

$$= \frac{4{,}000 \text{ L}}{0.50 \text{ LPS}} = 8{,}000 \text{ seconds}$$

$$= 2.2 \text{ hours}$$

2. Calculate the Pump TDH

The pump TDH is the sum of the depth of pumping level, maximum water level of reservoir and friction losses in pipes, fittings and valves which connect the source of water and reservoir.

a) Calculate the friction losses in the pipes (see Figure 14.4)

Diameter	Q(LPS)	$h_1/100$(M)	Length (M)	h_F(M)
38 mm	0.50	0.71	90.5	0.64

b) Calculate the Pump TDH

Friction Loss	0.64 M
Maximum Water Level of Reservoir	7.00
Depth of Pumping Water Level	6.00 M
TDH	13.64 M
say	15.00 M

Note: Friction losses due to valves and fittings were assumed to be negligible.

c) Estimate the Water Horsepower, W.H.P. and Brake Horsepower, B.H.P. assuming the efficiency, e = 30% (Jet Pump)

W.H.P. = (Q × H)/75 = (0.50 × 15)/75 = 0.10 HP

B.H.P. = W.H.P./e = 0.10/0.30 = 0.33 HP
Use 1/3 HP Pump

CASE 2. **Reservoir is Used only to Supply Water in Excess of the Maximum Day Demand.**

A. Design of Pump (see Case 1)

Q = 0.50 LPS
TDH = 15 M
B.H.P. = 1/3 HP

B. Design of Reservoir

1. Determine the Reservoir Capacity

Criterion for Capacity
= No. of Peak Hours × (Max. Hour Demand – Max. Day Demand)

Capacity = 3 × (0.58 – 0.25) × 3600
= 3564 say 4000 liters

Height of Water Level
= 2.00 M

From Fig. 12.5, Diameter
= 1.60 M

Height of Reservoir
= Height of Water Level + Freeboard
= 2.00 + 0.15
= 2.15 M

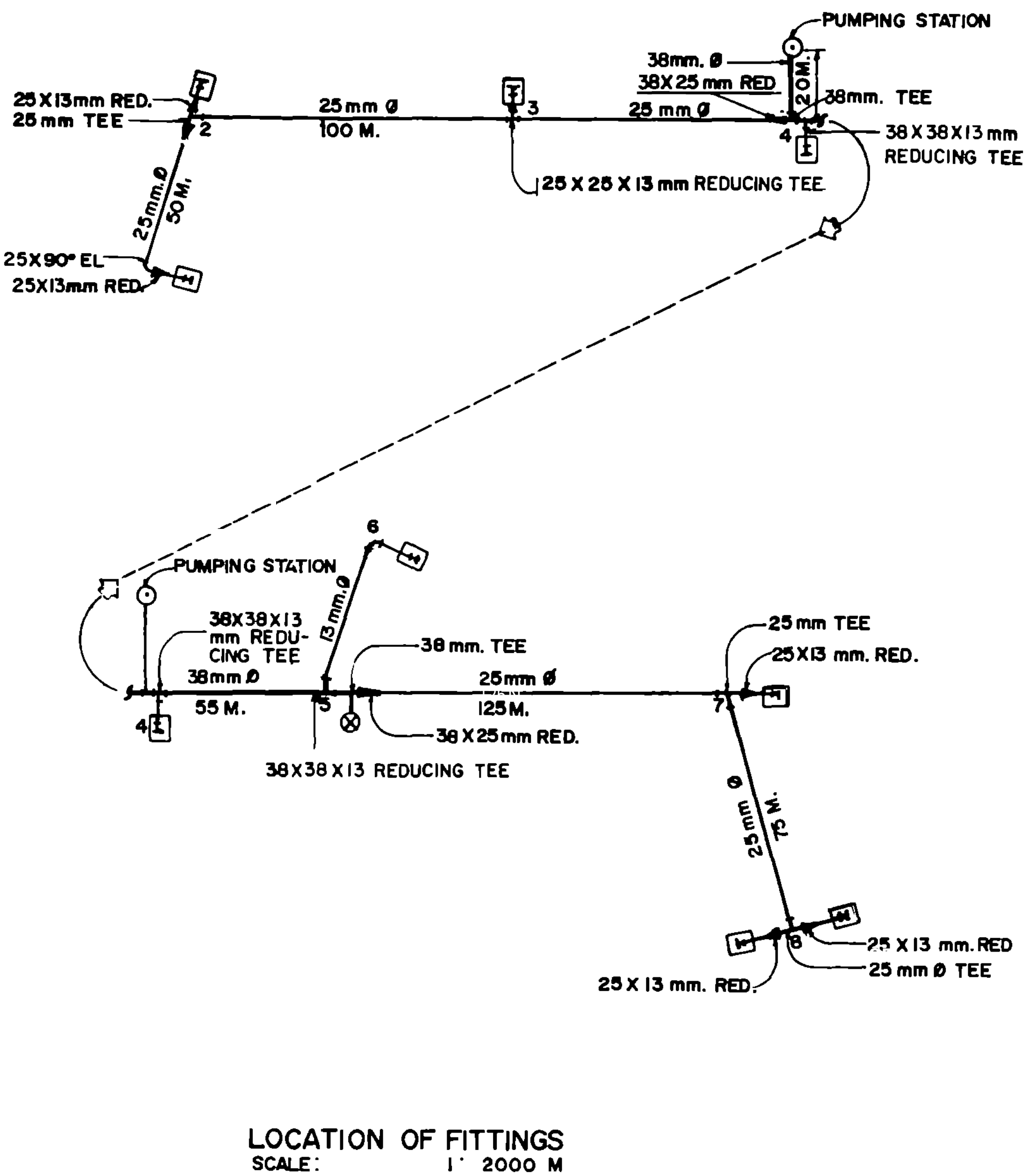


FIGURE 14.5

FLOATING-ON-THE-LINE RESERVOIR

2. Estimate the Minimum Water Level

Minimum Water Level = 5.0 M above water main (see Section III D, for Calculation)

3. Estimate the Maximum Water Level

Minimum Water Level . . . . 5.0 M
Height of Water Level . . . . 2.0 M
Maximum Water Level . . . . 7.0 M

V. FITTINGS

The locations, types and sizes of fittings are shown in Figures 14.4, 14.5 and Appendix L in the following table.

PVC Fittings

(Figure 14.4 and 14.5)

Junction	Elbow, 90°		Reducer		Tee		Reducing Tee	
No.	Quantity	Size (mm)	Quantity	Size (mm)	Quantity	Size (mm)	Quantity	Size (mm)
1	1	25	1	25 × 13				
2			1	25 × 13	1	25		
3							1	25 × 25 × 13
4			1	38 × 25	1	38	1	25 × 25 × 13
5			1	38 × 25	1	38	1	38 × 38 × 25
6	1	25						
7			1	25 × 13	1	25		
8			2	25 × 13	1	25		
Pump	3	38						
Reservoir	1	38			1	38		

G. I. Fittings
(Appendix L)

Public Faucet Installation = 16 pcs. 13 mm × 90° Elbow

VII. SUMMARY OF DESIGN

A. Water Demand

1) Average Water Demand . . . . 16,560 LPD
2) Maximum Day Demand . . . . 21,528 LPD
3) Maximum Hour Demand . . . . 270 LPH

B. Public Faucets

1) Location — see Figure 14.2
2) Number of Public Faucets
To be installed now 8
To be installed ultimately 10

C. Reservoir

CASE 1. Reservoir Capacity is Equivalent to one-fourth o) the Average Day Demand.

1. Capacity 4,000 liters
2. Reservoir Water Level
   a) Minimum Water Level 5.0 M above water main
   b) Maximum Water Level 7.0 M above water main

CASE 2. Reservoir is Used only to Supply Water in Excess of the Maximum Day Demand

1. Capacity 4,000 liters
2. Reservoir Water Level
   a) Minimum Water Level 5.0 M above water main
   b) Maximum Water Level 5.8 M above water main

D. Pipes (Figure 14.4)

Pipe	Diameter (mm)	Length (M)
a	25	50
b	25	100
c	25	70
d	38	20
e	38	55
f	25	50
g	25	125
h	25	75
i	38	3
Suction	38	7

E. Pump

1) Capacity 0.50 LPS
2) TDH 15.0 M
3) BHP 1/3 HP

BILL OF QUANTITIES
FLOATING-ON-THE-LINE RESERVOIR SYSTEM
RURAL AREA Z

DESCRIPTION	QUANTITY UNIT	UNIT COST	COST
1) PVC Pipes			
38 mm O	91 M	₱ 18.90	₱ 1,719.90
25 mm O	470 M	11.25	5,287.50
13 mm O	33 M	5.60	184.80
Sub-total			₱ 7,192.20
2) G.I. Pipes			
13 mm	12 M	9.50	114.00
3) PVC Fittings			
25 mm Elbow, 90°	3 Pc.	12.35	24.70
25 mm Tee	4 Pcs.	17.50	70.00
38 mm Tee	3 Pcs.	32.15	96.45
38 mm Elbow, 90°	4 Pcs.	28.60	114.40
13 × 25 mm Reducer	6 Pcs.	8.35	50.50
25 × 38 mm Reducer	2 Pcs.	15.50	31.00
25 × 25 × 13 mm Reducing Tee	2 Pcs.	17.50	35.00

38 × 38 × 13 mm Reducing Tee	1 Pc.	32.15	32.15
38 mm Socket	10 Pcs.	15.50	155.00
25 mm Socket	70 Pcs.	8.35	584.50
13 mm Socket	8 Pcs.	6.00	48.00
13 mm Adaptor Sockets	8 Pcs.	11.95	95.60
Sub-Total			1,336.90
4) 13 mm G.I. Elbow, 90/	16 Pcs.	2.10	33.60
5) 13 mm Bronze Public Faucets	8 Pcs.	26.00	208.00
6) Pump, 0.37 LPS × 15 M (⅓ HP)	1 Pc.	1,890.00	1,890.00
7) Valves			
		125.00	125.00
Check Valve, 38 mm	1 Pc.	125.00	125.00
Globe Valve, 38 mm	3 Pcs.	145.00	435.00
Material (Except Reservoir)			11,334.70

Description	Case 1 Reservoir	Case 2 Reservoir
1. Material Cost (Except Reservoir)	₱11,334.70	₱11,334.70
2. Reservoir	6,500.00	6,500.00
Total Material Cost	₱17,834.70	₱17,834.70
Labor Cost, 30% of Material Cost	5,350.41	5,350.41
Total Labor and Material Cost	₱23,185.11	₱23,185.11
Contingency, 5% of Labor and Material Cost	1,159.25	1,159.25
Total Project Cost	₱24,344.36	₱24,344.36

ALTERNATIVE TWO: USE OF MULTIPLE STORAGE TANKS SYSTEM
PROCEDURE FOR DESIGN

I. Water Demand (See Alternate One for Computation)

1) Average Water Demand .... 16,560 LPD
2) Maximum Day Demand .... 21,528 LPD
3) Maximum Hour Demand .... 2,070 LPH

II. Public Faucets (PF)

Location — (See Figure 14.6). A public faucet is installed in each storage tank. (See Figure 12.4A for features of the Reinforced Concrete (RC) Multiple Storage Tanks).

III. Storage Tank

1) Determine the height of the reservoir based on ground surface elevation. Shown in Figure 12.4A are the following data:
   a. Minimum Water Level .... 1.00 M
   b. Maximum Water Level .... 1.92 M

2) Capacity of the Tank
   a. No. of HH Served 5
   b. Capacity of Tank .... ½ × Average Day Demand for 5 HH

c. Tank Volume . . . . 827 liters

3) Location (See Figure 14.6)

4) Determine the number of times the tank is filled per day.

$$\text{No. of times the tank is filled per day} = \frac{\text{Maximum Day Demand}}{\text{Total Volume of Reservoir}}$$

$$= \frac{21{,}528 \text{ liters per day}}{8 \times 827 \text{ liters}}$$

$$= 3.25 \text{ times/day}$$

IV. Transmission and Distribution Mains.

1) Calculate the flow rate of water entering the tank.

Total tank filling time = Pump Operating time
= 12 hours.

$$\text{Flow rate, } Q = \frac{\text{Frequency of Filling} \times \text{Volume of Tank}}{\text{Total Tank Filling Time}}$$

$$= \frac{3.25 \times 827}{12}$$

$$= 224 \text{ Liters/hour}$$

$$= 0.063 \text{ LPS}$$

2) Calculate the flow rate in pipe lines. (Figure 14.7)

$Q_a = Q_1 = 0.063$ LPS

$Q_b = Q_a + Q_2 = 0.063 + 0.063 = 0.126$ LPS

$Q_c = Q_b + Q_3 = 0.126 + 0.063 = 0.189$ LPS

$Q_h = Q_8 = 0.126$ LPS

$Q_g = Q_h + Q_7 = 0.126 + 0.063 = 0.189$ LPS

$Q_f = Q_6 = 0.063$ LPS

$Q_e = Q_g + Q_f = 0.189 + 0.063 = 0.252$ LPS

$Q_d = Q_e + Q_c + Q_4 = 0.252 + 0.189 + 0.063$
$= 0.504$ LPS

3) Using Appendix O, determine the diameter of pipelines.

Pipe	Q(LPS)	Diameter in mm (Appendix O)	Diameter in mm (Recommended)	Length (M)
a	0.063	25	25	50
b	0.126	25	25	100
c	0.189	25	25	70
d	0.504	38	31	20
e	0.252	31	31	55
f	0.063	25	25	50
g	0.189	25	25	125
h	0.126	25	25	75

V. PIPE FITTINGS

The location, types and sizes of fittings are shown in Figure 14.7 and Appendix L and tabulated in the following table:

PVC FITTINGS (Figure 14.7)

Juntion No.	Elbow 90°		Reducer		Tee		Reducing Tee	
	Qty.	Size (mm)	Qty.	Size (mm)	Qty.	Size (mm)	Qty.	Size (mm)
1	1	25						
2					1	25		
3					1	25		
4			1	25 × 31	1	31	1	31 × 31 × 25
5			1	25 × 31			1	31 × 31 × 25
6	1	25						
7					1	25		
8					1	25		
Pump	3	31						

G.I. FITTINGS (Figure 12.4A)

Tank	16	25
	8	13

VI. PUMP

A. Determine the Pump Capacity

1. Design Criteria
   a. The pump capacity should at least be enough to supply the maximum day demand of the area to be served.
   b. Pump operating time . . . . 12 hours/day

2. Estimate the Pump Capacity

Pump Capacity = Maximum Day/Operating Time
= 21,528 1/d × 1d/12 hrs × 1 hr/3600 s.
= 0.50 LPS

B. Estimate the Pump TDH

The pump TDH is the sum of the friction loss from the water source to the farthest tank, the depth of pumping water level and the maximum water level of the tanks. From Figure 14.6 the farthest tank is located at point 8. The connecting pipes are pipes d, e, g and h.

1. Determine the friction loss in pipes d, e, g, and h.

Pipe	Q(LPS)	Diameter (mm)	$h_1/100$ M	Length(M)	Friction Loss
d	0.504	31	1.74	20	0.35
e	0.252	31	0.48	55	0.26
g	0.189	25	0.94	125	1.18
h	0.126	25	0.36	75	0.27
				Total friction loss	2.06

2. Determine the Pump TDH

Maximum Water Level .... 1.92 M
Depth of Pumping Level .... 6.00 M
Friction Loss .... 2.06 M
Minimum Pressure at the inlet of the
Reservoir .... 3.00 M
say .... 12.98 M

13.00 M

3. Calculate the pump WHP and BHP

$$WHP = \frac{Q \times H}{75} = \frac{0.5 \times 13}{75} = 0.09$$

Assume 30% efficiency (Jet Pump)

$$BHP = \frac{WHP}{e} = \frac{0.09}{0.3} = 0.30$$

Use 1/3 HP Pump

VII. SUMMARY OF DESIGN

1. Water Demand

a. Average Day Demand .... 16,560 LPD
b. Maximum Day Demand .... 21,528 LPD
c. Maximum Hour Demand .... 2,070 LPH

2) Public Faucets

a. Location (See Figure 14.6)

It should be noted that the PF is installed directly with the tank.

3) Reservoir (See Figure 12.4 A)

a. Type : Multiple Reinforced Concrete (RC) Tanks
b. Capacity : 827 liters/tank
c. No. of Tanks:

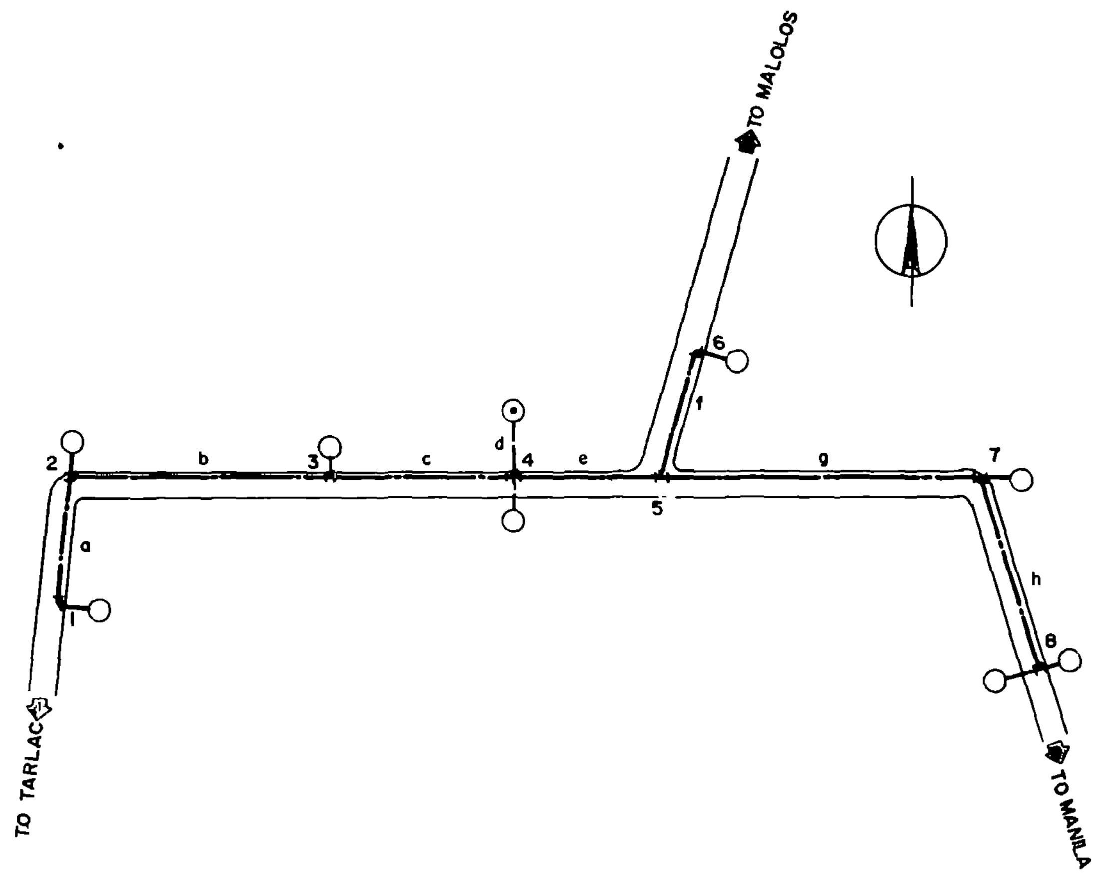
To be installed now................................ 8
To be installed ultimately 10

d. Reservoir Height

Minimum Water Level .... 1.00 M above water main
Maximum Water Level............ 1.92 M above water main

4) Main Pipes and Laterals (Figure 14.7)

Pipe	Diameter (mm)	Length (M)
a	25	50
b	25	100
c	25	70
d	31	20
e	31	55
f	25	50



LEGEND:

⊙ PUMPING STATION

○ STORAGE TANKS WITH PUBLIC FAUCETS

——·—— WATER MAINS

LOCATION OF PUMPING STATION,
STORAGE TANKS AND WATER MAINS

FIGURE 14 6

MULTIPLE STORAGE TANK SYSTEM

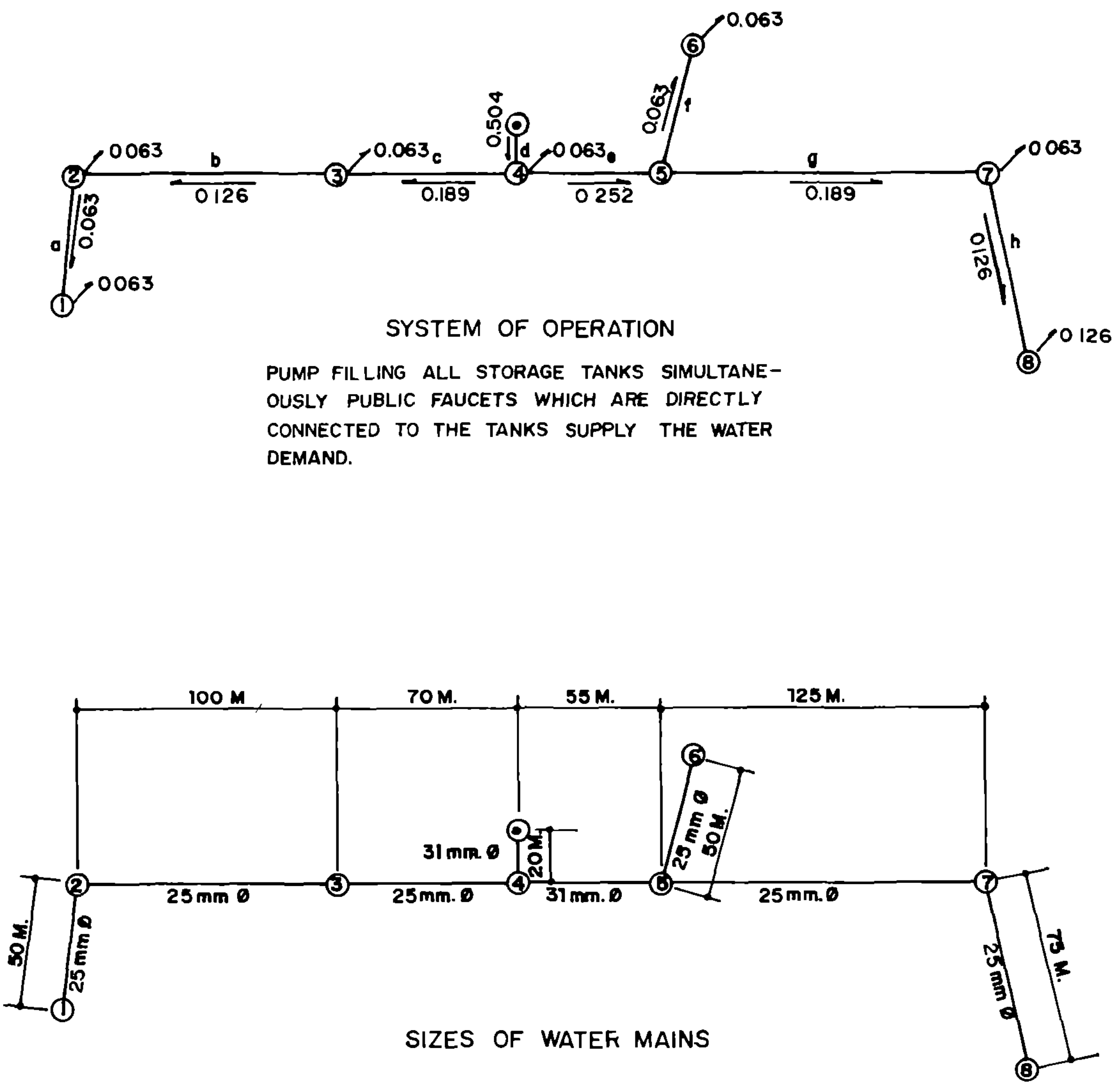


FIGURE 14.7

MULTIPLE STORAGE TANK SYSTEM

g	25	125
h	25	75
Suction	31	6

5) Pump

a. Capacity .... 0.50 LPS
b. TDH .... 13.00 M
c. B.H.P. .... 1/3 HP

BILL OF QUANTITIES
MULTIPLE STORAGE TANK SYSTEM
RURAL AREA Z

	DESCRIPTION	QUANTITY	UNIT	UNIT COST	COST
1)	PVC Pipes and Fittings				
	31 mm Ø	81	M	₱15.40	₱1,247.40
	25 mm Ø	497	M	18.90	9,393.30
	25 mm Elbow, 90°	2	Pcs.	12.35	24.70
	31 mm Elbow, 90°	3	Pcs.	17.90	53.70
	25 mm Tee (equal)	4	Pcs.	17.50	70.00
	31 mm Tee (equal)	1	Pc.	23.40	23.40
	25 × 31 mm Reducer	1	Pc.	11.55	11.55
	31 × 31 × 25 mm Reducing Tee	2	Pcs.	23.40	46.80
					₱10,870.85
2)	G.I. Pipes and Fittings				
	25 mm Ø	16	M	18.20	291.20
	13 mm Ø	8	M	9.50	76.00
	25 mm Elbow, 90°	16	Pcs.	4.60	73.60
	13 mm Elbow, 90°	8	Pcs.	2.10	16.80
					₱ 457.60
3)	13 mm Bronze Public Faucet	8	Pcs.	26.00	208.00
4)	Valves				
	Float Valve, 25 mm	8	Pcs.	150.00	1,200.00
	Globe Valve, 25 mm	8	Pcs.	80.00	640.00
	Globe Valve, 31 mm	1	Pc.	110.00	110.00
	Check Valve, 31 mm	1	Pc.	80.00	80.00
5)	Storage Tanks, 827 liters	8	Pcs.	650.00	5,200.00
6)	Pump, 0.50 LPS × 15 M (⅓ HP)	1	Pc.	1,890.00	1,890.00

Total Material Cost .... ₱20,656.95
Labor Cost, 30% of Material Cost 6,196.94

Total Labor and Material Cost .... ₱26,853.39
Contingency, 5% of Labor and Material Cost 1,342.65

Total Project Cost .... ₱28,196.06

ALTERNATIVE THREE: USE OF FILL-AND-DRAW ELEVATED RESERVOIR SYSTEM

PROCEDURE FOR DESIGN

I. Water Demand (See FLoating-on-the-Line Elevated Reservoir for Computation)

A. Average Water Demand .... 16,560 LPD

B. Maximum Day Demand .... 21,528 LPD
C. Maximum Hour Demand .... 49,680 LPD

II. Public Faucets (PF)

A. Shown in Figure 14.8 are the recommended locations of PF

B. Calculate the Maximum Hour Demand per PF in given location (see Floating-on-the-Line Elevated Reservoir, for calculation)

$Q_1 = 0.07$ LPS	$Q_5 = 0$ LPS
$Q_2 = 0.07$ LPS	$Q_6 = 0.07$ LPS
$Q_3 = 0.07$ LPS	$Q_7 = 0.07$ LPS
$Q_4 = 0.07$ LPS	$Q_8 = 0.14$ LPS

III. Transmission and Distribution Main

A. Determine the flow rate in pipes (see Figure 14.9)

$Q_a = Q_1 = 0.07$ LPS

$Q_b = Q_2 + Q_a = 0.07 + 0.07 = 0.14$ LPS

$Q_c = Q_3 + Q_b = 0.14 + 0.07 = 0.21$ LPS

$Q_d = Q_4 + Q_c + Q_e = 0.07 + 0.21 + 0.28 = 0.56$ LPS

$Q_e = Q_5 + Q_g + Q_f = 0 + 0.21 + 0.07 = 0.28$ LPS

$Q_f = Q_6 = 0.07$ LPS

$Q_h = Q_8 = 0.14$ LPS

$Q_g = Q_7 + Q_h = 0.07 + 0.14 = 0.21$ LPS

B. Select the longest route or network of pipes

The longest route is composed of pipes d, e, g and h. The pipe sizes are determined approximately using Appendix O given the number of HH served.

Pipe	No. of HH Served	Pipe Size (mm)
d	40	38
e	20	31
g	15	25
h	10	25

C. Calculate the friction loss in pipes d, e, g and h using Table 9.1

Pipe	Q(LPS)	Diameter (mm)	h_1/100(M) C	Length (M)	h_F(M)
d	0.56	38	1.00	15	0.15
e	0.28	31	0.67	55	0.37
g	0.21	25	0.94	125	1.18
h	0.14	25	0.48	75	0.36
	Total Friction Loss				2.06

D. Calculate the height of the Minimum Water Level of the Reservoir

The height of the minimum water level is the sum of the friction losses in pipes d, e, g and h and the minimum residual pressure at tapping point of PF

Friction Losses	2.06 M
Minimum Residual Pressure	3.00 M
Minimum Water Level	5.06 M
say	5.00 M above water main

E. Check the pipe diameter in the longest route and estimate the diameter of pipes a, b, c, f and pipes connecting the source to the reservoir.

1) Available Head of Reservoir to operate the system = Minimum Water Level = 5.0 M

2) Determine the diameter of pipes d, e, g and h using Table 9.1.

Find $h_1/100$ M of the longest route

$$\frac{h_1}{100\text{ M}} = \frac{\text{Available Head} - \text{Minimum Pressure}}{\text{Total Length of Pipe}} \times 100$$

Total length of Pipe $= L_d + L_e + L_g + L_h$

$L = 10 + 55 + 125 + 75 = 265\text{M}$

$$\frac{h_1}{100\text{ M}} = \frac{5-3}{265} \times 100 = 0.75\text{ M}$$

Pipe	Q(LPS)	$h_1/100$(M)	Diameter (mm) (Table 9.1)
d	0.56	0.75	38
e	0.28	0.75	31
g	0.21	0.75	25
h	0.14	0.75	25

3) Calculate the Diameter of pipes a, b, and c.

$$\frac{h_1}{100\text{ M}} = \frac{\text{Available Head at point 4-Minimum Pressure}}{\text{Total Length of Pipes a, b and c}}$$

Available Head at point 4 = 5 − friction loss in pipe d.

Friction loss in pipe d could be obtained using Table 9.1 with $Q_d = 0.56$ LPS and $D_d = 38$ mm

$h_L = 1.00\text{ M}/100\text{ M}$

$h_{fd} = h_L \times$ lenght of pipe d

$$h_{fd} = \frac{1.00\text{ M}}{100\text{ M}} \times 10 = 0.100\text{ M}$$

Available Head at point 4 = 5 − 0.100 = 4.90 M

$$\frac{h_1}{100\text{ M}} = \frac{4.90-3}{200} \times 100 = 0.86\text{ M}$$

Find the diameters of pipes a, b, and c using Table 9.1

Pipe	Q(LPS)	$h_1/100$ (M)	Diameter (mm) (Table 9.17
a	0.07	0.86	19
b	0.14	0.86	19
c	0.21	0.86	25

4) Calculate the diameter of pipe f

$$\frac{h_1}{100\ M} = \frac{\text{Available Head at point 5-Minimum Pressure}}{\text{Length of Pipe f}} \times 100$$

Available Head at Point 5 = 4.90 — Friction loss in pipe e

Friction loss in Pipe e could be obtained using Table 9.1 with Q_e = 0.28 LPS and D_e = 31 mm.

$$\frac{h_L}{100M} = 0.67\ M/100\ M$$

$$h_{fe} = \frac{h_L}{100M} \times \text{length of pipe e}$$

h_{fe} = 0.67/100 × 55 = 0.37

Available Head at Point 5 = 4.90 - 0.37 = 4.53 M

$$\frac{h_1}{100M} = \frac{(4.53 - 3) \times 100}{50} = 3.06\ M$$

From Table 9.1, with Q_f = 0.07 LPS and $h_1/100$ = 3.06 M

D_f = 13 mm

5) Estimate the diameter of pipe i and suction pipe which connects the water source to the reservoir (Figure 14.9)

a. Determine the Pump Capacity

1) Design Criteria

i. The pump capacity should at least be enough to supply the maximum day demand of the area to be served.

ii. Pump Operating Time — 12 hours/day

2) Calculate the Pump Capacity

Pump Capacity

= Maximum Day Demand/Operating Time

= 21,528 LPD × 1 d/12 hr. × 1 hr./3600 sec.

= 0.50 LPS

b. Estimate the diameter of pipe i and suction pipe. If the distance between nodes is not greater than 150 M, Appendix O could be reliably used in approximating the diameters.

Pipe	Length (M)	Capacity (LPS)	Diameter (mm)*
i	17.5	0.50	38
Suction	7	0.50	38

*Using Appendix O, look for the column flow rate, Q, PF and find the value nearest to Q = 0.50 LPS Draw a horizontal line to intersect with PVC pipe PF column The value is D = 38 mm

SUMMARY OF SELECTION OF PIPE SIZE

Pipe	Length (M)	Diameter	
		Computed	Recommended
a	50	19	25
b	100	19	25
c	70	25	25
d	10	38	31
e	55	31	31
f	50	13	25
g	125	25	25
h	75	25	25
i	10	31	31

IV. RESERVOIR

CASE 1. Reservoir Capacity is Equivalent to One-Half of the Average Day Demand.

1) Determine the Reservoir Capacity

Criterion for Capacity = 1/2 × Average Day Demand
Reservoir Capacity = 1/2 × 16,560
= 8,280 say 8,000 liters

Shape of Reservoir = Cylindrical
Height of Water Level = 2.00 M
From Figure 12.5,
Diameter = 2.30 M
Height of Reservoir = Height of Water Level + Freeboard
= 2.00 + 0.15
= 2.15 M

2) Estimate the Minimum Water Level

Minimum Water Level = 5.0 M above water main (see Section III D, page 127 for calculation)

3) Estimate the Maximum Water Level

Minimum Water Level = 5.0 M
Depth of Water = 2.0 M
Maximum Water Level = 7.0 M above water main

CASE 2. Reservoir is Used only to Supply Water in Excess of the Maximum Day Demand.

1) Determine the Reservoir Capacity

Criterion for Capacity	=	No. of Peak Hours × (Max. Hour Demand – Max. Day Demand)
Capacity	=	3 × (.058 – 0.25) × 3600
	=	3564 say 4,000 liters
Height of Water Level	=	0.80 M
From Figure 12.5, Diameter	=	2.50 M
Height of Reservoir	=	Height of Water Level + Free-board
	=	0.80 + 0.15
	=	0.95 M

2) Estimate the Maximum Water Level.

Minimum Water Level . . . . . 5.00 M
Height of Water Level . . . . . 0.80 M
Maximum Water Level . . . . 5.80 M above water main

V. FITTINGS

The location, types and sizes of fittings are shown in Appendix L and Figure 14.9.

PVC FITTINGS (Figure 14.9)

Junction No.	Elbow 90°		Reducer		Tee		Reducing Tee	
	Qty.	Size (mm)	Qty.	Size (mm)	Qty.	Size (mm)	Qty.	Size (mm)
1	1	25	1	13x25				
2			1	13x25	1	25		
3							1	25 × 25 × 13
4			1	25x31	1	31	1	31 × 31 × 25
5							1	31 × 31 × 25
6	1	13						
7			1	13x25	1	25		
8			2	13x25	1	25		
Pump	3	31						
Reservoir	3	31			1	31		

G.I. Fittings (Appendix L)

Public Faucet	16	13

VI. PUMP

A. Determine the Pump Capacity

Pump Capacity = 0.50 LPS
(see Section III E5, page 129 for Computation)

$$\text{Frequency of Filling the Reservoir} = \frac{\text{Maximum Day Demand}}{\text{Total Volume of Reservoir}}$$

$$= \frac{19285}{8000}$$

$$= 2.4 \text{ times per day}$$

$$\text{Reservoir filling time} = \frac{8{,}000 \text{ liters}}{0.50 \text{ LPS}} = 16{,}000 \text{ seconds}$$

$$= 4.5 \text{ hours}$$

B. Calculate the Pump TDH

The pump TDH is the sum of the depth of pumping water level, height of the maximum water level and friction losses in pipes, fittings and valves which connect the source of water and the elevated reservoir (see Figure 14.9).

1) Estimate the friction loss in pipes, valves, fittings, etc.

a. Length of pipe i = 0.50 + 10 + 7 = 17.50 M
Length of suction pipe = 7.00 M

b. Find the equivalent length (EQL) using Table 9.3 and the total length.

Element	Quantity	Unit	Diameter (mm)	EQL per Element	EQL (M)
Foot Valve	1	Pc.	31	2.13	2.13
Strainer	1	Pc.	31	4.88	4.88
Elbow, 90°	5	Pcs.	31	1.14	5.70
Gate Valve	1	Pc.	31	0.24	0.24
Check Valve	1	Pc.	31	2.74	2.74
				Total Equivalent Length	15.69

Length of Straight Pipe = Suction pipe + pipe i = 7 + 17.5
= 24.5 M

Total Length = Length of Straight Pipe + Equivalent Length
= 24.5 + 15.69 = 40. 19 M say 41 M.

c. Estimate the total friction loss, h_f

Using Table 9.1 with Q = 0.50 LPS and D = 31 mm

h_L = 1.74 M/100 M

$$h_f = h_L \times \text{total length} = \frac{1.74 \times 41}{100} = 0.71 \text{ M}$$

2) Estimate the Pump TDH

Friction Loss	0.71 M
Depth of Pumping Level	6.00 M
Depth of Water in Reservoir (assumed)	2.00 M
Minimum Water Level	5.00 M
Pump TDH	13.71 M
say	15.00 M

3) Calculate the Water Horsepower (W.H.P.) and Brake Horsepower (B.H.P.)

$$W.H.P. = \frac{Q \times H}{75} = \frac{0.50 \times 15}{75} = 0.10 \text{ HP}$$

With pumps having a 30% efficiency (Jet Pump)

$$B.H.P. = \frac{W.H.P.}{e} = \frac{0.10}{0.30} = 0.33 \text{ HP}$$

Use 1/3 HP Pump

VII. SUMMARY OF DESIGN

A. Water Demand

1) Average Water Demand . . . . 16,560 LPD
2) Maximum Day Demand . . . . 21,528 LPD
3) Maximum Hour Demand . . . . 2,070 LPH

B. Public Faucets (PF)

1) Location — see Figure 14.8
2) Number of PF
   To be installed now 8
   To be installed five years from now 10

C. Reservoir

1) Type . . . . Fill-and-Draw Elevated Reservoir
2) Capacity . . . . 8,000 liters
3) Reservoir Height
   Maximum Water Level . . . . 7.0 M above water main
   Minimum Water Level . . . . 5.0 M above water main

D. Main Pipes and Laterals (see Figure 14.9)

Pipe	Diameter (mm)	Length (M)
a	25	50.0
b	25	100.0
c	25	70.0
d	31	10.0
e	31	55.0
f	13	50.0
g	25	125.0
h	25	75.0
i	31	17.5
Suction	31	7.0

E. Pumps

1) Capacity 0.50 LPS
2) TDH 15 M
3) B.H.P. 1/3 HP

BILL OF QUANTITIES
FILL-AND-DRAW ELEVATED RESERVOIR SYSTEM
RURAL AREA Z

	DESCRIPTION	QUANTITY	UNIT	UNIT COST	COST
1)	PVC Pipes				
	31 mm ϕ	95	M	15.40	₱1,463.00
	25 mmϕ	470	M	11.25	5,287.50
	13 mm ϕ	36	M	5.60	201.60
					₱6,952.10
2)	G.I. Pipes and Fittings				
	13 mmϕ	12	M	9.50	114.00
	13 mm G.I. Elbow, 90°	16	Pcs.	2.10	33.60
					₱ 147.60
3)	PVC Fittings				
	25 mm Elbow, 90°	2	Pc.	9.55	19.10
	25 mm Tee	3	Pcs.	17.50	52.50
	31 mm Tee	2	Pcs.	23.40	46.80
	31 mm Elbow, 90°	6	Pcs.	17.90	107.40
	25 × 25 × 13 mm Reducing Tee	1	Pc.	17.50	17.50
	31 × 31 × 25 mm Reducing Tee	1	Pc.	23.40	23.40
	31 × 31 × 13 mm Reducing Tee	1	Pc.	23.40	23.40
	13 × 25 mm Reducer	5	Pcs.	8.35	41.75
	25 × 31 mm Reducer	2	Pcs.	11.55	23.10
	13 mm Socket	10	Pcs.	6.00	60.00
	25 mm Socket	70	Pcs.	8.35	584.50
	31 mm Socket	16	Pcs.	11.55	184.80
	13 mm Adaptor Socket	8	Pcs.	11.05	88.40
					₱1,272.65
4)	13 mm Bronze Faucets	8	Pcs.	26.00	208.00
5)	Pump, 0.50 LPS × 15 M (⅓ HP)	1	Pc.	1,890.00	1,890.00
6)	Valves				
	Check Valve, 31 mm	1	Pc.	80.00	80.00
	Globe Valve, 31 mm	1	Pc.	110.00	110.00
	Material Cost (Except Reservoir)				₱10,660.35

Description	Case 1 Reservoir	Case 2 Reservoir
1. Material Cost (Except Reservoir)	₱10,660.35	₱10,660.35
2. Reservoir	6,500.00	6,500.00
Total Material Cost	₱17,160.35	₱17,160.35
Labor Cost, 30% of Material Cost	5,148.10	5,148.10
Total Labor and Material Cost	₱22,308.45	₱22,308.45
Contingency, 5% of Labor and Material Cost	1,115.42	1,115.42
Total Project Cost	₱23,423.87	₱23,423.87

ALTERNATIVE FOUR: USE OF HYDROPNEUMATIC PRESSURE SYSTEM

PROCEDURE FOR DESIGN

		DEMAND
I.	**Water**	
	A. Average Day Demand	16,560 LPD
	B. Maximum Day Demand	21,528 LPD
	C. Maximum Hour Demand	2,070 LPH

II. **Public Faucets (PF)**

A . Decide on the location of Public Faucets.
Shown in Figure 14.8 are the locations of the PF.

B. Number of PF to be installed:

1) To be installed at present — 8
2) To be installed ultimately — 10

III. **Transmission and Distribution Mains**

See Alternative three for calculation and Figure 14.10 for illustration.

Pipe	Recommended Diameter (mm)	Length (M)
a	25	50
b	25	100
c	25	70
d	31	19
e	31	55
f	25	50
g	25	125
h	25	75

IV. **Reservoir**

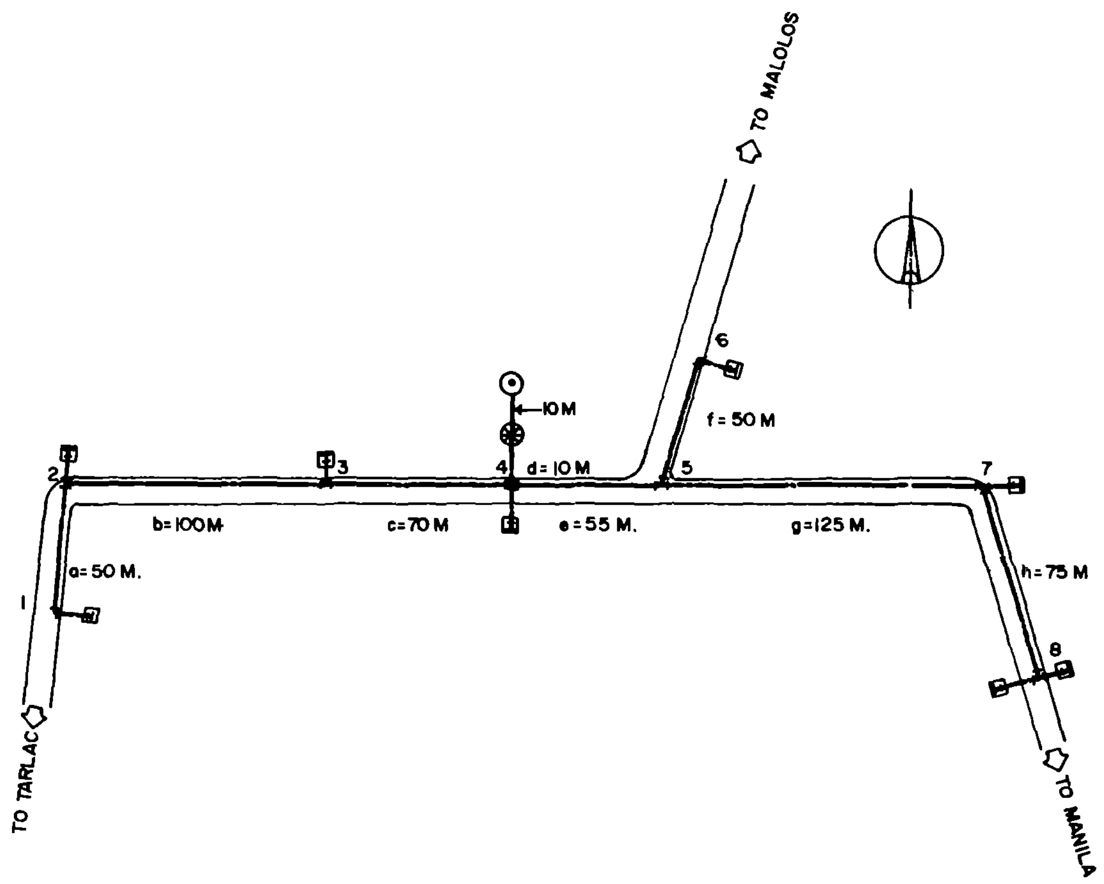
A. Calculate the Tank Volume

Tank Volume = 10 liters per capita
Tank Volume = 10 × Population = 10 × 240 = 2,400 lit. (640 gal.)

B. Calculate the Safe Working Pressure

1) Design Criteria
Minimum Residual Pressure . . . . 3 M
Differential Operating Pressure . . . . 5 M
Safe Working Pressure of the Tank = 1.5 × working pressure

2) Calculate the Total Pressure in the Tank
Static Head (between tank and highest PF). . . 1.00 M
Minimum Residual Pressure. . . . . 3.00 M
Friction Loss (see Fill-and-Draw



LEGEND:

- PUBLIC FAUCET
- PUMPING STATION
- RESERVOIR
- WATER MAINS

LOCATION OF PUBLIC FAUCETS, RESERVOIR, PUMPING STATIONS AND WATER MAINS

FIGURE 14.8

FILL-AND-DRAW RESERVOIR SYSTEM

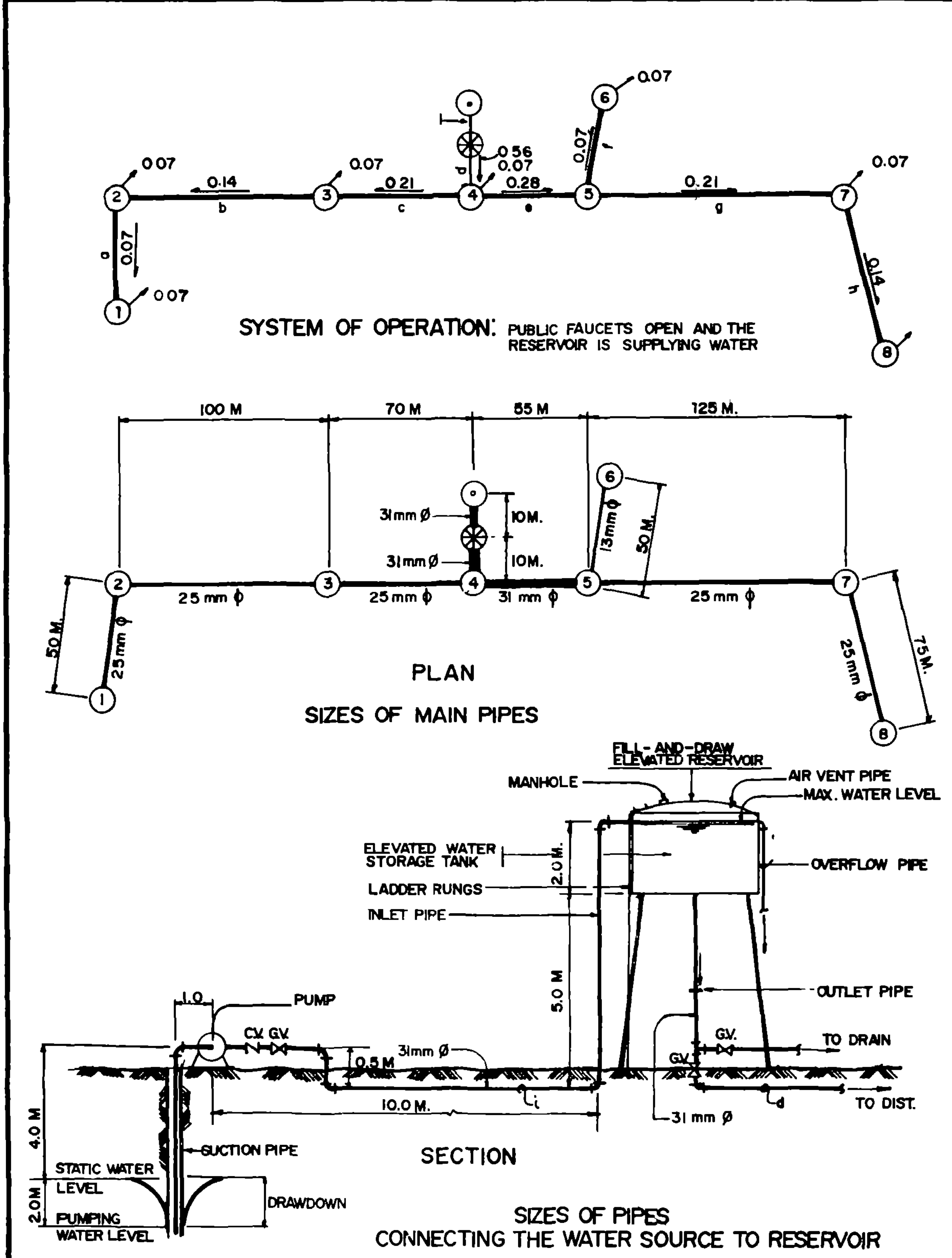


FIGURE 14.9

FILL-AND-DRAW ELEVATED RESERVOIR

Elevated Reservoir for computation of Friction Loss) . . . . 1.91 M
Differential Operating Pressure. . . . . 5.00 M

Total Working Pressure . . . . 10.91 M
say . . . . 11.00 M

3) Estimate the Maximum Working Pressure

Commercial pressure switches are stocked for set of operating values. In this design where the total working pressure = 11 M, the pressure switch to be ordered should operate on a 5 M differential, and should cut in at 10 M and cut out at 15 M. The maximum working pressure, therefore, is 15 M.

4) Calculate the Safe Working Pressure of Tank

Safe Working Pressure = 1.5 × Maximum Working Pressure
= 1.5 × 15 = 22.5 M Say 23 M

V. Pump Selection

A. Pump Capacity

1) Design Criteria

a. The discharge, Q must be enough to supply the Maximum Hour Demand

b. System operating for 24 hours/day

2) Calculate the Pump Capacity

$$\text{Pump Capacity} = \frac{\text{Maximum Hour Demand}}{\text{Pump Operating Time}}$$

= 49,680 LPD × 1 d/24 hr. × 1 hr./3600
= 0.575 LPS say 0.60 LPS

B. Pump TDH

The pump TDH is the sum of the maximum working pressure of tank and the height of the pumping water level.

Maximum Working pressure	15 M
Height of the pumping water level	6 M
Pump TDH	21 M

C. Calculate the Water Horsepower and Brake Horsepower

$$\text{W.H.P.} = \frac{Q \times H}{75} = \frac{0.60 \times 21}{75} = 0.168 \text{ HP}$$

With pumps having a 30% efficiency (Jet Pump)

$$\text{B.H.P.} = \frac{\text{W.H.P.}}{0.3} = \frac{0.168}{0.3} = 0.56 \text{ HP}$$

Use 1/2 HP Prime Mover.

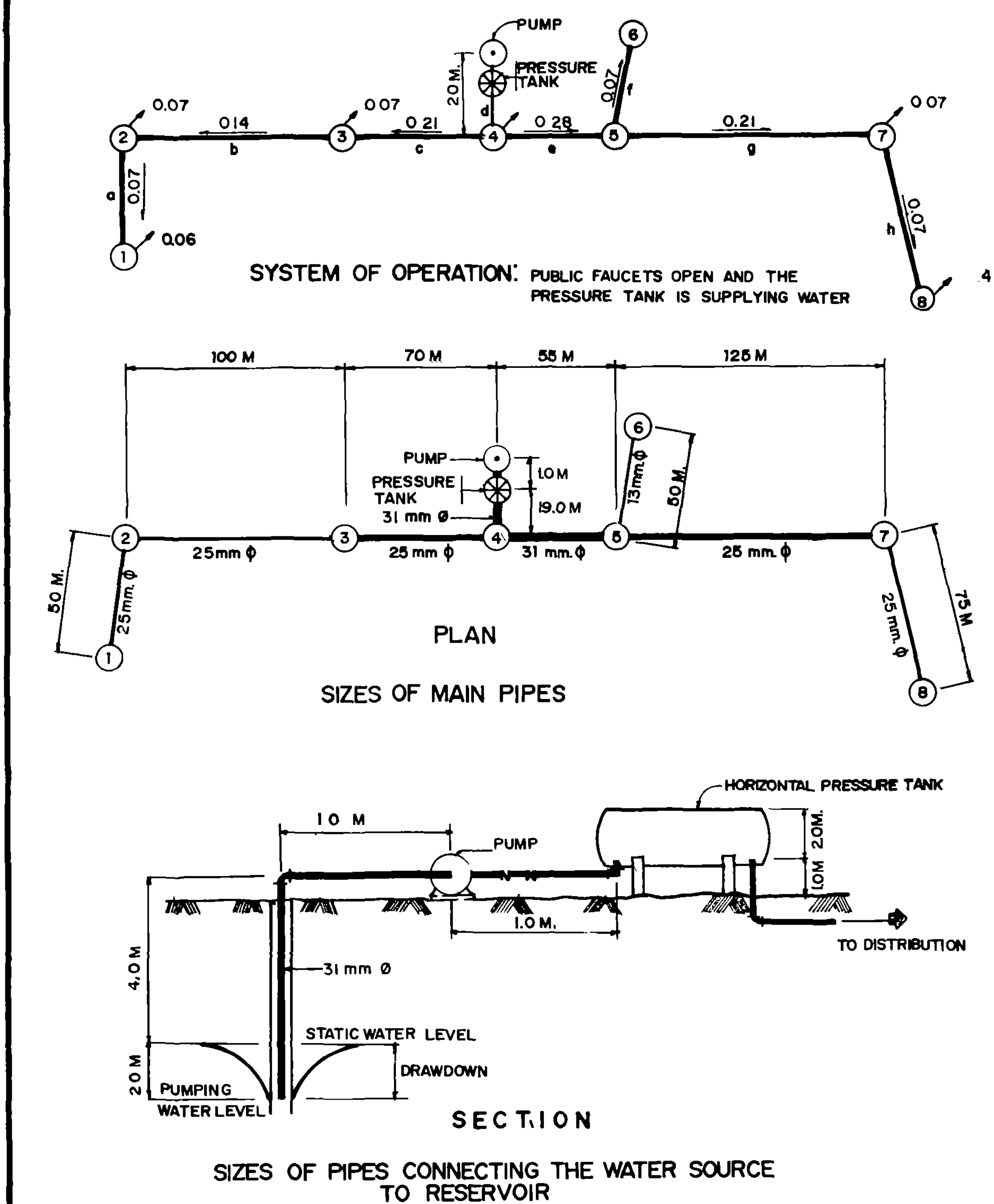


FIGURE 14.10

HYDROPNEUMATIC PRESSURE SYSTEM

VI. FITTINGS

The location, types and sizes of fittings are tabulated in the following table (see Figure 14.10).

Junction No.	Elbow 90°		Reducer		Tee		Reducing Tee	
	Qty.	Size (mm)	Qty.	Size (mm)	Qty.	Size (mm)	Qty.	Size (mm)
1	1	25		13 × 25				
2			1	13 × 25	1	25		
3								25 × 25 × 13
4			1	25 × 31	1	31		
5								31 × 31 × 13
6	1	13						
7			1	13 × 25	1	25		
8			2	13 × 25	1	25		
Pump	1	31						
Reservoir	1	31						

VII. SUMMARY OF DESIGN

A. Water Demand

1) Average Day Demand . . . . 16,560 LPD
2) Maximum Day Demand . . . . 21,528 LPD
3) Maximum Hour Demand . . . . 49,680 LPD

B. Public Faucets (PF)

1) Location (see Figure 14.8)
2) Number of PF
   To be installed now 8
   To be installed ultimately 10

C. Pressure Tank

1) Type . . . . Hydropneumatic Pressure System (Horizontal)
2) Volume . . . . 1400 liters
3) Safe Working Pressure . . . . 23 M

D. Main Pipes and Laterals (see Figure 14.10)

Pipe	Diameter (mm)	Length (mm)
a	25	50
b	25	100
c	25	70
d	31	19
e	31	55
f	13	50
g	25	125
h	25	75

E. Pumps

1)	Capacity	0.60 LPS
2)	TDH	21 M
3)	B.H.P.	1/2 HP

BILL OF QUANTITIES
HYDROPNEUMATIC PRESSURE SYSTEM
RURAL AREA Z

DESCRIPTION	QUANITY	UNIT	UNIT COST	COST
1) PVC Pipes				
31 mm ∅	85	M	15.40	₱1,309.00
25 mm∅	420	M	11.25	4,725.00
13 mm∅	86	M	5.60	481.60
				₱6,515.60
2) G.I. Pipes and Fittings				
13 mm ∅	12	M	9.50	114.00
13 mm G.I. Elbow, 90°	16	Pcs.	2.10	33.60
				₱147.60
3) PVC Fittings				
13 mm elbow, 90°	1	Pc.	7.95	7.95
25 mm Elbow, 90°	1	Pc.	12.35	12.35
25 mm Tee	3	Pcs.	17.50	52.50
31 mm Elbow, 90°	2	Pcs.	17.90	35.80
31 mm Tee	1	Pc.	23.40	23.40
25 × 25 × 13 mm Reducing Tee	1	Pc.	17.50	17.50
31 × 31 × 13 mm Reducing Tee	1	Pc.	23.40	23.40
13 × 25 mm Reducer	5	Pcs.	8.35	41.75
25 × 31 mm Reducer	1	Pc.	11.55	11.55
13 mm Socket	10	Pcs.	6.00	60.00
25 mm Socket	45	Pcs.	8.35	375.75
31 mm Socket	8	Pcs.	11.55	92.40
13 mm Adaptor Socket	8	Pcs.	11.05	88.40
				₱ 842.75
4) 13 mm Bronze Faucet	8	Pcs.	26.00	208.00
5) Reservoir, Hydropneumatic Pressure System	1400	liters	3.00	4,200.00
6) Pump, 0.50 LPS × 21 M (⅝ HP)	1	Pc.	2,190.00	2,190.00
7) Valves				
Check Valve, 31 mm	1	Pc.	80.00	80.00
Globe Valve, 31 mm	1	Pc.	110.00	110.00
Total Material Cost				₱14.293.85
Labor Cost, 30% of Material Cost				4,288.15
Total Labor and Material Cost				₱18,582.00
Contingency, 5% of Labor and Material Cost				9,929.10
TOTAL PROJECT COST				₱19,511.10

APPENDICES

APPENDIX A

LIST OF ABBREVIATIONS

A-C	Alternating Current
ACP	Asbestos Cement Pipe
ATM	Atmosphere
B.H.P.	Brake Horsepower
BLDG.	Building
B.O.	Blow off
B & S	Bell and Spigot
BW	Both Ways
CIP	Cast Iron Pipe
CONC.	Concrete
D or Ø	Diameter
DTL	Detail
ELEV.	Elevation
EL	Elbow
EXIST.	Existing
F.H.	Fire Hydrant
FT.	Foot or feet
F	Flanged
G.V.	Gate or Globe Valve
GAL.	Gallon
GALV.	Galvanized
GIP	Galvanized Iron Pipe
GPCD	Gallons per capita per day
GPM	Gallons per minute
HP	Horsepower
HT	Height
HW	Headwall
HWL	Head Water Level
LAT.	Latitude
LB.	Pound
LF	Linear Foot
LM	Linear Meter
LPS	Liters per second
LPCD	Liters per capita per day
MAX.	Maximum
mg/1	Milligrams per liter
MIN.	Minimum
MISC.	Miscellaneous
NO.	Number
N	North
O.C.	On Centers
PB	Polybutylene Plastic Pipe
PE	Polyethylene Plastic Pipe
PROJ.	Project
PVC	Polyvinyl Chloride Pipe
PWL	Pumping Water Leve
S.	South
SECT.	Section
SHT.	Sheet
SPECS.	Specifications
SQ.	Square
STA.	Station
STD.	Standard
SWL	Static Water Level
TEMP.	Temperature
V.	Valve
W.H.P.	Water Horsepower
WL	Water Level
WS	Water Surface
WT	Weight
W	West

APPENDIX B
METRIC UNITS AND PREFIXES

I. SYMBOLS FOR UNITS

M	— Meter	ha	— Hectare
gm	— Gram	l	— Liter
s	— Second	t	— Ton
K	— Kelvin	d	— Day

rad — Radian		h — Hour	
N — Newton		min — Minute	
Pa — Pascal		°C — Degrees Celsius	
J — Joule		W — Watt	

II. SYMBOLS FOR PREFIXES

Symbol	Prefix	Factor by which unit is multiplied
T	Tera	10^{12}
G	Giga	10^{9}
M	Mega	10^{6}
K	Kilo	10^{3}
d	Deci	10^{-1}
c	Centi	10^{-2}
m	Milli	10^{-3}
u	Micro	10^{-6}

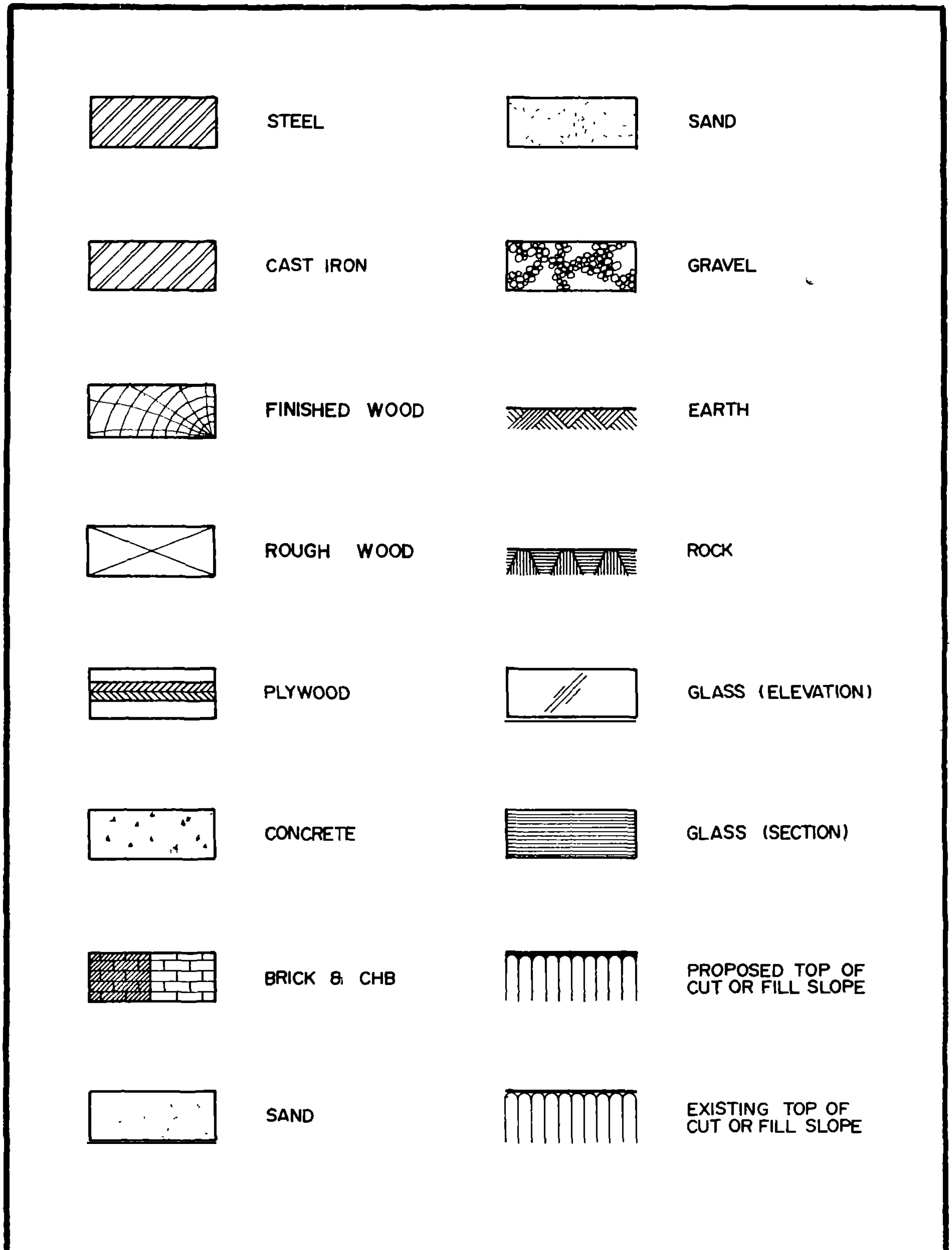
APPENDIX C

METRIC UNITS USED IN WATER SUPPLY SYSTEMS

	QUANTITY	UNIT	UNIT SYMBOL
1.	RAINFALL		
	Intensity	millimeter per hour	mm/h
2.	RIVERS, WELLS AND SPRINGS		
	Length	kilometer	km
	Velocity of flow	meter per second	M/s
	Volumetric flow rate	cubic meter per second	M^3/s
	Mass flow rate	kilogram per second	kg/s
3.	STORAGE		
	Capacity	liters	1
	Depth	meter	M
	Surface Area	square meter	M^2
4.	PIPES		
	Length	meter	M
	Diameter	millimeter	mm
	Hydraulic Head	meter	M
	Area of pipe	square meter	M^2
	Velocity of flow	meter per second	M/s
	Volumetric flow rate	cubic meter per second	M^3/s
	Slope	dimensionless	
5.	WATER DISTRIBUTION AND CONSUMPTION		
	Reservoir Capacity	liters	l
		cubic meter	M^3
	Pipe diameter	millimeter	mm
	Cross sectional area	square meter	M^2
	Daily water consumption	liters per capita per day	LPCD
	Daily water consumption	liters per day	LPD
	Piezometric Head	meter	M

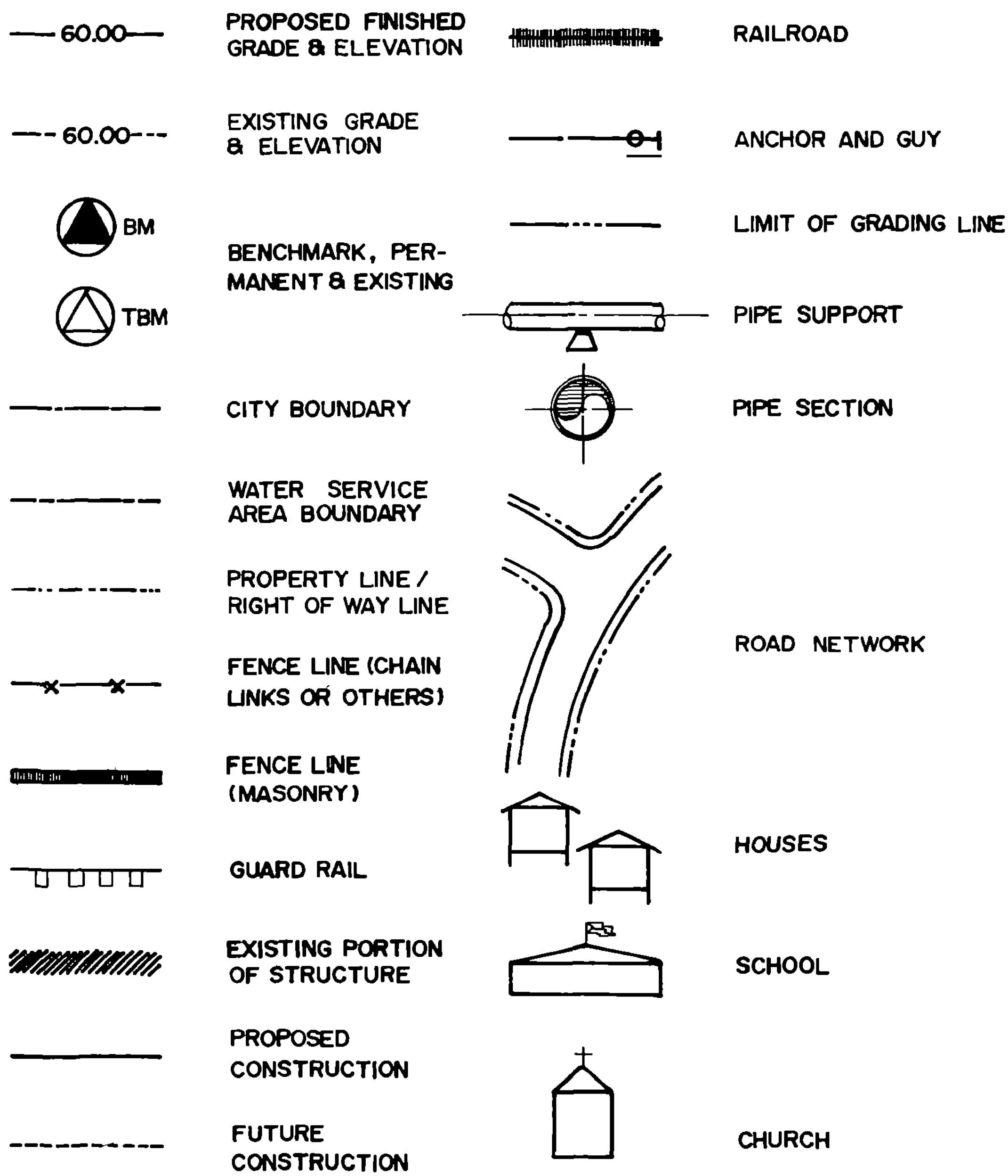
6. PUMPING MACHINERY

cross sectional area of Pump	square millimeter	MM^2
Velocity	meter per second	M/s
Volumetric flow rate	liters per second	l/s
Pressure	kilogram force per square centimeter	kgf/cm^2
Head (TDH)	meter	M
Concentration	milligram per liter	mg/l
Viscosity	poise	P
Speed	revolution per second	r/s
Efficiency	dimensionless	
Power	kilowatt	kw
Force	horsepower	HP
	newton	N



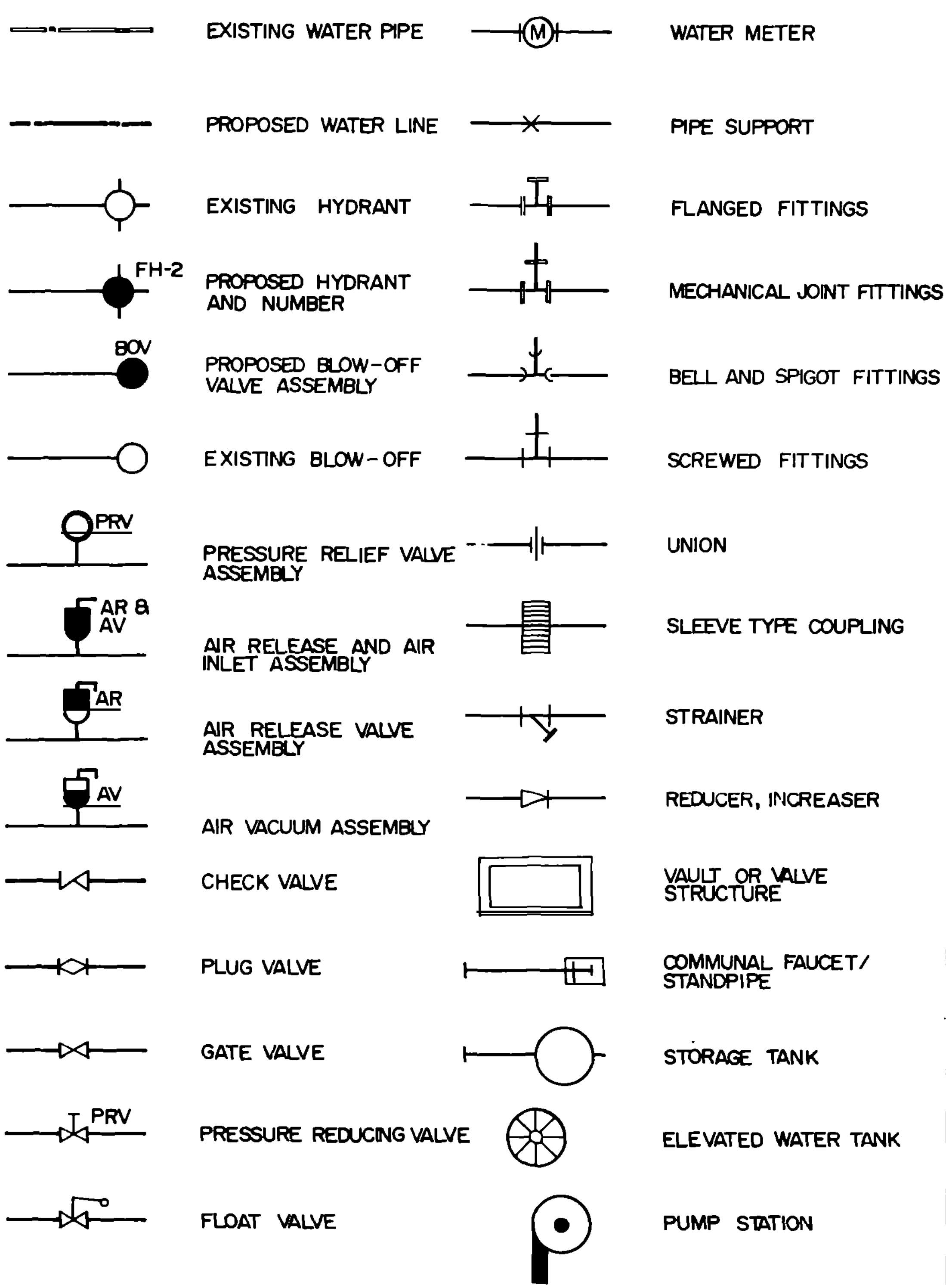
APPENDIX D

MATERIAL SYMBOLS



APPENDIX E

CIVIL DESIGN AND SYMBOLS



APPENDIX F

MECHANICAL SYMBOLS

LENGTH

M	mm	cm	km	inch	foot	mile
1	1000	100	0.001	39.370 08	3.280 84	0.0$_3$62 14
0.001	1	0.1	0.0$_5$1	0.039 37	0.0$_2$32 81	0.0$_6$62 14
0.01	10	1	0.0$_4$1	0.3937	0.032 81	0.0$_5$62 14
1000	10^6	10^5	1	39 370.08	3280.84	0.621 37
0.0254	25.4	2.54	0.0$_4$254	1	0 833 33	0.0$_4$15 78
0.3048	304.8	30.48	0.0$_3$30 48	12	1	0.0$_3$18 94
0.9144	914.4	91.44	0.0$_3$91.44	36	3	0.0$_3$56 82
5.0292	5029.2	502.92	0.0$_2$50 29	198	16.5	0.0$_2$31 25
1609.344	1 609 344	160 934.4	1.609 34	63 360	5280	1

AREA

M^2	mm^2	cm^2	ha	in^2	ft^2	acre
1	10^6	10^4	0.0$_3$1	1550.0031	10 763 91	0.0$_3$24 71
0 0$_5$1	1	0 01	0.0$_9$1	0.0$_2$155	0.0$_4$10 76	0.0$_9$24 71
0 0$_3$1	100	1	0.0$_7$1	0.155	0.0$_2$10 76	0.0$_7$24 71
100	10^8	10^6	0.01	155 000.31	1076.391	0 024 71
10^4	10^{10}	10^8	1	15 500 031	107 639.1	2.471 05
10^6	10^{12}	10^{10}	100		10 763 910	247.105 38
0.0$_3$64 52	645.16	6.4516	0.0$_7$64 52	1	0 0$_2$69 44	0.0$_6$15 94
0 0929	92 903.04	929.0304	0.0$_5$929	144	1	0 0$_4$22 96
0.836 13	836 127.36	8361 2736	0 0$_4$83 61	1296	9	0.0$_3$2066
4046.8564		40 468 564	0.404 69	6 272 640	43 560	1
			258.9988		27 878 400	640

VOLUME

M^3	mm^3	cm^3	litre,dm^3	in^3	gal	ft^3
1	10^9	10^6	1000	61 023.744	264 172 05	35.314 67
0.0$_8$1	1	0.001	0 0$_5$1	0.0$_4$61 02	0 0$_6$26 42	0 0$_7$35 31
0 0$_6$1	1000	1	0 001	0.061 02	0 0$_3$26 42	0.0$_4$35 31
0 001	10^6	1000	1	61.023 74	0.264 17	0.035 31
0.0$_4$16 39	16 387.064	16.387 06	0 016 39	1	0 0$_2$43 29	0 0$_3$57 87
0.0$_3$94 64	946 352.95	946 352 95	0 946 35	57.75	0.25	0.033 42
0.0$_2$11 37	1 136 523	1 136.523	1 136 52	69.354 89	0.300 24	0.040 14
0.0$_2$37 85	3 785 411.8	3785.4118	3.785 41	231	1	0.133 68
0.0$_2$45 46	4 546 092	4546.092	4.546 09	277.419 55	1.200 95	0.160 54
0.028 32	28 316.847	28 316.847	28.316 85	1728	7.480 52	1
0.764 55		764 554.86	764.554 86	46 656	201.974 03	27

10^5 means 100,000 = 5 ZEROS TO THE RIGHT

0 0$_5$ means 0 000001 = 5 ZEROS TO THE LEFT

APPENDIX G

METRIC CONVERSION GUIDE

FLOW, VOLUME / TIME

M^3/s	M^3/h	L/s	L/min	L/h	gpm	ft^3/s
1	3600	1000	60 000	3 600 000	15 850.323	35.314 67
0 016 67	60	16.666 67	1000	60000	264.172 05	0.588 58
$0.0_3 27\ 78$	1	0.277 78	16.666 67	1000	4.402 87	$0.0_2 981$
0.001	3.6	1	60	3600	15.850 32	0.035 31
$0\ 0_4 16\ 67$	0 06	0.016 67	1	60	0 264 17	$0.0_3 58\ 86$
$0.0_6 27\ 78$	0.001	$0.0_3 27\ 78$	0.016 67	1	$0.0_2 44\ 03$	$0.0_5 981$
$0.0_2 37\ 85$	13.627 48	3.785 41	227.124 71	13 627.482	60	0.133 68
$0.0_4 63\ 09$	0.227 12	0.063 09	3.785 41	227.124 71	1	$0.0_2 22\ 28$
0.028 32	101.940 65	28.316 85	1699.0108	101 940.65	448.831 17	1
$0.0_3 47\ 19$	1.699 C1	0.471 95	28.316 85	1699 0108	7 480 52	0 016 67
$0.0_5 78\ 66$	0 028 32	$0.0_2 78\ 66$	0.471 95	28.316 85	C.124 68	$0.0_3 27\ 78$
$0.0_3 21\ 24$	0.764 55	0.212 38	12.742 58	764.554 86	3.366 23	$0\ 0_2 75$

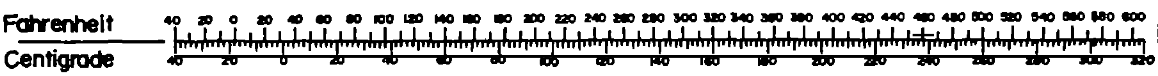
PRESSURE, FORCE / AREA

KPa	Pa	MPa	Kg/cm^2	mm Hg 32°F	in Hg 32°F	in H_2O 39.2°F	psi
1	1000	0.001	0.0102	7.500 64	0.2953	0.334 56	0.145 04
0.001	1	$0\ 0_5 1$	$0.0_4 102$	$0.0_2 75\ 01$	$0\ 0_3 29\ 53$	$0.0_3 33\ 46$	$0.0_3 145$
1000	10^6	1	10.197 16	7500.6376	295.300 59	334.562 29	145.037 74
89.0665	98 066.5	0.098 07	1	735.561 27	28.959 09	32.809 35	14.233 34
100	10^5	0.1	1.019 72	750.063 76	29.530 06	33.456 23	14.503 77
0.133 32	133.322	$0.0_3 13\ 33$	$0.0_2 136$	1	0.039 37	0.04 46	0.019 34
3.386 38	3386.38	$0.0_2 33\ 86$	0.034 53	25 .4	1	1.132 96	0.491 15
0 249 08	249.082	$0.0_3 24\ 91$	$0.0_2 254$	1.868 27	0.073 55	0.083 33	0.036 13
2.988 98	2988.98	$0.0_2 29\ 89$	0.030 48	22.419 26	0.882 65	1	0.433 51
6.894 76	6894.7573	$0.0_2 68\ 95$	0.070 31	51.715 06	2.036 03	2.306 73	1

SPEED, VELOCITY

M/s	M/min	km/h	ft/s	mph	knot (int)
1	60	3.6	3.280 84	2.236 94	1.943 84
0.01	0.6	0.036	0.032 81	0.022 37	0.019 44
0.016 67	1	0.06	0.054 68	0.037 28	0.0324
0.277 78	16.666 67	1	0.911 34	0.621 37	0.539 96
0.3048	18.288	1.097 28	1	0.681 82	0.592 48
$0.0_2 508$	0.3048	0.018 29	0.016 67	0.011 36	$0.0_2 98\ 75$
0.447 04	26.8224	1.609 34	1.466 67	1	0.868 98
0.514 44	30.866 67	1.852	1.687 81	1.150 78	1

TEMPERATURE CONVERSION



RULE OF THUMB: Centigrade to Fahrenheit (Centigrade = Celsius)

$F = 1.8°C + 32$

Example. Given °C = 32 find °F

Solution: °F = 1.8(32) + 32
= 57.6 + 32 = 89.6°

(KPa) Kilopascals (MPa) Megapascals (Hg) Mercury (H_2O) Water

APPENDIX H

METRIC CONVERSION GUIDE

APPENDIX I

COST OF MATERIALS OF CONSTRUCTION
(In Metro Manila, As of April 1979)

I. PIPES

Pipe Size		Price Per Linear Meter*			
mm	in	G.I. Pipe	PVC Pipe	PE Pipe	PB Pipe
13	1/2	9.50	5.60	3.75	6.35
19	3/4	12.30	7.75	4.83	9.50
25	1	18.20	11.25	7.23	15.30
31	1-1/4	24.80	15.40	10.70	22.00
38	1-1/2	30.65	18.90	14.10	32.00
50	2	39.85	24.60	20.00	54.00
63	2-1/2	74.75	40.70	26.90	72.00
75	3	86.80	56.80	33.80	
100	4	130.70	77.15	51.20	
150	6	210.85	151.50	76.80	

2. G.I. FITTINGS

Nominal mm	Size in.	Elbow, 90°	Tee	Cross Tee	Coupling	Reducer Coupling	Reducer Elbow
13	1/2	2.10	3.90	7.15	1.80	2.30	3.30
19	3/4	3.10	3.85	9.50	2.10	3.20	3.50
25	1	4.60	6.10	12.80	3.50	4.30	5.40
31	1-1/4	7.10	9.15	18.90	4.90	6.15	9.15
38	1-1/2	9.40	11.40	25.66	6.10	7.50	11.50
50	2	14.10	17.00	33.30	9.10	11.00	16.40
63	2-1/2	25.50	42.00	64.00	20.00	21.00	41.00
75	3	41.00	53.00	86.00	27.00	32.00	69.00
100	4	74.00	96.00	161.00	46.00	59.00	115.00
150	6	345.00	400.00	600.00	161.00	184.00	327.00

3. PVC FITTINGS

Nominal mm	Size in.	Elbow, 90°	Tee Equal	Adaptor Unions	Adaptor Sockets	Sockets	Caps	Adaptor Bushes equal
13	1/2	7.95	9.20	32.55	11.95	6.00	5.60	10.75
19	3/4	9.55	11.95	38.15	13.15	6.80	6.00	12.35
25	1	12.35	17.50	50.00	19.10	8.35	7.20	14.35
31	1-1/4	17.90	23.40	63.90	25.00	11.55	9.15	17.10
38	1-1/2	28.60	32.15	87.30	32.15	15.50	17.90	27.40
50	2	42.90	50.80	127.75	59.60	22.70	23.80	36.95
63	2-1/2	85.75	89.70			46.00	50.00	

*Source of Price Lists·

1. G I. Pipe . Boulevard Construction Supply
   Quezon Blvd , Metro Manila
2. PVC Pipe : Jardine Davies
   22 Buendia Avenue, Makati, Metro Manila
3. PE Pipe · MOLDEX Products, Inc
   3 West Sixth, Quezon City
4. PB Pipe Gascom International Corporation
   750 Shaw Boulevard, Mandaluyong, Metro Manila

4. PVC REDUCERS

Tee Reducers

Nominal d_1	Size d_2	(mm) d_1	Price Per Piece	Nominal d_1	Size d_2	(mm) d_1	Price Per Piece
19	13	19	11.95	38	25	38	32.15
25	19	25	17.50	38	19	38	32.15
25	13	25	17.50	38	13	38	32.15
31	25	31	23.40	50	38	50	50.80
31	19	31	23.40	50	31	50	50.80
31	13	31	23.40	50	25	50	50.80
38	31	38	32.15	50	19	50	50.80

Reducing Sockets

19	13		6.80	31	13		11.55
25	19		8.35	38	31		15.50
25	13		8.35	38	25		15.50
31	25		11.55	38	19		15.50
31	19		11.55	50	38		22.70

5. PB FITTINGS

Flare Nut

Nominal Size (mm)	Price	Nominal Size (mm)	Price
13	1.95	19	4.70
		25	6.25

Flare Nut

13×13	2.65	19×13	6.00
19×19	6.85	25×25	10.85

Nominal Size (mm)	Price	Nominal Size (mm)	Price
Female Adapter			
13×13	9.00	25×25	13..80
19×19	11.65	25×19	12.55
19×13	12.00		
Male Adapter			
13×19	2.70	19×25	6.50
13×19	2.70	25×25	9.95
19×19	6.00		
Flare 90°ELL			
13×13	3.70	19×19	7.85
		25×25	15.25
Flare Tee			
13×13×13	5.55	19×19×13	8.85
13×13×6	4.95	19×13×13	7.95
13×13×19	7.80	19×19×25	8.85
19×19×19	9.30	25×25×25	21.80
19×13×19	8.85	25×25×19	21.80

Flare Cap

13	1.95	19	4.70
		25	6.95

Flare Union

13×13	2.65	19×19	6.85
19×13	6.00	25×25	10.85

6. PE FITTINGS

Nominal mm	Size in.	Butt-Welded Joints	Slip-On Coupling	Elbow, Long Radius	Tee	Cross Tee	Bushing Reducer	End Cap	Plug
13	1/2	₱1 22	₱4 00	₱14.88	₱5.22	6.94	50×25mm ₱14 38	₱3.27	₱4.22
19	3/4	1.22	4 50	15 66	5 77	9 00	50×35mm 17 33	3 77	8 38
25	1	1 77	5 22	17.22	9 66	12 83	75×50mm 96.00	4.22	12 00
31	1-1/4	1 77	6.22	30 00	12 50	16 66	75×63mm 99 61	5 22	13 77
38	1-1/2	1.77	7.77	33 61	15.94	21 22	100×25mm 168 00	6 38	15 61
50	2	3 00	9 44	42 00	24 00	32 05	100×38mm 174 00	8 00	18 00
63	2-1/2	3 61	14.05	50.05	31.77	42.33	100×50mm 180 00	11.61	20 38
75	3	4 77	17 66	90 77	48 88	73 38	100×75mm 195 00	15.38	33.61
100	4	7 22	26 88	167 55	72 33	108 50	150×50mm 216 00	23 66	39 61
125	5	8 38	38 38	240.00	151 66	202 22	150×75mm 222 00	35 13	46.22
150	6	12.00	64 38	324.00	201 55	268.66	150×100mm 228 00	51 00	55.22

7. VALVES

Nominal mm	Size in.	Gate Valve	Globe Valve	Check Valve
13	1/2		₱ 25.00	₱ 25.00
19	3/4		55.00	35.00
25	1		80.00	60.00
31	1¼		110.00	80.00
38	1½		145.00	125.00
50	2	₱300.00	160.00	240.00
63	2½	365.00	240.00	360.00
75	3	480.00	360.00	470.00
100	4	600.00	900.00	600.00

8. STEEL ELEVATED STORAGE TANKS

Platform = 10 M above ground

Capacity M^3	Gallons	Price Per Tank (P5.00-7.00 per gallon)	
8	2,000	₱ 10,000.00	₱ 14,000.00

12	3,000	15,000.00	21,000.00
20	5,000	25,000.00	35,000.00
40	10,000	50,000.00	70,000.00
60	15,000	75,000.00	105,000.00
80	20,000	100,000.00	140,000.00
100	25,000	125,000.00	175,000.00

9. PUMPS

A. Myers Ejecto Pumps for Shallow Well and Booster Service (Price FOB Makati — 1 April 1979)

HP	BASIC PUMP*	WITH BUILT-IN EJECTOR	PRESSURE TANKS
1/3	₱1,890.00	₱2,030.00	21 gal.-₱ 300.00
1/2	2,050.00	2,190.00	42 gal.- 460.00
3/4	2,540.00	2,680.00	82 gal.- 660.00
1	2,730.00	2,870.00	120 gal.- 1,000.00
1½	5,310.00	5,450.00	220 gal.- 1,550.00
2	6,310.00	6,450.00	315 gal.- 2,400.00

B. Myers Ejector Pumps for Deepwell

		With Air Valve, Air Volume Control and Ejector Package	
HP	BASIC PUMP*	Size of Well Casing	Price
1/3	₱1,890.00	50 mm	₱2,800.00
		63 mm	2,910.00
		75 mm	2,670.00
1/2	2,050.00	50 mm	2,960.00
		63 mm	3,070.00
		75 mm	2,830.00
3/4	2,540.00	50 mm	3,450.00
		63 mm	3,560.00
		75 mm	3,640.00
1	2,730.00	50 mm	3,640.00
		63 mm	3,750.00
		75 mm	3,830.00
1-1/2	5,310.00	50 mm	5,870.00
		63 mm	5,980.00
		75 mm	6,060.00
2	6,310.00	75 mm	8,760.00
		100 mm	8,760.00
		150 mm	8,940.00

*Basic pump includes pump and motor, pressure regulator, pressure switch and gauge.

APPENDIX J

WATER CONSUMPTION RATES STUDY ON PUBLIC FAUCET SYSTEM AND INDIVIDUAL HOUSEHOLD CONNECTION CENTER

A. Public Faucet System in Sinisian, East Lemery, Batangas

The experimental area is composed of 177 households and has a population of 703. The water distribution system employed is the public faucet system. It is operated continuously for 24 hours per day. The water consumption rate of this barangay was monitored for one week, and the result was plotted and shown in Figure J.1.

The result indicates that the average water consumption as obtained from the supply pipes of 5 households (32 persons) is 43 LPCD and the maximum day demand, and peak hour is 120% and 272% of the average day demand, respectively. However, the average water consumption as obtained from the water source is 74 LPCD and the peak hour is 207% of the average day demand occuring at 7:00 a.m. Therefore, the amount of water unaccounted for is 31 LPCD or about 42% of the water production.

B. Household Connection in Caniogan, Morong, Rizal

Caniogan, Morong, Rizal is composed of 159 households (951 persons) of which only 102 households (594 persons) have individual household connections. The water supply system in this barrio is operated for 17 hours per day. The consumption rate was monitored for one week, and the result was plotted and shown in Figure J.2.

The result of the study indicates that the average water consumption for each household connection is 75 LPCD and the maximum day demand and peak hour demand is 150% and 299% of the average day demand, respectively. However, the average water demand as obtained from the source is 159 LPCD and the peak hour demand is 210% of the average day demand. Thus, the amount of water unaccounted for is 84 LPCD or 53% of the water production.

C. Summary

Average Water Consumption for Public Faucet System	43 LPCD
Average Water Consumption for Individual Household Connection	75 LPCD
Maximum Day Demand	130% of average day demand
Maximum Hour Demand	200-300% of average day demand

D. Recommendation

From the information obtained from our limited studies, the following figures are recommended:

Water Consumption Rate for Public Faucet System	43 LPCD

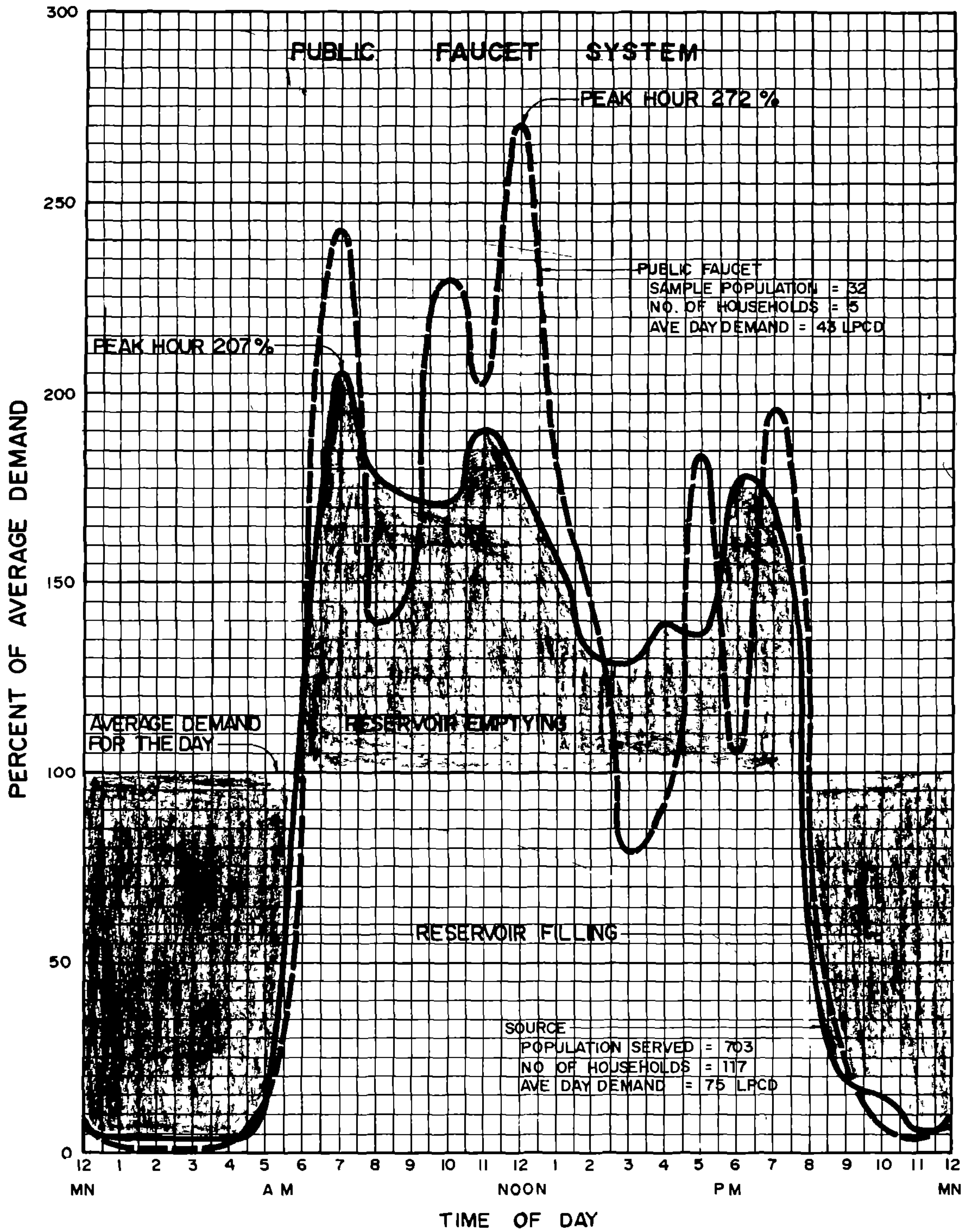


FIGURE J.1

HOURLY VARIATION OF WATER DEMAND FOR SINISIAN, EAST LEMERY, BATANGAS

Water Consumption Rate for Household Connection	75 LPCD
Maximum Day Demand	1.3 × Average Day Demand
Maximum Hour Demand:	
Less than 100 HH or 600 persons	3 × Average Day Demand
More than 100 HH or 600 persons	2.5 × Average Day Demand

The amount of water unaccounted for as noted in this study is 42-53% of the average water consumption. The generally accepted value for wastage is 15%, however, because of the result of this study, we are recommending 30% for newly installed water systems.

For Public Faucet System:

Water Consumption Rate = 1.3 × 43 = 55.90 LPCD
say 60 LPCD

For Household Connection:

Water Consumption Rate = 1.3 × 75 = 97.50 LPCD
say 100 LPCD*

For Combined Public Faucets and some Household

Connections = (60 + 100)/2
80 LPCD*

*The figures recommended above are however tentative and may be modified as more are obtained from the succeeding studies

APPENDIX K

PREPARATION OF CHLORINE SOLUTION

A. Disinfection of Water Supplies

Data:

Water Consumption	=	10,000 LPD
Dosage of residual chlorine	=	0.2 mg./L
Chlorine Demand	=	0.4 mg./L

Required:

a. Dosage, mg/1
b. Dosage Rate, gm/day
   1) Using Chlorine gas
   2) Using HTH
   3) Using Bleaching Powder
   4) Using Sodium Hypochlorite

Analysis:

a. Calculate the dosage

Dosage = Chlorine Demand + Chlorine Residual
Dosage = 0.4 + 0.2 = 0.6 mg/1

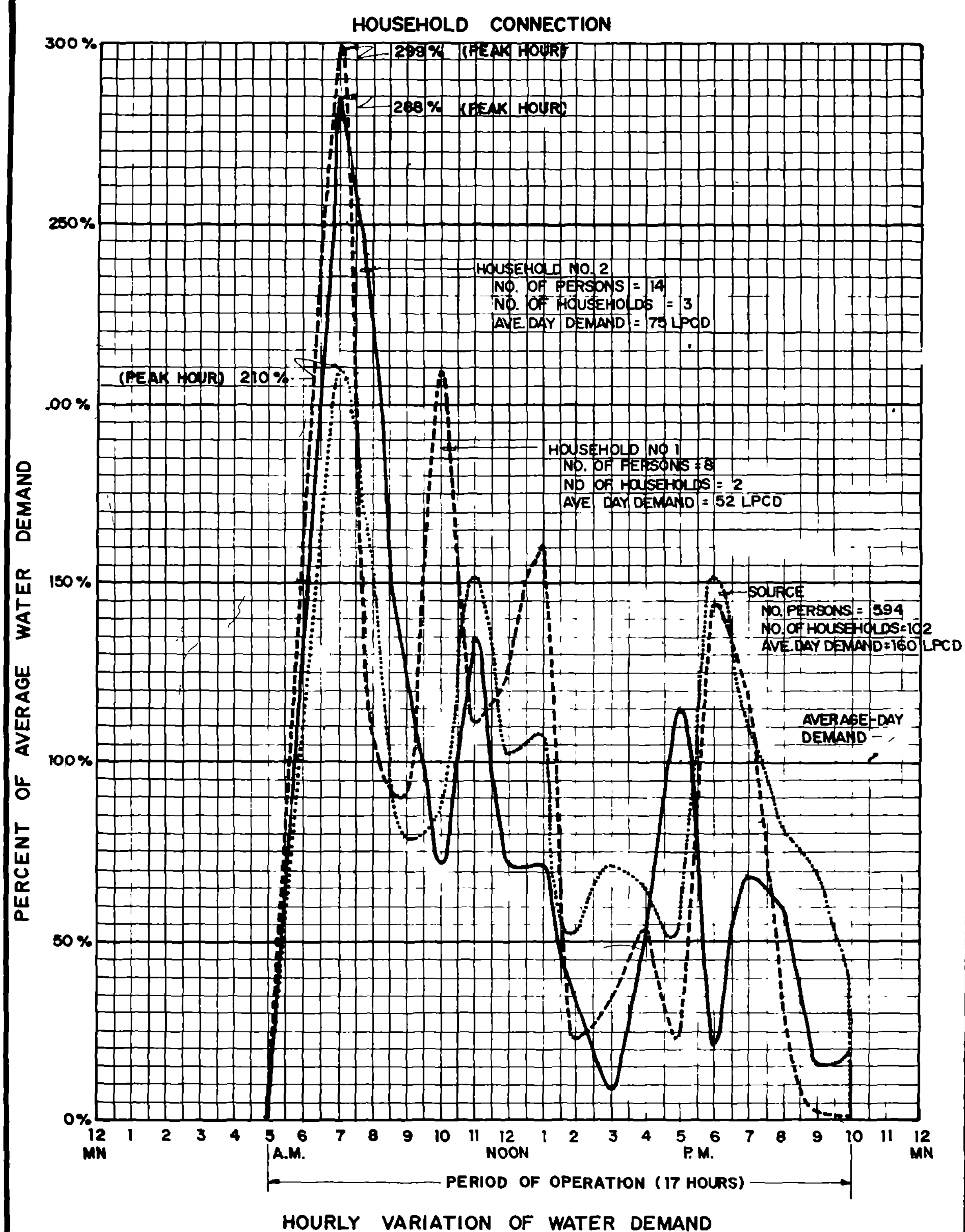


FIGURE J.2

HOURLY VARIATION OF WATER DEMAND FOR CANIOGAN, MORONG, RIZAL

b. Calculate the dosage rate

Dosage Rate = Dosage × volume of water to be treated
= 0.6 mg/1 × 10,000 l/day
= 6,000 mg/day = 6 gm/day

1) Using Chlorine gas, calculate the dosage rate. Available chlorine Content = 100% (Table 6.1)

$$\text{Dosage rate} = \frac{6 \text{ gm/day}}{1} = 6 \text{ gm/day}$$

2) Using HTH, calculate the dosage rate. Available chlorine content = 70% (Table 6.1).

$$\text{Dosage rate} = \frac{6 \text{ gm/day}}{0.7} \quad 8.57 \text{ gm/day}$$

3) Using Bleaching Powder, calculate the dosage rate. Available chlorine content of Bleaching Powder = 35% (Table 6.1).

$$\text{Dosage rate} = \frac{6 \text{ gm/day}}{0.35} = 17.1 \text{ gm/day}$$

4) Using Sodium Hypochlorite, calculate the dosage rate. Available chlorine Content = 12% (Table 6.1).

$$\text{Dosage rate} = \frac{6 \text{ gm/day}}{0.12} = 50 \text{ gm/day}$$

B. Disinfection of New Constructed/repaired wells

Data:

Diameter of Well	= 30 cm. = 0.3 M
Static Water Level	= 6 M
Total Depth of Well	= 10 M

Required:

Calculate the amount of chlorine compounds required.

Design Criteria:

Dosage	= 50 mg/l
Contact time	= 24 hours

Analysis:

a. Calculate the volume of water in the well. Height of water column in the well, H = 10 − 6 = 4M

$$\text{Volume of Water} = \frac{\pi}{4} D^2H$$

$$= \frac{\pi}{4} \times (0.3)^2 \times 4 = 0.283 \text{ M}^3$$

= 283 liters

b. Calculate the amount of chlorine compounds to be applied A

1) Using Bleaching Powder

$$A = \frac{\text{Volume of Water} \times \text{Dosage}}{\text{Available Chlorine}}$$

$$A = \frac{(283)(50)}{0.35} = 40{,}428 \text{ mg} = 40.4 \text{ gms.}$$

2) Using HTH

$$A = \frac{(283)(50)}{0.70} = 20{,}214 \text{ mg} = 20.2 \text{ gms.}$$

C. Disinfection of Reservoirs

Data:

Diameter	: 4 M
Height	: 3 M

Required:

Calculate the amount of Chlorine Compounds required.

Design Criteria:

Dosage	= 300 mg/l
Contact time	= 1 hour

Analysis:

a. Calculate the volume of reservoir, V

Note: To completely disinfect the reservoir, it must be filled with chlorine solution.

$$V = \frac{\pi}{4} D^2 H = \frac{\pi}{4}(4)^2(3) = 37.7 \text{ M}^3 = 37{,}700 \text{ liters.}$$

b. Calculate the amount of chlorine compounds required, A

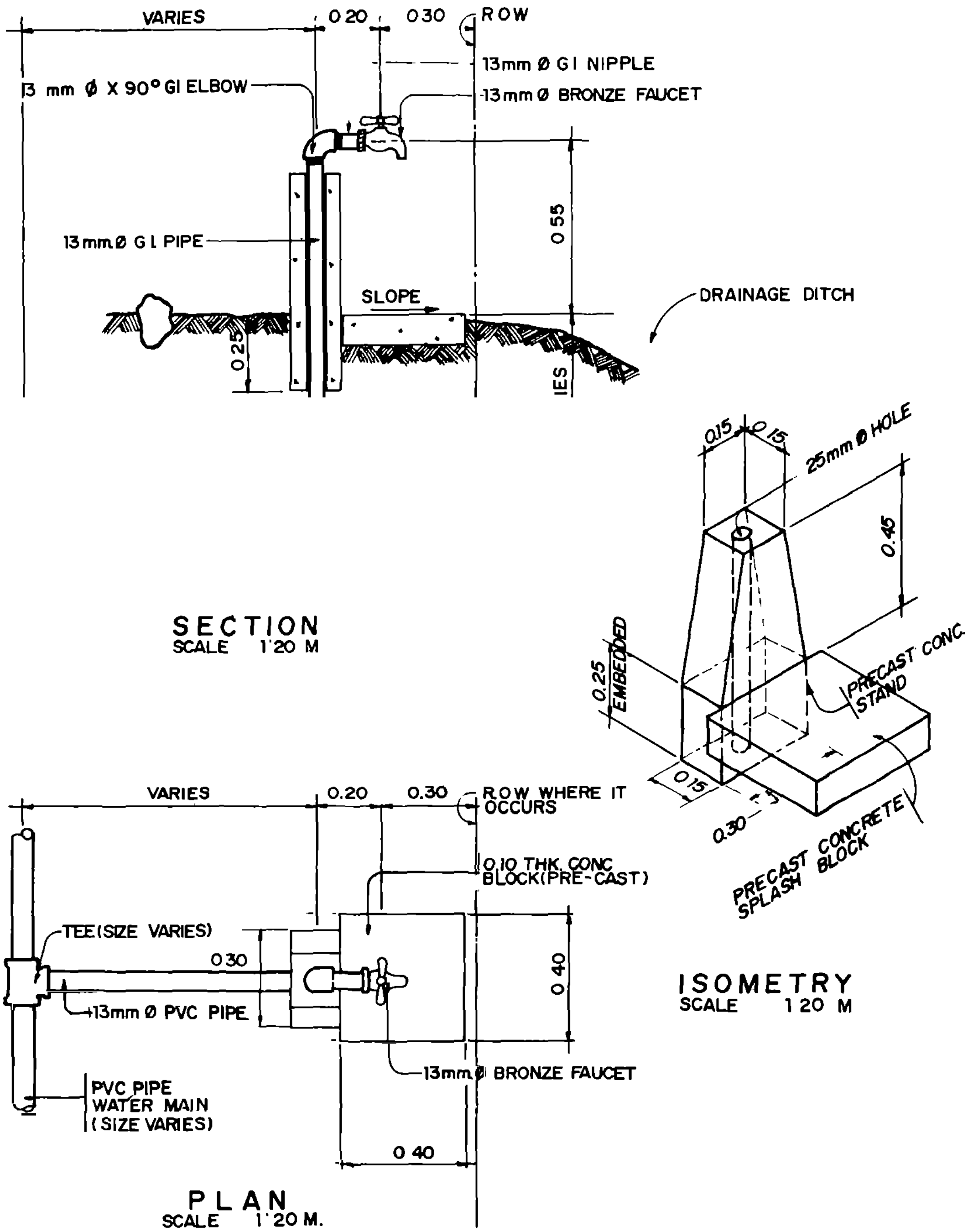
1) Using Bleaching Powder.

$$A = \frac{\text{Volume of Reservoir} \times \text{Dosage}}{\text{Available Chlorine}}$$

$$= \frac{(37{,}700)(300)}{0.35} = 32{,}300{,}000 \text{ mg} = 32.3 \text{ kg.}$$

2) Using HTH

$$A = \frac{(37{,}700)(300)}{0.70} = 16{,}157{,}142 \text{ mg} = 16.2 \text{ kg.}$$



APPENDIX L

PUBLIC FAUCET INSTALLATION

APPENDIX M

COMPUTATION OF VOLUME OF HYDROPNEUMATIC PRESSURE TANK

$$\text{Volume of Tank, } V = \frac{\text{No. of Hours of Peak Demand} \times \text{(Peak Demand-Max. Day Demand)}}{\text{24 Hours}} \times \text{Population Served}$$

where:

No. of Hours of Peak Demand = 3
Peak Demand = Peaking Factor × Ave. Day Demand
Max. Day Demand = 1.3 × Ave. Day Demand
Ave. Day Demand = 60 × Population Served

For Peaking Factor = 3 (Good for Population less than 600)

$$\text{Volume of Tank V,} = \frac{3 \times 60\,(3 - 1.3)}{24} \times \text{Population Served}$$

$$V = 12.75 \times \text{Population Served}$$

For Peaking Factor = 2.5 (Good for Population greater than 600)

$$\text{Volume of tank, V} = \frac{3 \times 60\,(2.5 - 1.3)}{24} \times \text{Population Served}$$

$$V = 9.00 \times \text{Population Served}$$

$$\text{Ave. Volume of Tank, } V_a = \frac{12.75 + 9.00}{2} \times \text{Population Served}$$

$$V_a = 10.87 \times \text{Population Served}$$

Therefore,

For Rural Water Supply System, V = 10 × Population Served will be satisfactory.

APPENDIX N

GUIDELINES IN THE DESIGN OF A RURAL WATER SUPPLY SYSTEM

The design and layout of the water supply system involves the arrangement of storage tanks, pumping stations, pipings and controls together in a system that best fits the condition of the area under consideration. To develop a satisfactory rural water supply system, it is recommended that the designer follow the guidelines presented below:

A. Type and Source of Water (Refer to Chapters 2, 4 and 5)

1. Identify all possible water sources in the vicinity and determine the yield and quality.

    a. Determination of Water Quality (Refer to Chapter 3)

        i. The most simple test in determining water quality is to find out if the inhabitants like the water. If they do, it probably has no iron, not too hard and is low in chlorides.

        ii. If further check on water quality is necessary, get water samples from each source and have it analyzed in the nearest government laboratory to determine its physical and chemical properties.

        iii. A bacteriological test should not be made. Most possible sources are not usually adequately protected, hence, a bad report would normally result, yet the same sources after being protected and chlorinated will yield potable water. Testing unprotected sources bacteriologically will result in many excellent water source being discarded. Only sources having satisfactory quality should be tested for quantity.

    b. Determination of the yield of Source (Refer to Chapters 8 and 10)

       For a water source to be acceptable, it must be able to supply at least the maximum day demand of the area to be served.

2. Selection of Water Sources

   In case a number of sources are available, use Figure N (outline the decisions and steps to take in order to determine the most suitable water source) in making the decisions.

   Select a source which is closer to the user to minimize transmission piping cost. A source located at a higher elevation would be preferable to one located on the same or lower level than the barrio as this would entail lower pumping cost. A decision has to be made in order to get the lowest cost in such instance as tapping a distant water source which could supply water without pumping but requires more investment in pipings.

B. Water Demand

Determine the expected water demand of the area. The water system is expected to serve the community adequately for five (5) years.

In Chapter 8, the methodology of calculating the water demand is

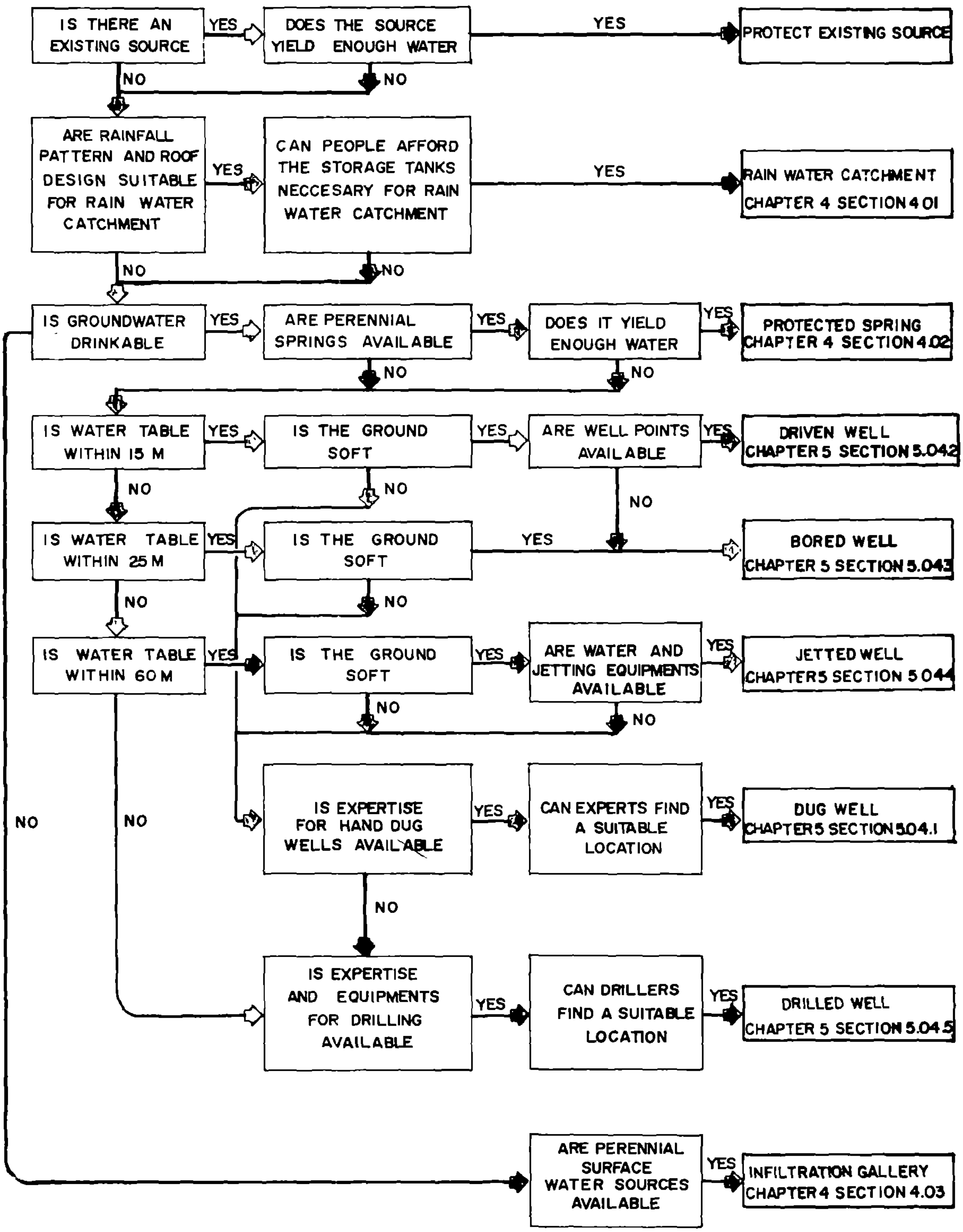


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FIGURE N

SELECTION OF WATER SOURCE

presented. If follows the following procedure:

a. Calculate the design population
b. Estimate the average day demand
c. Estimate the maximum day demand
d. Estimate the maximum hour demand

C. Water Source to Supply the Area

Determine the water source or sources capable of supplying the necessary water. In cases where two or more water sources are necessary to meet the future demand, develop first the water source or sources which would satisfy the present demand only. However, provision for connecting the additional sources which will meet the future demand has to be made.

D. Prepare Site Plan

Prepare a freehand sketch or a scaled layout indicating the location/position of water sources, roads, rivers, bridges, houses, regularity of terrain, obstacles, etc. in the area.

E. Level of Service

Call a meeting of the intended beneficiaries of the project to discuss what level of service they want (Public Faucet System or Household Connection) considering their capability and willingness to pay.

F. Public Faucets (PF)

Using the sketch/map of the area, determine the location of public faucets such that a cluster of 5-7 houses will be served equally. Select the shortest routes to connect the public faucets to the main pipe.

The water demand per public faucet are:

1. Design population per PF = 42
2. Average Day Demand per PF = 2520 LPD
3. Maximum Hour Demand per PF = 7560 LPD

G. Design of Main Pipes and Laterals (Refer to Chapters 9 and 11)
Procedure:

1. Calculate the flows in the laterals and main pipes.
2. Calculate the pipe diameters corresponding to the pipe flows.
3. After the pipe sizes are determined, find out if there are sizes with relatively short lengths. The diameter of these short length pipes can be changed to correspond to the nearest larger size that will be used in quantity. This will reduce the number of sizes of pipes and fittings required, simplifying the bill of materials, procurement, delivery from stores and installation. The additional cost is usually slight.
4. Select the type of pipe (plastic or G.I. pipe).
5. Location of valves, fittings, etc.

H. Design of Reservoirs or Storage Tanks (Refer to Chapter 12)

Procedure:

1. Decide the location of the reservoir(s). Reservoir(s) should be located, if possible, at elevated places and/or central to the distribution system.

2. Calculate the capacity of the reservoir(s). Reservoir(s) can be the most expensive part of the water supply system, hence, the capacity should not be more than the necessary to supplement the average discharge to the system during times of peak demand. Suggested minimum storage requirements are found in Appendix O. If larger quantities of storage tanks can be constructed without greatly increasing the cost and monthly payments, this certainly should be done.
3. Determine the type and materials of construction of reservoir(s). Reservoir(s) may be of elevated, ground level or hydropneumatic pressure system type and the material of construction may be either steel or concrete. The volume of storage, the location, reservoir material and choice of type of tank depend primarily on cost and what is available. Readily available standard sized units should be selected rather than design a special tank for each project.

I. Design of Pumps (Chapter 13)

Procedure:

1. Calculate the Total Dynamic Head (THD).
2. Determine the capacity of pump necessary for the project.
3. Determine the type of pump given the information in I-1 and I-2.
4. Also, select the type of pump which is adaptable to the area under consideration.
5. Determine available power supply.

J. Estimate the entire cost of the project

Procedure:

1. Calculate the cost in developing the water source.
   a. If source is existing well or spring, calculate the cost of improvement.
   b. If source is new well, calculate the well construction cost.
   c. If source is spring, calculate the cost of enlarging the eye of the spring, construction of spring box, etc.
2. Calculate the cost of the storage tanks and accessories.
3. Calculate the cost of pipes, valves and fittings.
4. Calculate the cost of pumps and appurtenances.
5. Calculate the labor cost.
6. Add the contractor's tax, profit and reserve for contingency.
7. Calculate the cost of the entire project.

K. Financing of the Project

Determine the funds available for the project. If the funds are insufficient and cannot be raised, take the following actions in decreasing priority.

1. Reduce storage volume.
2. Change the type of pipe (from G.I. to PVC to PB to PE).
3. Shorten the pipe routes and decrease the number of public faucets.
4. Return to step D.

Repeat the process until the cost of project is equal to the funds available to finance the project.

The use of this guideline is illustrated in Chapter 14. The Distribution Network Design of a Rural Water Supply System.

NO. OF HOUSE-HOLDS	PRESENT POPULATION	DESIGN POPULATION	FLOW RATE, (Q) LPS	WATER MAIN(mm)		RESERVOIR SIZES (LITERS)			
				PLASTIC	GI	PF*	HH *	PF**	HH**
10	60	69	0 14	25	25	2070	3450	880	1470
20	120	138	0.29	31	38	4140	6900	1760	2950
30	180	207	0.43	38	38	6210	10350	2640	4400
40	240	276	0.58	38	50	8280	13800	3520	5870
50	300	345	0.72	38	50	10350	17250	4400	7350
60	360	414	0 86	50	50	12420	20700	5280	8800
70	420	483	1.01	50	63	14490	24150	6160	10260
80	480	552	1.15	50	63	16560	27600	7040	11730
90	540	621	1.29	50	63	18630	31050	7920	11730
100	600	690	1.44	63	63	20700	34500	7920	11730
125	750	863	1.80	63	75	25890	43150	7920	13000
150	900	1035	2.16	63	75	31050	51750	9300	15500
200	1200	1380	2.87	75	100	41400	69000	12420	20700
250	1500	1725	3 59	75	100	51750	86250	15525	25900
300	1800	2070	4 31	75	100	62100	103500	18630	31000
400	2400	2760	5.75	100	100	82800	138000	28840	41400
500	3000	3450	7.19	100	150	103500	172500	31050	51800
600	3600	4140	8 62	100	150	124200	207000	37260	62100
800	4800	5520	11.50	150	200	165600	276000	49680	82800

* BASED ON 1/2 AVERAGE DAY DEMAND

** RESERVOIR IS USED ONLY TO SUPPLY WATER IN EXCESS OF THE MAXIMUM DAY DEMAND [(MAX HOUR DEMAND – MAX DAY DEMAND) X 3 HRS OF PEAK DEMAND]

BASIS : AVERAGE DAY DEMAND RATE

PF=60 LPCD
HH=100 LPCD

DESIGN PERIOD = 5 YRS (MULTIPLIER 1.15)
NO.OF PERSONS PER HH = 6
PIPE DESIGN IS BASED ON MAX. HOUR DEMAND

APPENDOX O

WATER SYSTEM TABLE

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