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## Using Water Resources

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# Using Water Resources

a **VITA** publication

# **Using Water Resources**

**This manual is excerpted  
from the Village Technology Handbook.**

**Published by VITA, Volunteers in Technical Assistance**

# Introduction

USING WATER RESOURCES is an excerpt from VITA's widely known VILLAGE TECHNOLOGY HANDBOOK. It has been issued as a separate volume to meet the large, worldwide demand for information on developing and maintaining water supplies. This manual provides material which is technically competent and is presented so that it can be used easily by audiences having different levels of skill.

VITA's information is prepared for the purpose of aiding development processes in the Third World. However, VITA realizes that materials contained here and in other VITA publications are useful to people everywhere. Therefore, VITA's Publication Service is pleased to offer the worldwide appropriate/alternative technology community the technologies developed, designed, and adapted by VITA Volunteers.

The material contained in this volume has been used widely. For example, by:

- . Volunteer representatives of many nations -- the United States, Switzerland, Japan, and so on -- working in development activities around the world.
- . Local community groups in the States and village organizations throughout the developing and developed world.
- . Development organizations seeking information upon which to base and/or implement projects.
- . Do-it-yourselfers wanting guidelines for water resources development.

VITA's aim is to provide these publications at prices which ensure the information is available to as many people as possible.

In the text, dimensions are given in metric units, with English units in parentheses. In the illustrations, only metric units are given.

Reference materials, along with information on where they can be obtained, are listed at the end of specific entries.

# The Village Technology Handbook

The VILLAGE TECHNOLOGY HANDBOOK was begun in 1962 by VITA Volunteers who were looking for a means of keeping the world's villages in touch with each other. VITA people felt that technologies developed and found useful in one village should be made available to other communities. Thus, the first VILLAGE TECHNOLOGY HANDBOOK was published in 1963 to bring together information on a number of topics directly related to village development.

The first edition of the VILLAGE TECHNOLOGY HANDBOOK was published in two volumes. In 1970, the material was edited, rechecked for accuracy by VITA specialists, and republished in one volume. Bibliographic material was added to guide readers to other sources of information, particularly on those subjects not covered in detail in the Handbook. A further, but limited, revision of the material was printed in January 1975.

The VILLAGE TECHNOLOGY HANDBOOK contains information from many sources; yet all of the entries describe techniques and devices which can be made and used in villages.

In addition to the material on water resources, which has been excerpted for this volume, the complete Handbook contains information in the following areas:

- . Health and Sanitation
- . Agriculture
- . Food Processing and Preservation
- . Construction
- . Home Improvement
- . Crafts and Village Industry

# About VITA

VITA . . .

is a private, non-profit development organization based in the United States. Since 1960 VITA has supplied information and assistance, primarily by mail, to people seeking help with technical problems in more than 100 developing countries. Providing its services in response to requests from individuals and groups working to improve homes, farms, communities, businesses, and lives, VITA helps select and implement technologies appropriate to the situation.

VITA's technical services are provided by a worldwide corps of 4500 skilled Volunteer experts and a central staff of twenty.

VITA consultants can help design a bridge using local materials; collaborate on a windmill plan for pumping water or generating electricity; devise an agricultural implement; develop a method for reconstituting powdered milk for a school lunch program; find out why a pump being tested is not working; evaluate a small leathercraft business.

Over the years VITA has gained worldwide recognition for developing technologies responsive to specific cultural and technical contexts.

Areas of particular interest to VITA are:

- agriculture and animal husbandry
- alternative energy systems (wind, solar, bio-gas, etc.)
- water and sanitation
- food processing
- small-scale industries
- equipment design
- project feasibility and evaluation
- low-cost housing and construction
- crafts production and marketing

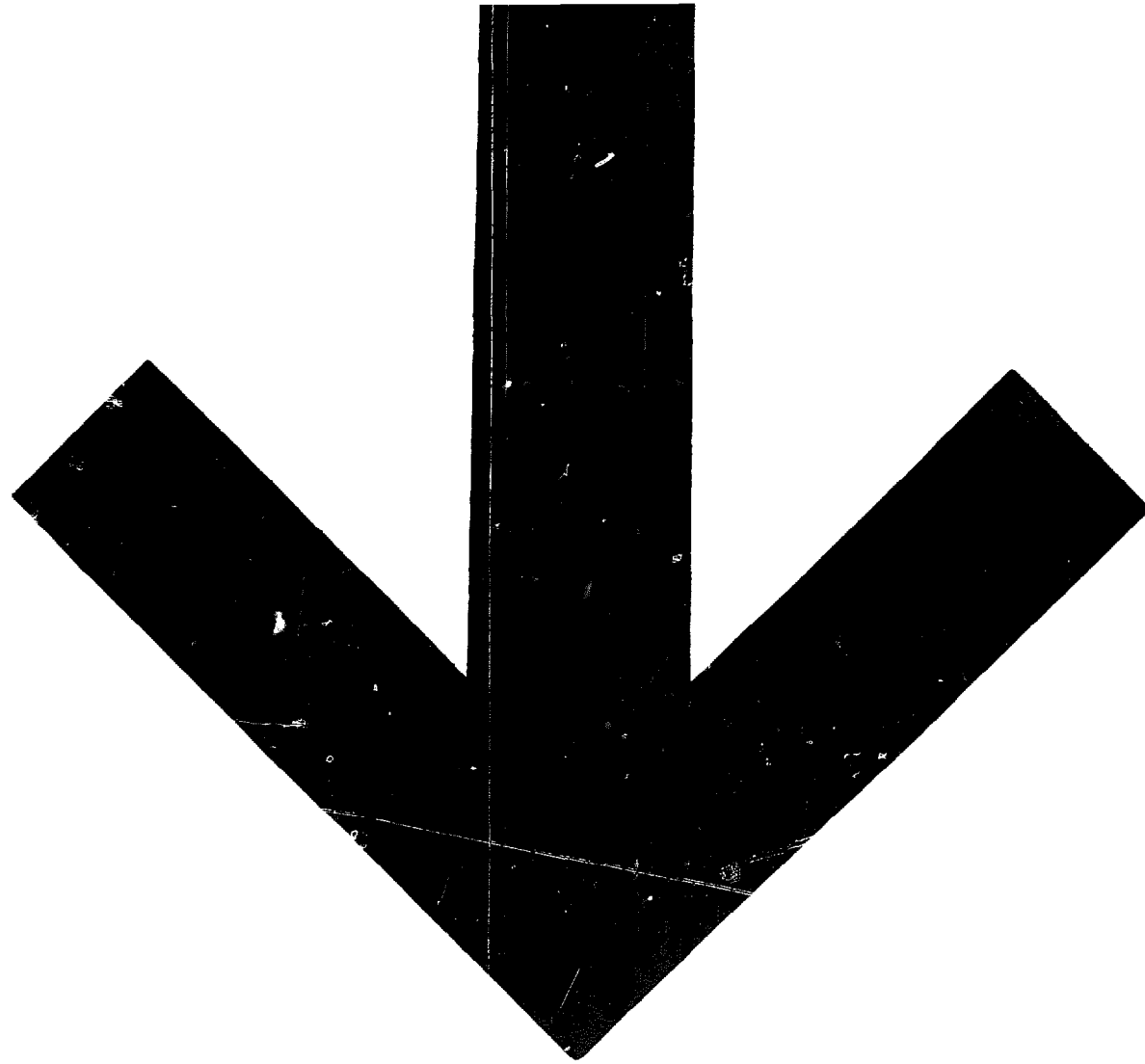
VITA currently publishes about 50 appropriate technology manuals, many available in French and Spanish as well as English. These manuals deal with such specific topics as windmills, solar cookers, water wheels, rabbit raising.

In addition, a number of VITA Technical Bulletins are available. These are plans and case studies which present ideas and alternatives to encourage further experimentation and testing and provide access to some of the best from VITA Volunteers and others. Complete lists of publications and technical bulletins are available upon request.

*VITA News* is a quarterly newsletter which provides an important communications link among far-flung organizations involved in technology transfer and adaptation. The *News* contains reviews of new books, technical abstracts, updates on worldwide activities, notices of new organizations.

VITA is a dynamic, flexible organization with an extremely cost-effective program for meeting development needs. Funding comes from a variety of public and private sources. As a non-profit organization, VITA relies on individual, business and foundation support to ensure the continuation of its activities. Contributions in any amount from people anywhere in the world are sincerely appreciated.

For further information, write to VITA, 3706 Rhode Island Avenue, Mount Rainier, Maryland 20822 USA.



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SYMBOLS AND ABBREVIATIONS  
USED IN THIS BOOK

@	. . . .	at
"	. . . .	inch
'	. . . .	foot
C	. . . .	degrees Celsius (Centigrade)
cc	. . .	cubic centimeter
cm	. . .	centimeter
cm/sec	. . .	centimeters per second
d or dia.	. . .	diameter
F	. . . .	degrees Fahrenheit
gm	. . .	gram
gpm	. . .	gallons per minute
HP	. . .	horsepower
kg	. . .	kilogram
km	. . .	kilometer
l	. . . .	liter
lpm	. . .	liters per minute
l/sec	. . .	liters per second
m	. . . .	meter
ml	. . .	milliliters
mm	. . .	millimeters
m/m	. . .	meters per minute
m/sec	. . .	meters per second
ppm	. . .	parts per million
R	. . . .	radius

# *Water Resources*



# Developing Water Sources

There are three main sources of water for small water-supply systems: ground water, surface water and rainwater. The entries which follow describe the methods of getting water from these three sources:

1. Getting Ground Water from Wells and Springs.
2. Building Small Dams to Collect Surface Water.
3. Collecting Rainwater in Cisterns.

The choice of the source of water depends on local circumstances. A study of the local area should be made to determine which source is best for providing water which is (1) safe and wholesome,

(2) easily available and (3) sufficient in quantity.

Once the water is made available, it must be brought from where it is to where it is needed and steps must be taken to be sure that it is pure. These subjects are covered in sections on:

Water Lifting

Water Transport

Water Purification

An added section on Map Making gives guidelines which will be helpful in irrigation and drainage projects.

\* \* \* \* \*

## GETTING GROUND WATER FROM WELLS AND SPRINGS

This section explains ground water and then describes a variety of methods of collecting ground water:

1. Tubewells
  - a. Well Casing and Platforms
  - b. Hand-Operated Drilling Equipment
  - c. Driving Wells
2. Dug Wells
3. Spring Development

### Ground Water

Ground water is subsurface water which fills small openings (pores) of loose sediments (such as sand and gravel) or rocks. For example, if we took a clear glass bowl, filled it with sand, and then poured in some water, we would notice



FIGURE 1

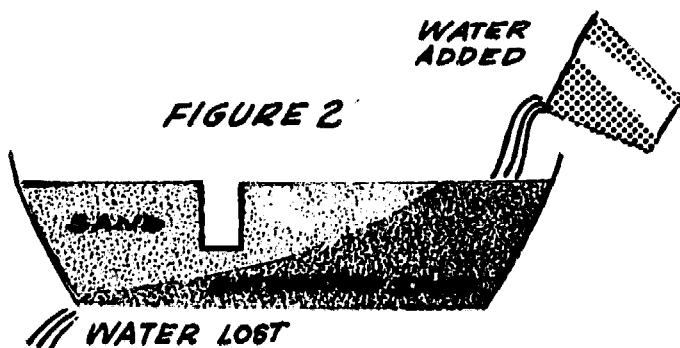
the water "disappear" into the sand (see Figure 1). However, if we looked through the side of the bowl, we would see water in the sand, but below the top of the sand. The sand containing the water is said to be saturated. The top of the saturated sand is called the water table; it is the level of the water in the sand.

The water beneath the water table is true ground water available (by pumping) for human use. There is water in the soil above the water table, but it does not flow into a well and is not available for usage by pumping.

If we inserted a straw into the saturated sand in the bowl in Figure 1 and sucked on the straw, we would obtain some water (initially, we would get some sand too). If we sucked long enough, the water table or water level would drop toward the bottom of the bowl. This is exactly what happens when water is pumped from a well drilled below the water table.

The two basic factors in the occurrence of ground water are: (1) the presence of water, and (2) a medium to "house" the water. In nature, water is primarily provided by precipitation (rain and snow), and secondarily, by surface water features (rivers and lakes). The medium is porous rock or loose sediments.

The most abundant ground-water reservoir occurs in the loose sands and gravels in river valleys. Here the water table roughly parallels the land surface, that is, the depth to the water table is generally constant. Disregarding any drastic changes in climate, natural ground-water conditions are fairly uniform or balanced. In Figure 2, the water poured into the bowl (analogous to precipitation) is balanced by the water discharging out of the bowl at the lower elevation (analogous to discharge into a stream). This movement of ground water is slow, generally centimeters or inches per day.



When the water table intersects the land surface, springs or swamps are formed (see Figure 3). During a particularly wet season, the water table will come much closer to the land surface than it normally does and many new springs or swampy areas will appear. On the other hand, during a particularly dry season, the water table will be lower than normal and many springs will "dry up." Many shallow wells may also "go dry."

### Flow of Water to Wells

A newly dug well fills with water a meter or so (a few feet) deep, but after some hard pumping it becomes dry. Has the well failed? Was it dug in the wrong place? More likely you are witnessing the phenomenon of drawdown, an effect every pumped well has on the water table, (see Figure 4).

Because water flows through sediments slowly, almost any well can be pumped dry temporarily if it is pumped hard enough. Any pumping will lower the water level to some degree, in the manner shown in Figure 4. A serious problem arises only when the drawdown due to normal use lowers the water table below the level of the well.

After the well has been dug about a meter (several feet) below the water table, it should be pumped at about the rate it will be used to see if the flow into the well is adequate. If it is not sufficient, there may be ways to improve it. Digging the well deeper or wider will not only cut across more of the water-bearing layer to allow more flow into the well, but it will also enable the well to store a greater quantity of water which may seep in overnight. If the well is still not adequate and can be dug no deeper, it can be widened further, perhaps lengthened in one direction, or more wells can be dug. If it is possible to do so safely, another method is to dig horizontal tunnels out from the bottom of the well. The goal of all

these methods is to intersect more of the water-bearing layers, so that the well will produce more water without lowering the water table to the bottom of the well.

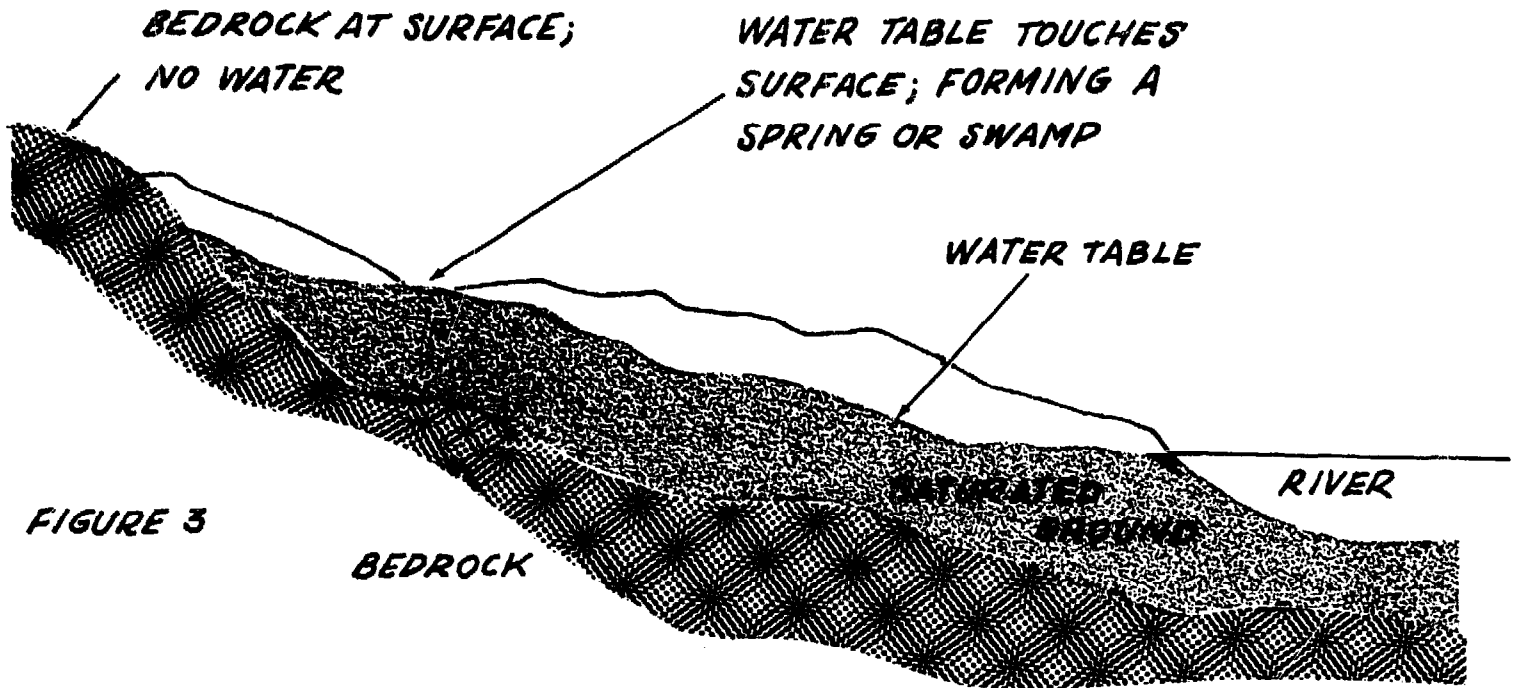


FIGURE 3

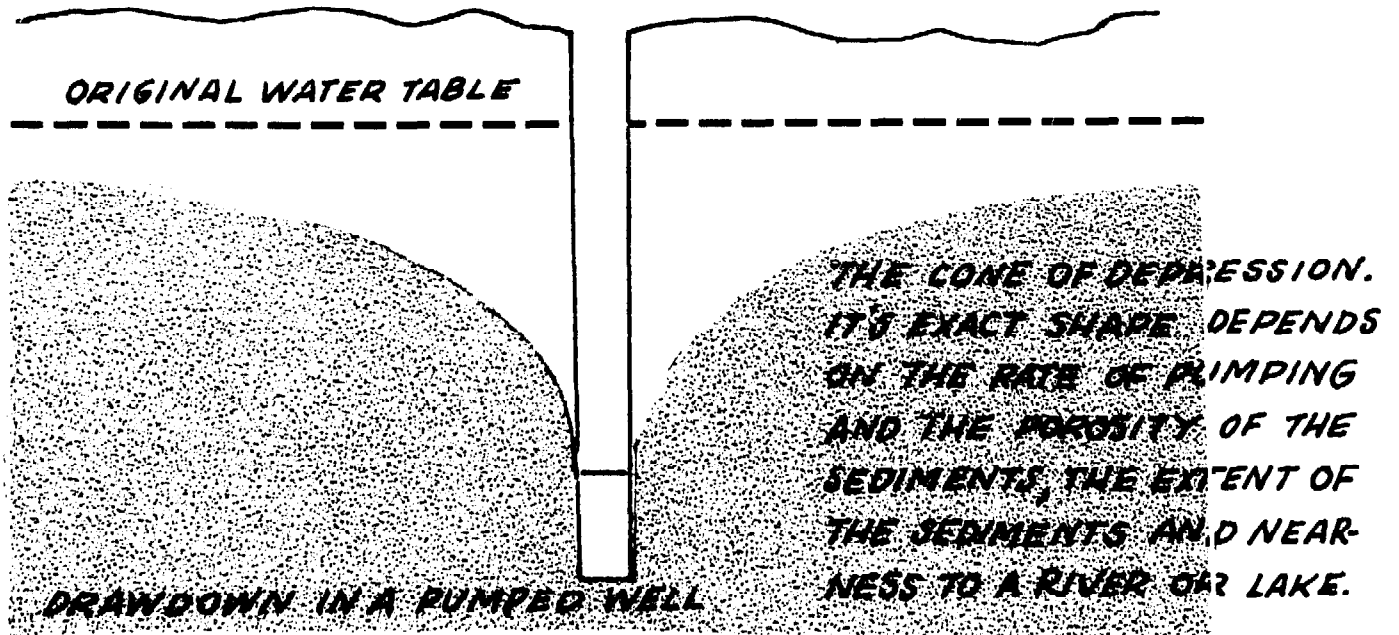


FIGURE 4

## Where to Dig a Well

Four important factors to consider in choosing a well site are:

1. Nearness to Surface Water
2. Topography
3. Sediment Type
4. Nearness to Pollutants

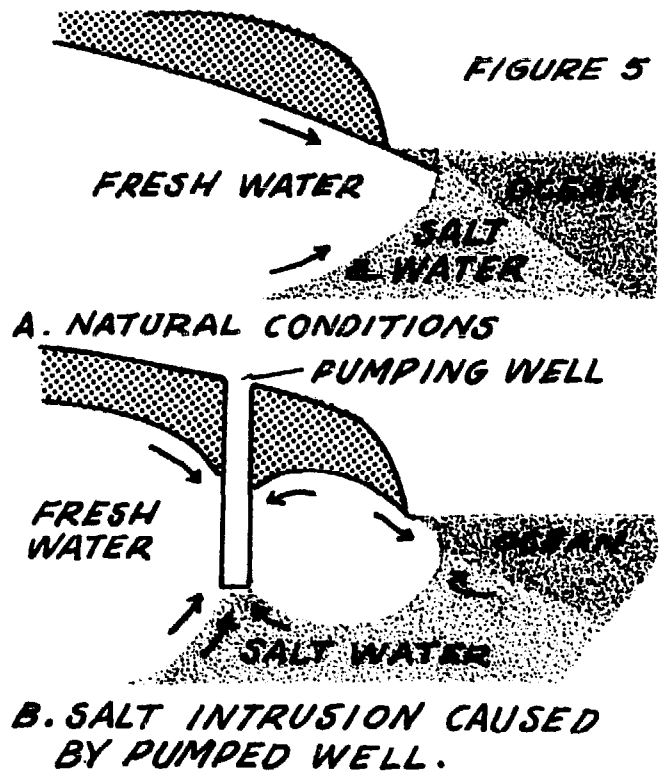
### 1. Nearness to Surface Water

If there is any surface water nearby, such as a lake or a river, locate the well as near it as possible. It is likely to act as a source of water and keep the water table from being lowered as much as without it. This does not always work well, however, as lakes and slow-moving bodies of water generally have silt and slime on the bottom, which prevent water from entering the ground quickly.

There may not seem to be much point to digging a well near a river, but the filtering action of the soil will result in water that is cleaner and more free of bacteria. It may also be cooler than surface water. If the river level fluctuates during the year, a well will give cleaner water (than stream water) during the flood season, although ground water often gets dirty during and after a flood; a well will also give more reliable water during the dry season, when the water level may drop below the bed of the river. This method of water supply is used by some cities: a large well is sunk next to a lake or river and horizontal tunnels are dug to increase the flow.

Wells near the ocean, and especially those on islands, may have not only the problem of drawdown but that of salt water encroachment. The underground boundary between fresh and salt water generally slopes inland: Because salt water is heavier than fresh water, it flows in under it. If a well near the

shore is used heavily, salt water may come into the well as shown in Figure 5. This should not occur in wells from which only a moderate amount of water is drawn.



### 2. Topography

Ground water, being liquid, gathers in low areas. Therefore, the lowest ground is generally the best place to drill or dig. If your area is flat or steadily sloping, and there is no surface water, one place is as good as another to start drilling or digging. If the land is hilly, valley bottoms are the best places to look for water.

You may know of a hilly area with a spring on the side of a hill. Such a spring could be the result of water moving through a layer of porous rock or a fracture zone in otherwise impervious rock. Good water sources can result from such features. If you can see layers of rock sticking out of the hillside, you may be able to guess where a water-bearing layer can be found by digging down from higher on the hill. This is because most layers continue over short distances.

### 3. Sediment Type

Ground water occurs in porous or fractured rocks of sediments. Gravel, sand and sandstone are more porous than clay, unfractured shale and granite or "hard rock."

Figure 6 shows in a general way the relationship between the availability of ground water (expressed by typical well discharges) and geologic material (sediments and various rock types). For planning the well discharge necessary for irrigating crops, a good rule of thumb for semi-arid climates -- 37.5cm (15") of precipitation a year -- is a 1500 to 1900 liters (400 to 500 U.S. gallons) per minute well which will irrigate about 65 hectares (160 acres) for about 6 months. From Figure 6, we see that wells in sediments are generally more than adequate. However, enough ground water can be obtained from rock, if necessary, by drilling a number of wells. Deeper water is generally of better quality. Water from shallow wells is generally harder than water from rock aquifers; this may be important for hospitals and some industries.

Sand and gravel are normally porous and clay is not, but sand and gravel can contain different amounts of silt and clay which will reduce their ability to carry water. The only way to find the yield of a sediment is to dig a well and pump it.

In digging a well, be guided by the results of nearby wells, the effects of seasonal fluctuations on nearby wells, and keep an eye on the sediments in your well as it is dug. In many cases you will find that the sediments are in layers, some porous and some not. You may be able to predict where you will hit water by comparing the layering in your well with that of nearby wells.

Figures 7, 8 and 9 illustrate several sediment situations and give guidelines on how deep to dig wells.

### 4. Nearness to Pollutants

If pollution is in the ground water, it moves with it. Therefore, a well should always be uphill and 15 to 30 meters (50 to 100 feet) away from a latrine, barnyard, or other source of pollution. If the area is flat, remember that the flow of ground water will be downward, like a river, toward any nearby body of surface water. Locate a well in the upstream direction from pollution sources.

The deeper the water table, the less chance of pollution because the pollutants must travel some distance downward before entering ground water. The water is purified as it flows through the soil.

Extra water added to the pollutants will increase their flow into and through the soil, although it will also help dilute them. Pollution of ground water is more likely during the rainy than the dry season, especially if a source of pollution such as a latrine pit is allowed to fill with water. See also "Introduction to Sanitary Latrines," p. 147. Similarly, a well that is heavily used will increase the flow of ground water toward it, perhaps even reversing the normal direction of ground water movement. The amount of drawdown is a guide to how heavily the well is being used.

Polluted surface water must be kept out of the well pit. This is done by casing and sealing the well.

#### Well Casing and Seal

The purpose of casing and sealing wells is to prevent contaminated surface water from entering the well or nearby ground water. As water will undoubtedly be spilled from any pump, the top of the well must be sealed with a concrete slab to let the water flow away rather than re-enter the well directly. It is also helpful to build up the pump area with dirt to form a slight hill which will help drain away spilled water and rain water.

**FIGURE 6** AVAILABILITY OF GROUND WATER IN WATER BEARING SEDIMENTS OR ROCK TYPES

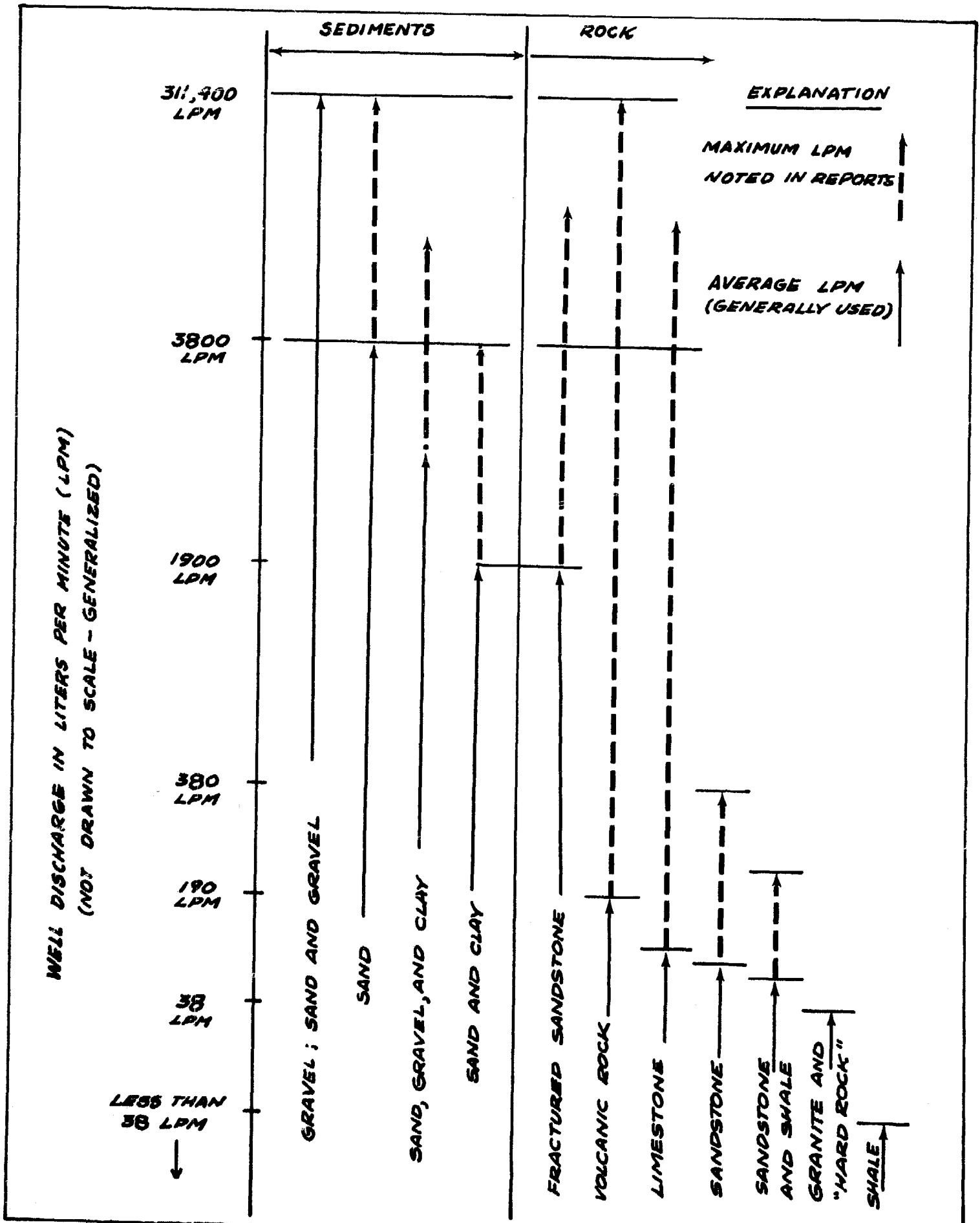




Figure 6. Availability of ground water from various sediments and rock types.

Aquifers (water-bearing sediments) of Sand and Gravel. Generally yield 11,400 lpm (3000 gpm) (but they may yield less depending on pump, well construction and well development).

Aquifers of Sand, Gravel, and Clay (Intermixed or Interbedded). Generally yield between 1900 lpm (500 gpm) and 3800 lpm (1000 gpm), but can yield more--between 3800 lpm (1000 gpm) and 11,400 lpm (3000 gpm)--depending on the percentage of the constituents.

Aquifers of Sand and Clay. Generally yield about 1900 lpm (500 gpm) but may yield as much as 3800 lpm (1000 gpm).

Aquifers of Fractured Sandstone. Generally yield about 1900 lpm (500 gpm) but may yield more than 3800 lpm (1000 gpm) depending on the thickness of the sandstone and the degree and extent of fracturing (may also yield less than 1900 lpm (500 gpm) if thin and poorly fractured or interbedded with clay or shale).

Aquifers of Limestone. Generally yield between 38 lpm (10 gpm) and 190 lpm (50 gpm) but have been known to yield more than 3800 lpm (1000 gpm) due to caverns or nearness to stream, etc.

Aquifers of Granite and/or "Hard Rock". Generally yield 38 lpm (10 gpm) and may yield less (enough for small household).

Aquifers of Shale. Yield less than 38 lpm (10 gpm), not much good for anything except as a last resort.

Casing is the term for the pipe, cement ring or other material that supports the well wall. It is usually impermeable in the upper part of the well to keep out polluted water (see Figure 7) and may be perforated or absent in the lower part of the well to let water enter. See also "Well Casing and Platforms," p. 12, and "Reconstructing Dug Wells," p. 59.

In loose sediment, the base of the well should consist of a perforated casing surrounded by coarse sand and small pebbles; otherwise, rapid pumping may bring into the well enough material to form a cavity and collapse the well itself. Packing the area around the well hole in the water-bearing layer with fine gravel will prevent sand from washing in and increase the effective size of the well. The ideal gradation is from sand to 6mm (1/4") gravel next to the well screen. In a drilled well it may be added around the screen after the pump pipe is installed.

### Well Development

Well development refers to the steps taken after a well is drilled to insure maximum flow and well life by preparing the sediments around the well. The layer of sediments from which the water is drawn often consists of sand and silt. When the well is first pumped, the fine material will be drawn into the well and make the water muddy. You will want to pump out this fine material to keep it from muddying the water later and to make the sediments near the well more porous. However, if the water is pumped too rapidly at first, the fine particles may collect against the perforated casing or the sand grains at the bottom of the well and block the flow of water into it.

A method for removing the fine material successfully is to pump slowly until the water clears, then at successively higher rates until the maximum of the pump or well is reached. Then the water level should be permitted to return to normal and the process repeated until consistently clear water is obtained.

Another method is surging, which is moving a plunger (an attachment on a drill rod) up and down in the well. This causes the water to surge in and out of the sedimentary layer and wash loose the fine particles, as well as any drilling mud stuck on the wall of the well. Coarse sediment washed into the well can be removed by a bailing bucket, or it may be

SHALLOW BODY OF POLLUTED WATER

DEEPER BODY OF PURE WATER

CASING TO KEEP OUT POLLUTED WATER

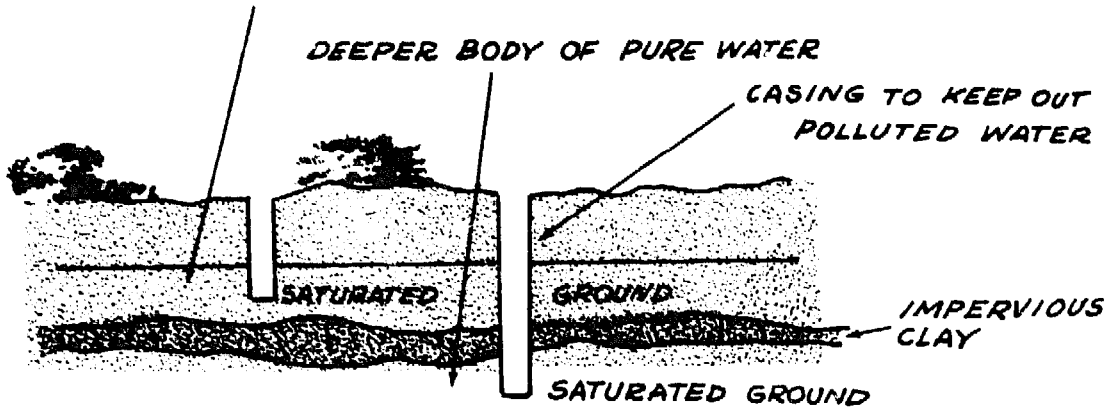
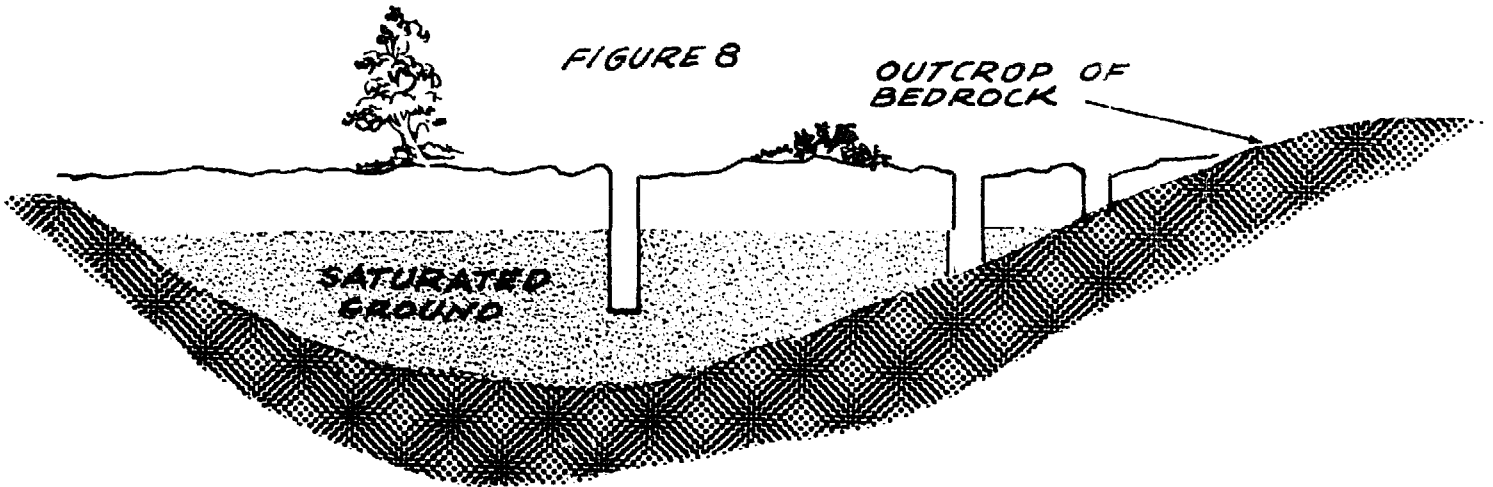


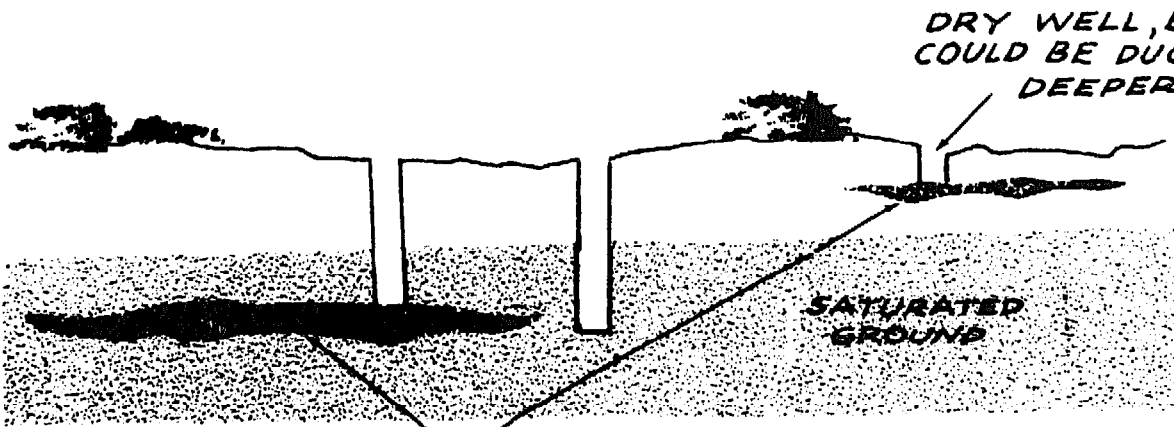
FIGURE 7

FIGURE 8

OUTCROP OF BEDROCK



DRY WELL, BUT  
COULD BE DUG  
DEEPER



IMPERVIOUS  
CLAY BODIES

FIGURE 9

left in the bottom of the well to serve as a filter.

#### Sources:

Michael T. Field, VITA Volunteer, Schenectady, New York

John Chronic, VITA Volunteer, Boulder, Colorado

David B. Richards, VITA Volunteer, Fort Collins, Colorado

Yaron M. Sternberg, VITA Volunteer, Bloomington, Indiana.

A Primer on Ground Water, H. L. Baldwin and C. L. McGuinness, U. S. Government Printing Office, Washington, D. C., 1964, 26 pages, U.S. \$0.25

This inexpensive booklet discusses ground water in more detail than this article and is a useful reference for anyone working with wells.

Ground Water Hydrology, D. K. Todd, Wiley & Sons, New York, 1959, 336 pages, U.S. \$0.95.

One of several textbooks available, this book describes the mathematical approach to ground water study. It also contains much information on related subjects such as well development and water law.

Water Supply for Rural Areas and Small Communities, E. G. Wagner and J. N. Lanoix, World Health Organization, Geneva, 1959, 340 pages, \$6.75.

This excellent book has a variety of information on ground water, wells, and water systems, all aimed at the village level.

Hydrogeology, S. N. Davis and R. J. M. DeWiest, Wiley & Sons, New York, 1966, 300 pages, U.S. \$11.00

Another textbook, but concentrates on the importance of geology on the occurrence of ground water.

Water Well Handbook, K. E. Anderson, Missouri Water Well Drillers Association, P. O. Box 250, Rolla, Missouri, 1965, 281 pages, U.S. \$3.00.

Comprehensive handbook used by well drillers and field engineers; includes charts, tables, and other data dealing with drilling equipment, hardware associated with well construction and installation of pumps. Many consider this the practical bible of water wells.

Ground Water and Wells, Edward E. Johnson, Inc., Saint Paul, Minnesota 55104, 440 pages, 1966, about \$5.00.

An excellent semi-technical reference book used by the water-well industry covering such items as: ground water occurrence, well design as related to geology, well drilling, well maintenance, and well operation.

Wells, Department of the Army, Technical Manual (TM 5-297), 1957, Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., 264 pages, \$1.00.

An elementary, comprehensive book on well drilling and well construction. Easy to read and understand, but not as up to date as the other references above.

Small Water Supplies, Bulletin No. 10, The Ross Institute, Keppel Street (Gower Street), London, W.C. 1, England, 1967, 67 pages.

## TUBEWELLS

Where soil conditions permit, the tubewells described here will, if they have the necessary casing, provide pure water. They are much easier to install and cost much less than large diameter wells.

Tubewells will probably work well where simple earth borers or earth augers work (i.e., alluvial plains with few rocks in the soil), and where there is a permeable water-bearing layer 15 to 25 meters (50 to 80 feet) below the surface. They are sealed wells, and consequently sanitary, which offer no hazard to small children. The small amounts of materials needed keep the cost down. These wells may not yield enough water for a large group, but they would be big enough for a family or a small group of families.

The storage capacity in small diameter wells is small. Their yield depends largely on the rate at which water flows from the surrounding soil into the well. From a saturated sand layer, the flow is rapid. Water flowing in quickly replaces water drawn from the well. A well which taps such a layer seldom goes dry. But even when water-bearing sand is not reached, a well with even a limited storage capacity may yield enough water for a household.

### Well Casing and Platforms

In home or village wells, casing and platforms serve two purposes: (1) to keep well sides from caving in, and (2) to seal the well and keep any polluted surface water from entering the well.

Two low-cost casing techniques are described here:

1. Method A, from an American Friends Service Committee (AFSC) team in Rasulia, Madhya Pradesh, India.
2. Method B, from an International

Voluntary Services (IVS) team in Vietnam.

### Method A. (See Figure 1)

#### Tools and Materials

Asbestos cement, tile, concrete, or even galvanized iron will do.

Casing pipe (from pump to water-bearing layer to below minimum water table).

Sand

Gravel

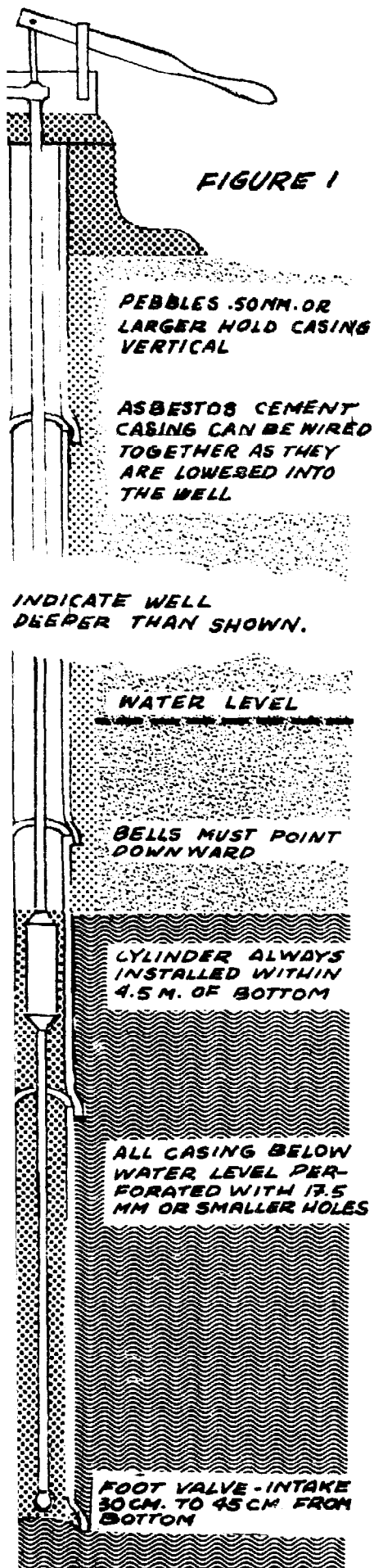
Cement

Device for lowering and placing casing (see Figure 2).

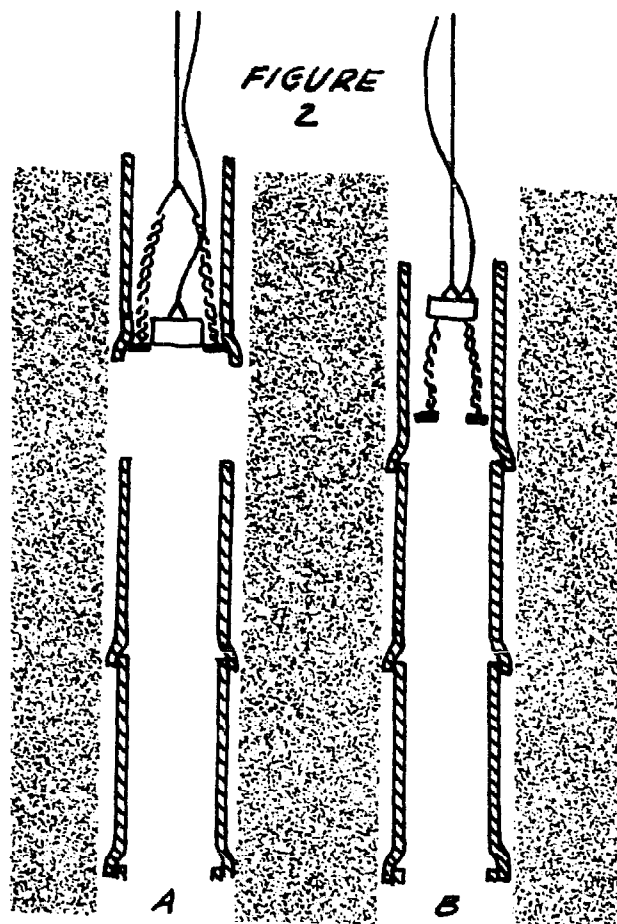
Drilling rig - see "Tubewell Boring"

Foot valve, cylinder, pipe, handpump.

The well hole is dug as deep as possible into the water-bearing strata. The diggings are placed near the hole to make a mound, which later will serve to drain spilled water away from the well. This is important because backwash is one of the few sources of contamination for this type of well. The entire casing pipe below water level should be perforated with many small holes no larger than 5mm (3/16") in diameter. Holes larger than this will allow coarse sand to be washed inside and plug up the well. Fine particles of sand, however, are expected to enter. These should be small enough to be pumped immediately out through the pump. This keeps the well clear. The first water from the new well may bring with it large quantities of fine sand. When this happens, the first strokes should be strong and steady and continued until the water comes clear.



Perforated casing is lowered, bell end downward, into the hole using the device shown in Figure 2. When the casing is properly positioned, the trip cord is pulled and the next section prepared and lowered. Since holes are easily drilled in asbestos cement pipe, they can be wired together at the joint and lowered into the well. Be sure the bells point downward, since this will



prevent surface water or backwash from entering the well without the purifying filtration effect of the soil; it will also keep sand and dirt from filling the well. Install the casing vertically and fill the remaining space with pebbles. This will hold the casing plumb. The casing should rise 30 to 60cm (1' to 2') above ground level and be surrounded with a concrete pedestal to hold the pump and to drain spilled water away from the hole. Casing joints within 3 meters (10 feet) of the surface should be sealed with concrete or bituminous material.

## Method B

Plastic seems to be an ideal casing material, but because it was not readily available, the galvanized iron and concrete casings described here were developed in the Ban Me Thuot area of Vietnam. The materials for one 20 meter (65') well, not including a pump, cost about U.S. \$17 in 1959.

### Tools and Materials

Wooden V-block, 230cm (7 1/2') long  
(see Figure 3)

Angle iron, 2 sections, 230cm (7 1/2') long

Pipe, 10cm (4") in diameter, 230cm (7 1/2') long

Clamps

Wooden mallet

Soldering Equipment

Galvanized sheet metal: 0.4mm x 1 meter x 2 meter (0.016" x 39 1/2" x 79") sheets

### Plastic Casing

Black plastic pipe for sewers and drains was almost ideal. Its friction joints could be quickly slipped together and sealed with a chemical solvent. It seemed durable but was light enough to be lowered into the well by hand. It could be easily sawed or drilled to make a screen. Care must be taken to be sure that any plastic used is not toxic.

### Galvanized Sheet Metal Casing

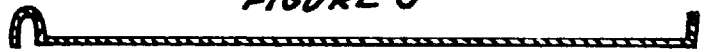
Galvanized sheet metal was used to make casing similar to downspouting. A thicker gauge than the 0.4mm (0.016") available would have been preferable. Because the sheet metal would not last indefinitely if used by itself, the well hole was made oversize and

the ring-shaped space around the casing was filled with a thin concrete mixture which formed a cast concrete casing and seal outside the sheet metal when it hardened.

The 1 meter x 2 meter (39 1/2" x 79") sheets were cut lengthwise into three equal pieces which yielded three 2-meter (79") lengths of 10cm (4") diameter pipe.

The edges were prepared for making seams by clamping them between the two angle irons, and then pounding the edges with a wooden mallet to the shape shown in Figure 3.

*FIGURE 3*



The seam is made slightly wider at one end than at the other to give the pipe a slight taper which allows successive lengths to be slipped a short distance inside one another.

The strips are rolled by bridging them over a 2-meter (79") wooden V-shaped block and applying pressure from above with a length of 5cm (2") pipe (see Figure 4). The sheet metal strips are shifted from side to side over the V-block as they are being bent to produce as uniform a surface as possible. When the strip is bent enough, the two edges are hooked together and the 5cm (2") pipe is slipped inside. The ends of the pipe are set up on wooden blocks to form an anvil, and the seam is firmly crimped as shown in Figure 4.

After the seam is finished, any irregularities in the pipe are removed by applying pressure by hand or with the wooden mallet and pipe anvil. A local tinsmith and his helper were able to make six to eight lengths (12-16 meters) of the pipe per day. Three lengths of pipe were slipped together and soldered as they were made, and the remaining joints had to be soldered as the casing was lowered into the well.

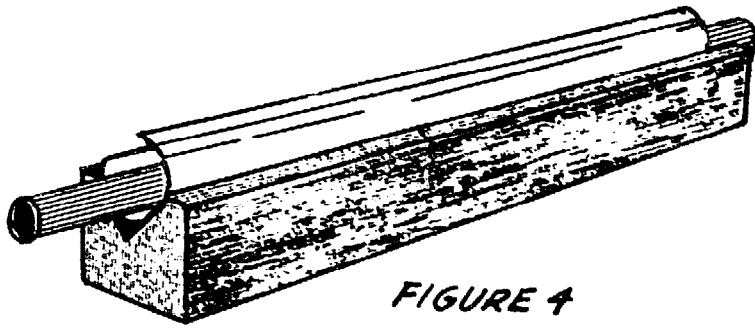


FIGURE 4



FIGURE 5

The lower end of the pipe was perforated with a hand drill to form a screen. After the casing was lowered to the bottom of the well, fine gravel was packed around the perforated portion of the casing to above the water level.

The cement grouting mortar which was used around the casings varied from pure cement to a 1:1 1/2 cement : sand ratio mixed with water to a very plastic consistency. The grout was put around the casing by gravity and a strip of bamboo about 10 meters (33 feet) long was used to "rod" the grout into place. A comparison of volume around the casing and volume of grouting used indicated that there may have been some voids left probably below the reach of the bamboo rod. These are not serious however, as long as a good seal is obtained for the first 8 to 10 meters (26 to 33 feet) down from the surface. In general, the greater proportion of cement used and the greater the space around the casing, the better seemed to be the results obtained. However, insufficient experience has been obtained to reach any final conclusions. In addition, economic considerations limit both of these factors.

Care must be taken in pouring the grout. In one case, two sections of

casing were not assembled perfectly straight: the casing, as a result, was not centered in the well, the pressure of the grouting was not equal all the way around, and the casing collapsed. With reasonable care, pouring the grout in several stages and allowing it to set in-between should eliminate this. The grouting, however, cannot be poured in too many stages because a considerable amount sticks to the sides of the well each time, reducing the space for successive pourings to pass through.

A proposed modification of the above method which has not yet been tried is as follows: In areas such as Ban Me Thuot, where the structure of the material through which the well is drilled is such that there is little or no danger of cave-in, the casing serves only one purpose, as a sanitary seal. It is therefore proposed that the well be cased only about 8 meters (26 feet) down from the ground surface. To do this, the well would be drilled to the desired depth with a diameter roughly the same as that of the casing. The well would then be reamed out to a diameter 5 to 6cm (2" to 2 1/4") larger than the casing down to the depth the casing will go. A flange fitted at the bottom of the casing with an outside diameter about equal to that of the reamed hole will center the casing in the hole and support the casing on the shoulder where the reaming stopped. Grouting would then be poured as in the original method. This modification would (1) save considerable costly material, (2) allow the well to be made a smaller diameter except near the top, (3) lessen grouting difficulties, and (4) still provide adequate protection against pollution.

#### Concrete Tile Casing

If the well is enlarged to an adequate diameter, precast concrete tile with suitable joints could be used as casing. This would require a device

for lowering the tile into the well one by one and releasing them at the bottom. Mortar would have to be used to seal the joints above the water level, the mortar being spread on each successive joint before it is lowered. Asbestos cement casing would also be a possibility where it was available with suitable joints.

### No Casing

The last possibility would be to use no casing at all. It is felt that when finances or skills do not permit the well to be cased, there are certain circumstances under which an uncased well would be superior to no well at all. This is particularly true in localities where the custom is to boil or make tea out of all water before drinking it, where sanitation is greatly hampered by insufficient water supply, and where small scale hand irrigation from wells can greatly improve the diet by making gardens possible in the dry season.

The danger of pollution in an uncased well can be minimized by: (1) choosing a favorable site for the well and (2) making a platform with a drain which leads away from the well, eliminating all spilled water.

Such a well should be tested frequently for pollution. If it is found unsafe, a notice to this effect should be posted conspicuously near the well.

### Well Platform

In the work in the Ban Me Thuot area, a flat 1.75 meter (5.7') square slab of concrete was used around each well. However, under village conditions, this did not work well. Large quantities of water were spilled, in part due to the enthusiasm of the villagers for having a plentiful water supply, and the areas around wells became quite muddy.

The conclusion was reached that the only really satisfactory platform would be a round, slightly convex one with a small gutter around the outer edge. The gutter should lead to a concreted drain which would take the water a considerable distance from the well.

If the well platform is too big and smooth, there is a great temptation on the part of the villagers to do their laundry and other washing around the well. This should be discouraged. In villages where animals run loose it is necessary to build a small fence around the well to keep out animals, especially poultry and pigs, which are very eager to get water, but tend to mess up the surroundings.

### Sources:

Explanatory Notes on Tubewells, by Wendell Mott, American Friends Service Committee, Philadelphia, Pennsylvania, 1956 (mimeo).

Report by Richard G. Koegel, International Voluntary Services, Ban Me Thuot, Vietnam, 1959 (mimeo).



## Hand-Operated Drilling Equipment

Two methods of drilling a shallow tubewell with hand-operated equipment are described here: Method A operates by turning an earth-boring auger; Method B uses a ramming action.

Method A was used by an American Friends Service Committee (AFSC) team in India; Method B was used by an International Voluntary Services (IVS) team in Vietnam.

### Method A

This simple hand-drilling rig was used by an American Friends Service Committee team in India to dig wells 15 to 20cm (6" to 8") in diameter up to 15 meters (50') deep.

### Tools and Materials

Earth auger, with coupling to attach to 2.5cm (1") drill line (see entry on tubewell earth augers)

Standard weight galvanized steel pipe:

#### For Drill Line:

4 pieces: 2.5cm (1") in diameter and 3 meters (10') long (2 pieces have threads on one end only; others need no threads.)

2 pieces: 2.5cm (1") in diameter and 107cm (3 1/2') long

#### For Turning Handle:

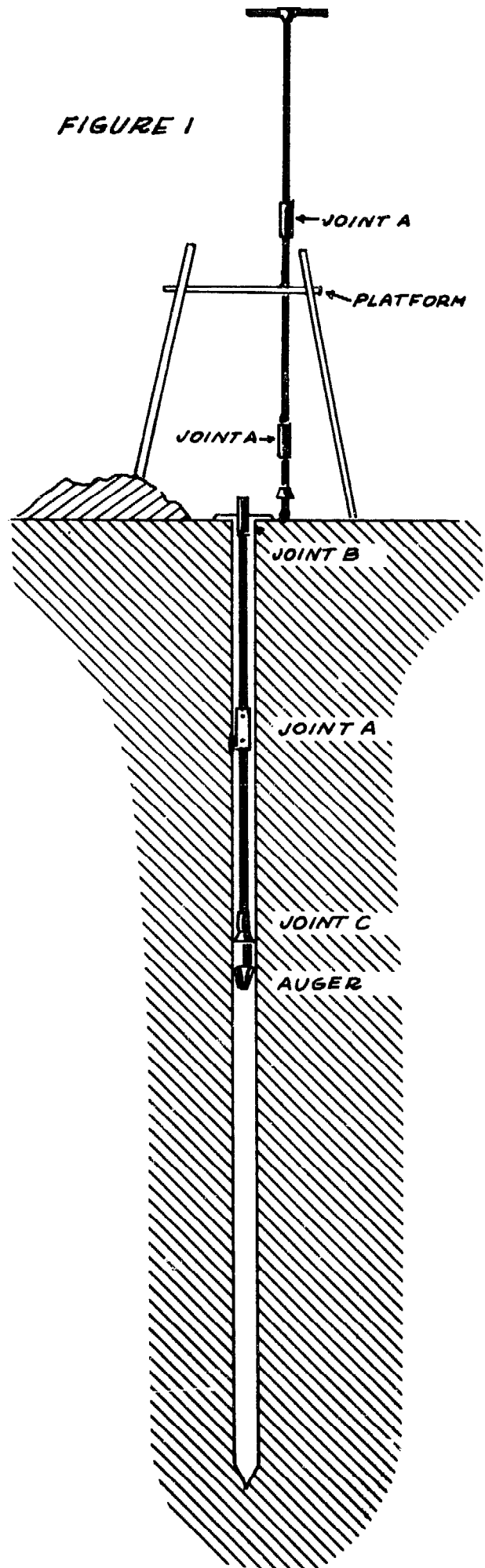
2 pieces: 2.5cm (1") in diameter and 61cm (2') long

2.5cm (1") T coupling

#### For Joint A:

4 pieces: 32mm (1 1/4") in diameter and 30cm (1') long

FIGURE 1



### Sections and Couplings for Joint B:

23cm (9") section of 32mm (1 1/4") diameter (threaded at one end only)

35.5cm (14") section of 38mm (1 1/2") diameter (threaded at one end only)

Reducer coupling: 32mm to 25mm (1 1/4" to 1")

Reducer coupling: 38mm to 25mm (1 1/2" to 1")

8 10mm (3/8") diameter hexagonal head machine

steel/bolts 45mm (1 3/4") long, with nuts

2 10mm (3/8") diameter hex head steel machine bolts 5cm (2") long, with nuts

9 10mm (3/8") steel hex nuts

### To Make Toggle Bolt:

1 3mm (1/8") diameter countersink head iron rivet 12.5mm (1/2")

1 1.5mm (1/16") sheet steel, 10mm (3/8") x 25mm (1")

Drills: 3mm (1/8"), 17.5mm (13/16"), 8.75mm (13/32")

Countersink

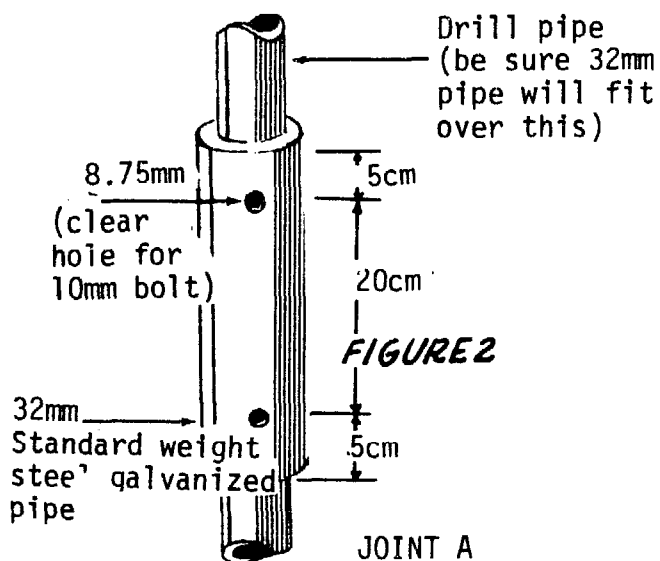
Thread cutting dies, unless pipe is already threaded

Small tools: wrenches, hammer, hacksaw, files

For platform: wood, nails, rope, ladder

Basically the method consists of rotating an ordinary earth auger. As the auger penetrates the earth, it fills with soil. When full it is

pulled out of the hole and emptied. As the hole gets deeper, more sections of drilling line are added to extend the shaft. Joint A in Figures 1 and 2 describe a simple method for attaching new sections.



By building an elevated platform 3 to 3.7 meters (10 to 12 feet) from the ground, a 7.6 meter (25 foot) long section of drill line can be balanced upright. Longer lengths are too difficult to handle. Therefore, when the hole gets deeper than 7.6 meters (25 feet), the drill line must be taken apart each time the auger is removed for emptying. Joint B makes this operation easier. See Figures 1 and 3.

Joint C (see construction details for Tubewell Earth Auger) is proposed to allow rapid emptying of the auger. Some soils respond well to drilling with an auger that has two sides open. These are very easy to empty, and would not require Joint C. Find out what kinds of augers are successfully used in your area, and do a bit of experimenting to find the one best suited to your soil. See the entries on augers.

Joint A has been found to be faster to use and more durable than pipe

threaded connectors. The pipe threads become damaged and dirty and are difficult to start. Heavy, expensive pipe wrenches get accidentally dropped into the well and are hard to get out. By using a sleeve pipe fastened with two 10mm (3/8") bolts, these troubles can be avoided. Neither a small bicycle wrench nor the inexpensive bolts will obstruct drilling if dropped in. Be sure the 32mm (1 1/4") pipe will fit over your 25mm (1") pipe drill line before purchase. See Figure 2.

Four 3 meter (10') sections and two 107cm (3 1/2') sections of pipe are the most convenient lengths for drilling a 15 meter (50') well. Drill an 8.75mm (13/32") diameter hole through each end of all sections of drill line except those attaching to Joint B and the turning handle which must be threaded joints. The holes should be 5cm (2") from the end.

When the well is deeper than 7.6 meters (25'), several features facilitate the emptying of the auger as shown in Figures 3 and 4. First the full auger is pulled up until Joint B appears at the surface. See Figure 4A. Then a 19mm (3/4") diameter rod is put through the hole. This allows the whole drill line to rest on it making it impossible for the part still in the well to fall in. Next remove the toggle bolt, lift out the top section of line and balance it beside the hole. See Figure 4B. Pull up the auger, empty it, and replace the section in the hole where it will be held by the 19mm (3/4") rod. See Figure 4C. Next replace the upper section of drill line. The 10mm (3/8") bolt acts as a stop which allows the holes to be easily lined up for reinsertion of the toggle bolt. Finally withdraw the rod and lower the auger for the next drilling. Mark the location for drilling the 8.75mm (13/32") diameter hole in the 32mm (1 1/4") pipe through the toggle bolt hole in the 38mm (1 1/2") pipe. If the hole is located with the 32mm (1 1/4") pipe resting on

the stop bolt, the holes are bound to line up.

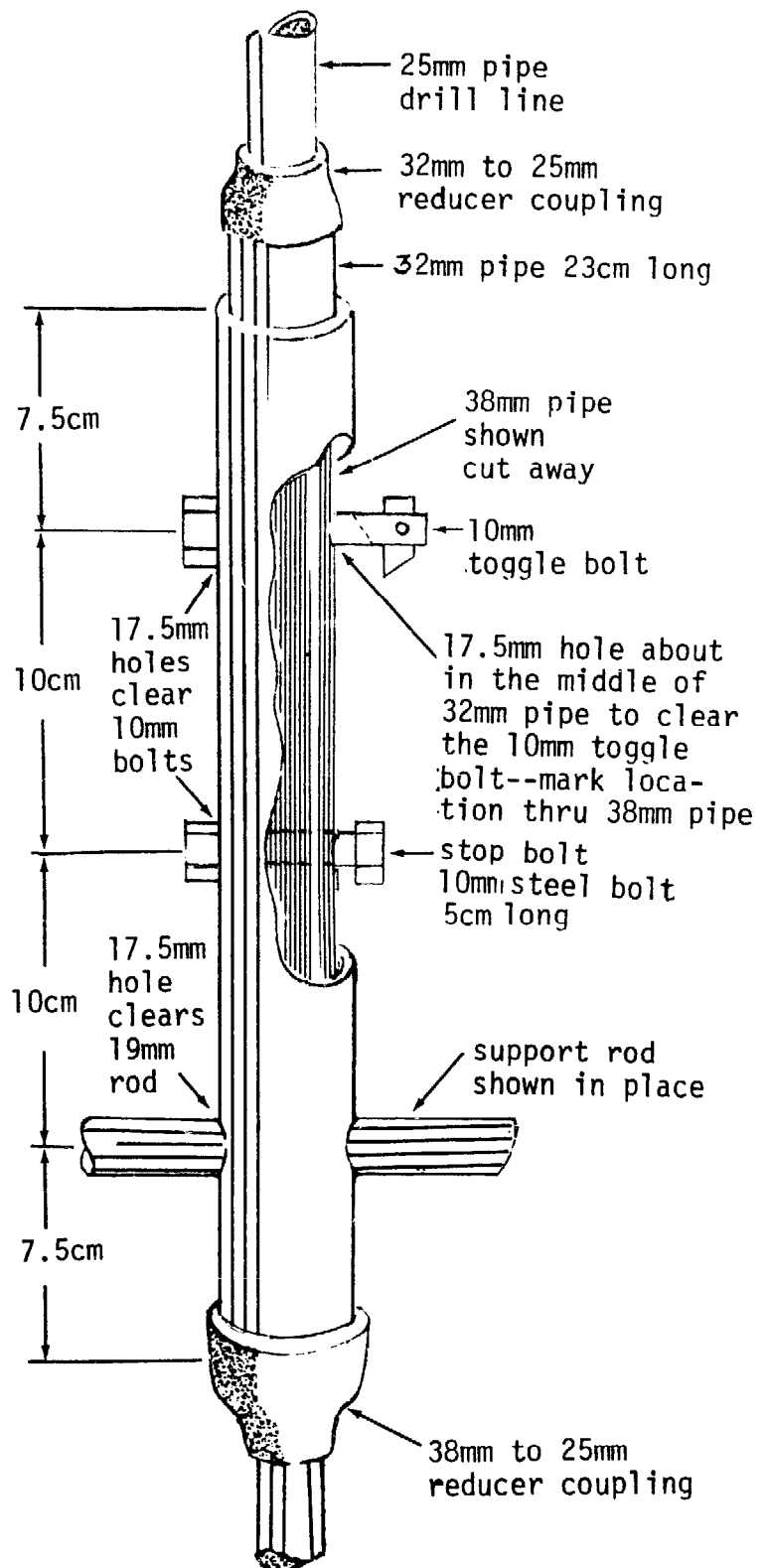


FIG. 3 JOINT B

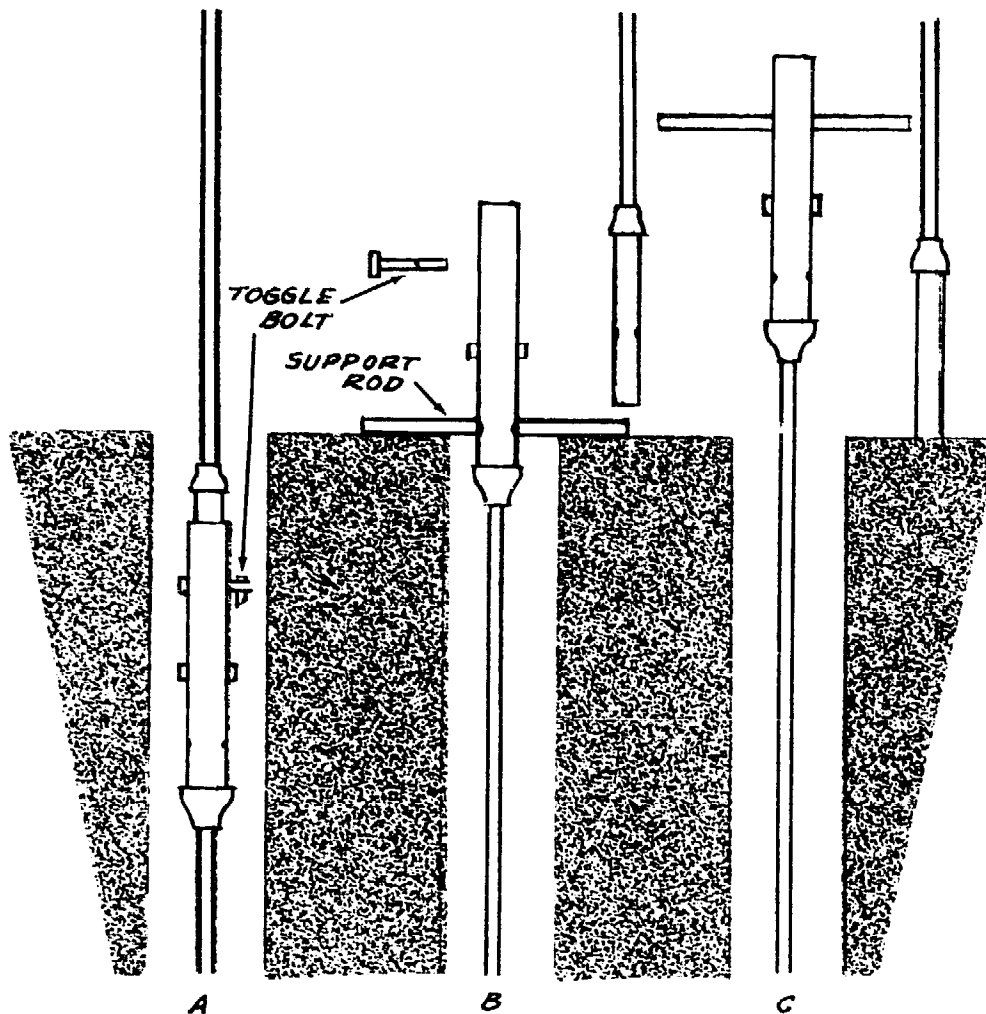


FIGURE 4 JOINT B IN OPERATION

Sometimes a special tool is needed to penetrate a water-bearing sand layer, because the wet sand caves in as soon as the auger is removed. If this happens a perforated casing is lowered into the well, and drilling is accomplished with an auger that fits inside the casing. A percussion type with a flap, or a rotary type with solid walls and a flap are good possibilities.

See the entries describing these devices. The casing will settle deeper into the sand as sand is dug from beneath it. Other sections of casing must be added as drilling proceeds. Try to penetrate the water bearing sand layer as far as possible, (at least 3 feet). Ten feet of perforated casing embedded in such a sandy layer will provide a very good flow of water.

## Tubewell Earth Auger

This earth auger is made from a 15cm (6") steel tube. Similar devices have long been used with power drilling equipment, but this particular design needs field trial (see Figure 5).



**FIGURE 5**  
**TUBEWELL EARTH AUGER**

This auger can be made without welding equipment, but some of the bends in the pipe and the bar can be made much more easily when the metal is hot (see Figure 6).

An open earth auger, which is easier to empty than this one, is better suited for some soils. This auger cuts faster than the Tubewell Sand Auger.

## Tools and Materials

Galvanized pipe: 32mm (1 1/4") in diameter and 21.5cm (8 1/2") long

Hexagonal head steel bolt: 10mm (3/8") in diameter and 5cm (2") long, with nut

2 hex. head steel bolts: 10mm (3/8") in diameter and 9.5cm (3 3/4") long

2 Steel bars: 1.25cm x 32mm x 236.5mm (1/2" x 1 1/4" x 9 5/16")

4 Round head machine screws: 10mm (3/8") in diameter and 32mm (1 1/4") long

2 flat head iron rivets: 3mm (1/8") in diameter and 12.5mm (1/2") long

Steel strip: 10mm x 1.5mm x 2.5cm (3/8" x 1/16" x 1")

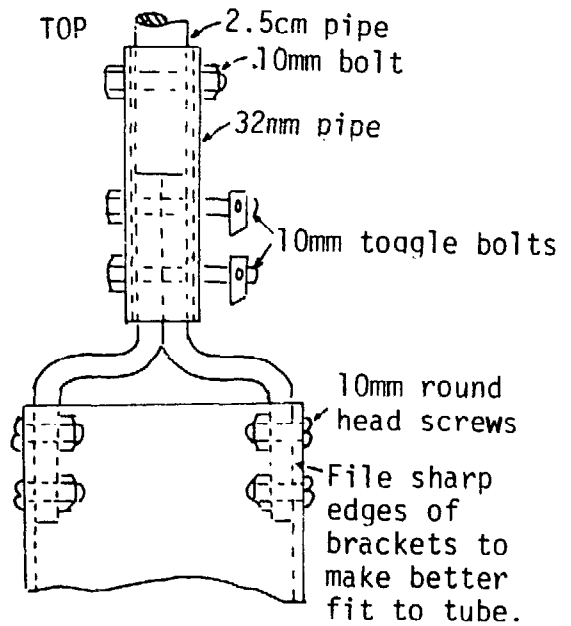
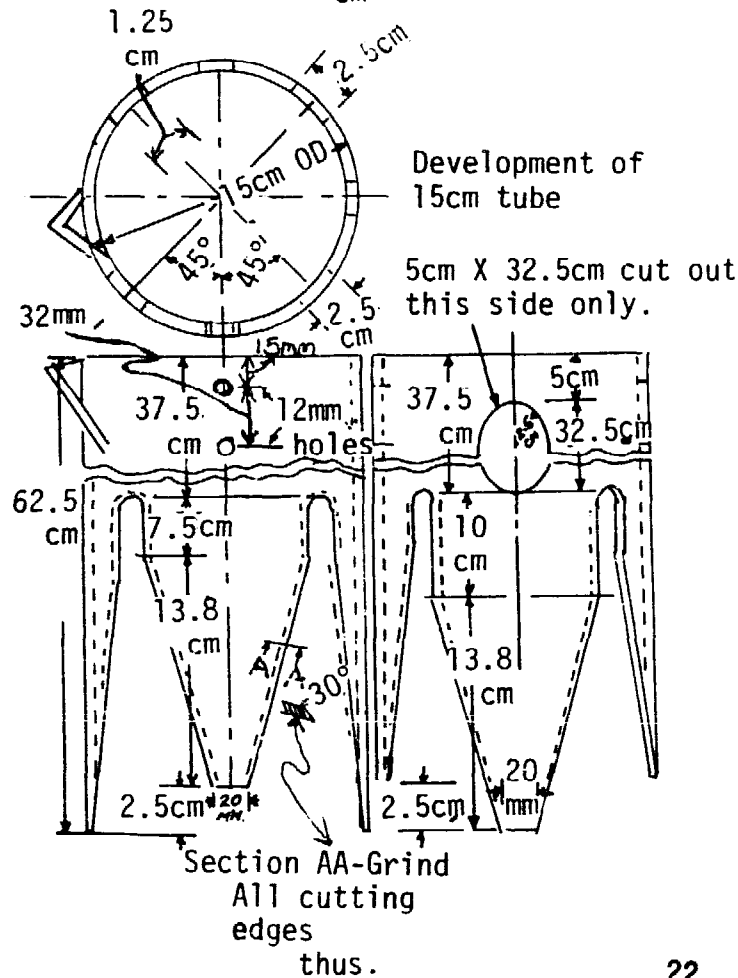
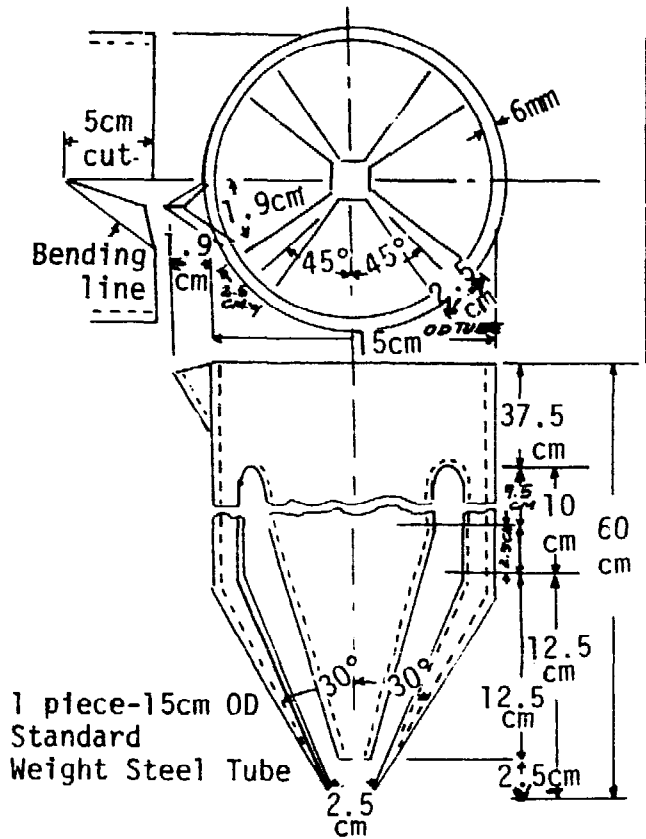
Steel tube: 15cm (6") outside diameter, 62.5cm (24 5/8") long

Hand tools

Source:

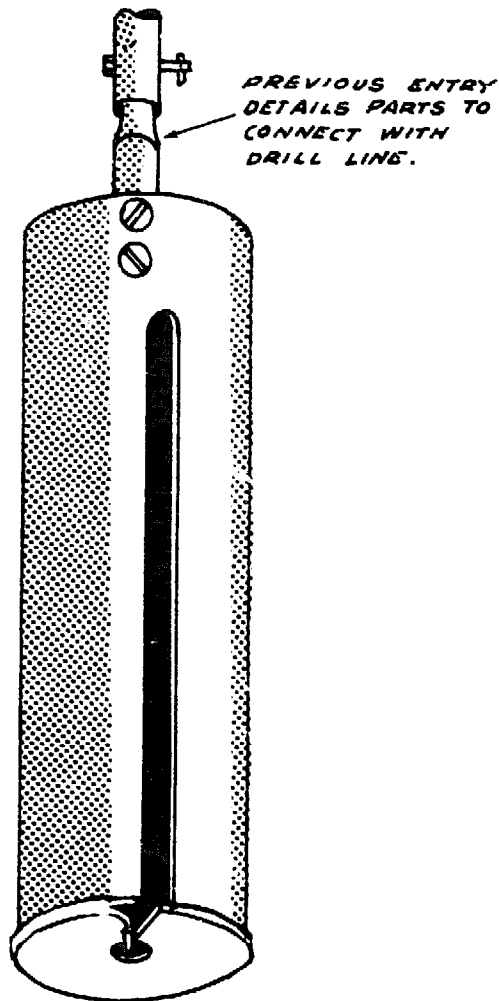
Wells, Technical Manual 5-297, AFM 85-23, U.S. Army and Air Force, 1957.

FIGURE 6



## Tubewell Sand Auger

This sand auger can be used to drill in loose soil or wet sand, where an earth auger is not so effective. The simple cutting head requires less force to turn than the "Tubewell Earth Auger," but it is more difficult to empty.



**FIGURE 7**  
**TUBEWELL SAND AUGER**

A smaller version of the sand auger made to fit inside the casing pipe can be used to remove loose, wet sand.

This design needs field trial, although similar devices have long been used with power drilling equipment.

## Tools and Materials

Steel tube: 15cm (6") outside diameter and 46cm (18") long

Steel plate: 5mm x 16.5cm x 16.5cm  
(3/16" x 6 1/2" x 6 1/2")

Acetylene welding and cutting equipment

Drill

Source:

Wells, Technical Manual 5-297, AFM 85-23, U.S. Army and Air Force, 1957.

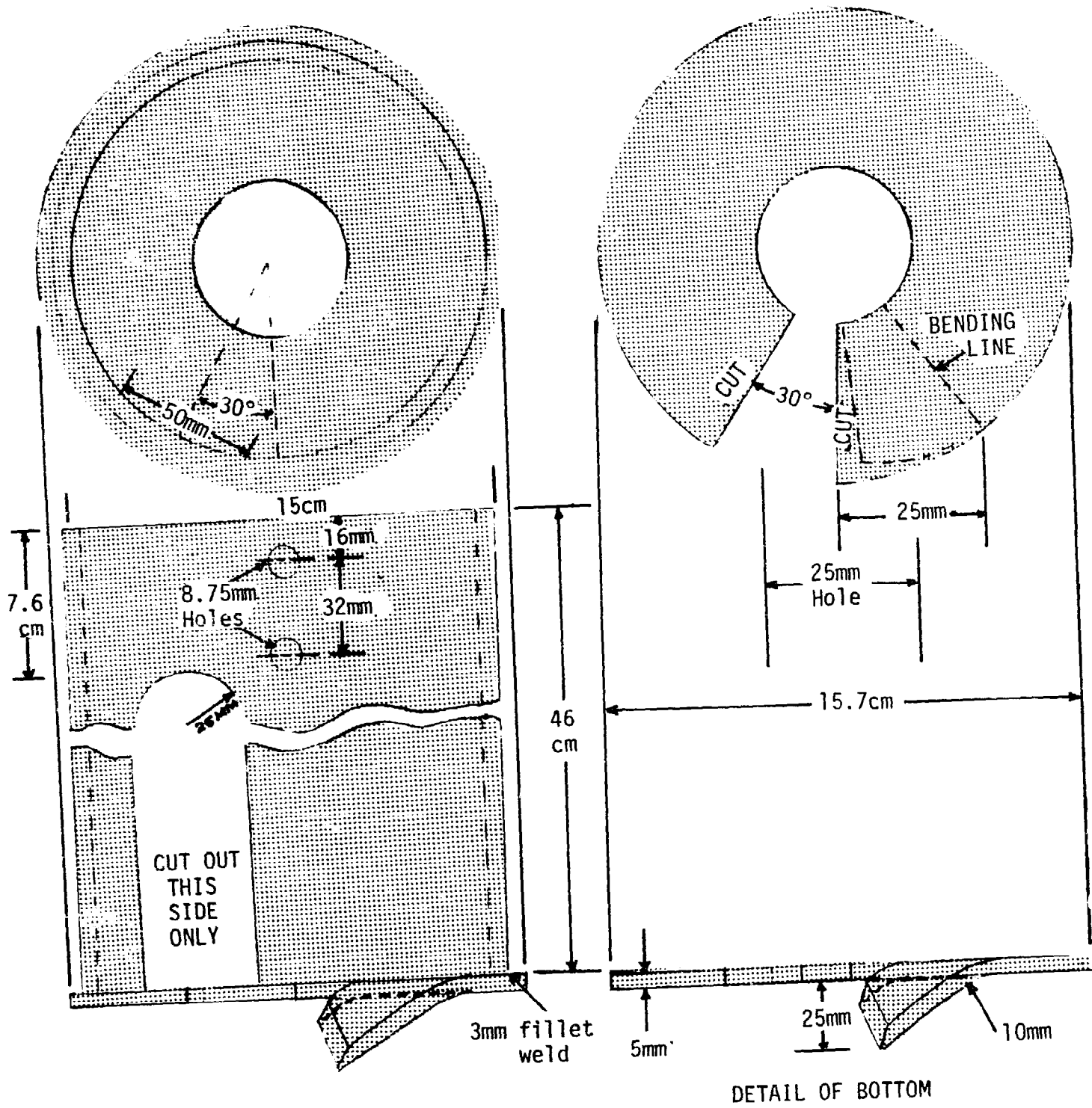


FIGURE 8



## Tubewell Sand Bailer

The sand bailer can be used to drill from inside a perforated well casing when a bore goes into loose wet sand and the walls start to cave in. It has been used in making many tubewells in India.

### Tools and Materials

Steel tube: 12.5cm (5") in diameter and 91.5cm (3') long

Truck innertube or leather: 12.5cm (5") square

Pipe coupling: 15cm to 2.5cm (5" to 1")

Small tools

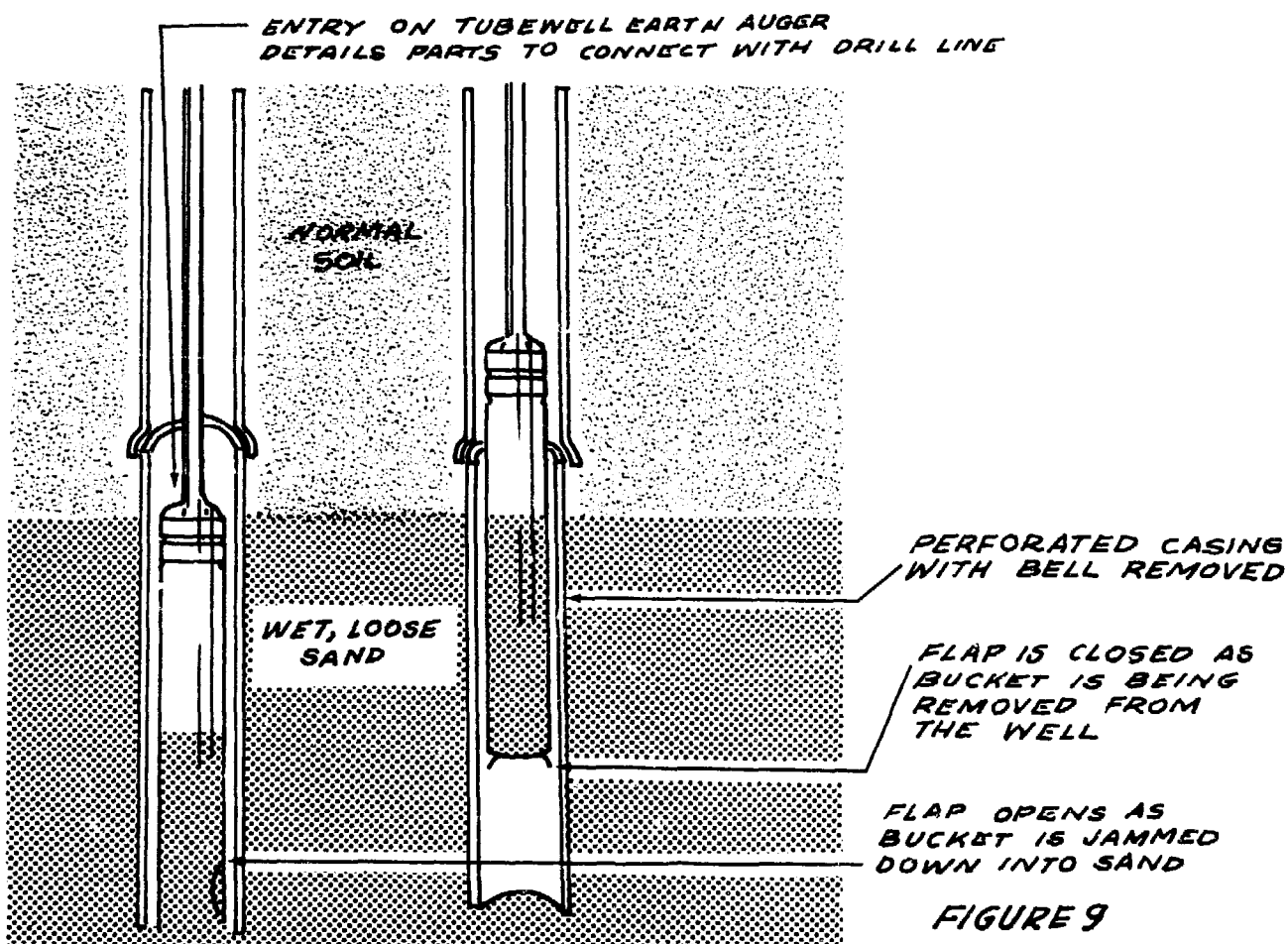
By repeatedly jamming this "bucket" into the well, sand will be removed from below the perforated casing allow-

ing it to settle deeper into the sand layer. The casing prevents the walls from caving in. The bell is removed from the first section of casing; at least one other section rests on top of it to help force it down as digging proceeds. Try to penetrate the water bearing sand layer as far as possible: 3 meters (10') of perforated casing embedded in such a sandy layer will usually provide a very good flow of water.

Be sure to try your sand "bucket" in wet sand before attempting to use it at the bottom of your well.

Source:

Explanatory Notes on Tubewells, by Wendell Mott, American Friends Service Committee, Philadelphia, Pennsylvania, 1956 (mimeo).



USING A SAND BAILER TO DRILL FROM INSIDE A WELL CASING

## Method B

The equipment described here has been used successfully in the Ban Me Thuot area of Vietnam. One of the best performances was turned in by a crew of three inexperienced mountain tribesmen who drilled 20 meters (65') in a day and a half. The deepest well drilled was a little more than 25 meters (80'); it was completed, including the installation of the pump, in six days. One well was drilled through about 11 meters (35') of sedimentary stone.

The cost of the equipment, excluding labor, was U.S. \$35.19 in 1957 in Vietnam.

## Tools and Materials

### For tool tray:

Wood: 3cm x 3cm x 150cm (1 1/4" x 1 1/4" x 59")

Wood: 3cm x 30cm x 45cm (1 1/4" x 12" x 17 3/4")

### For safety rod:

Steel rod: 1cm (3/8") in diameter, 30cm (12") long

Drill

Hammer

Anvil

Cotter pin

### For auger support:

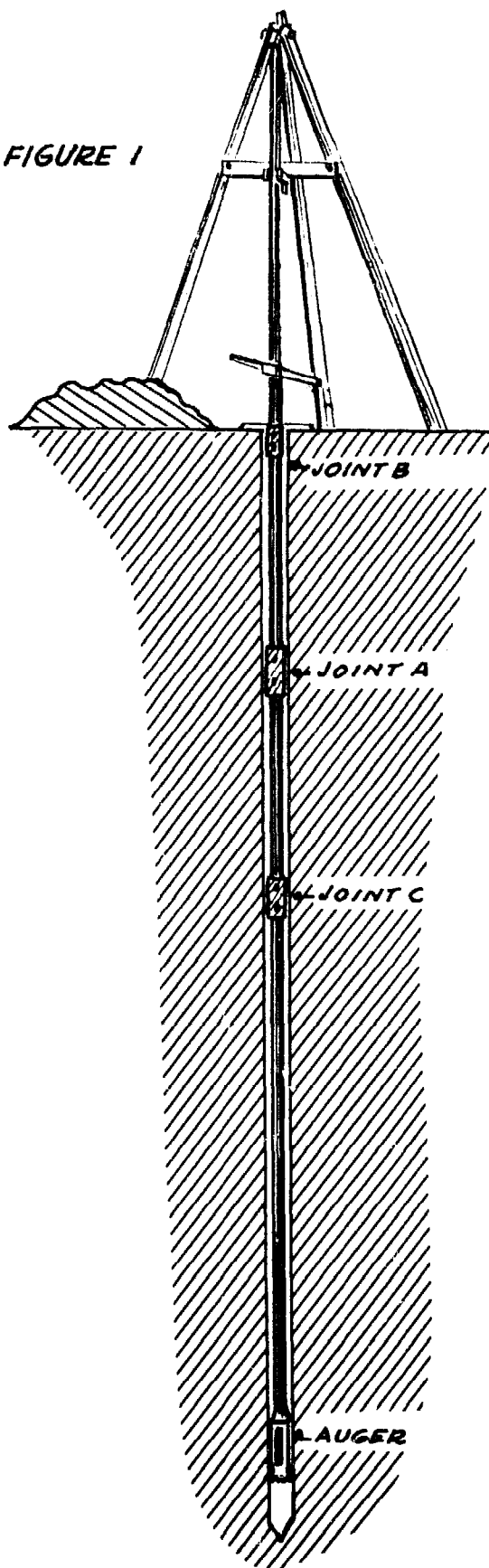
Wood: 4cm x 45cm x 30cm  
(1 1/2" x 17 3/4" x 12")

Steel: 10cm x 10cm x 4mm  
(4" x 4" x 5/32")

## Location of the Well

Two considerations are especially important for the location of village

FIGURE 1



wells: (1) the average walking distance for the village population should be as short as possible; (2) it should be easy to drain spilled water away from the site to avoid creating a mud-hole.

In the Ban Me Thuot area, the final choice of location was in all cases left up to the villagers. Water was found in varying quantities at all the sites chosen. (See "Getting Ground Water from Wells and Springs.")

### Starting to Drill

A tripod is set up over the approximate location for the well (see Figure 1). Its legs are set into shallow holes with dirt packed around them to keep them from moving. To make sure the well is started exactly vertically, a plumb bob (a string with a stone tied to it is good enough) is then hung from the auger guide on the tripod's crossbar to locate the exact starting point. It is helpful to dip a small starting hole before setting up the auger.

### Drilling

Drilling is accomplished by ramming the auger down to penetrate the earth and then rotating it by its wooden handle to free it in the hole before lifting it to repeat the process. This is a little awkward until the auger is down 30cm to 60cm (1' to 2') and should be done carefully until the auger starts to be guided by the hole itself. Usually two or three men work together with the auger. One system which worked out quite well was to use three men, two working while the third rested, and then alternate.

As the auger goes deeper it will be necessary from time to time to adjust the handle to the most convenient height. Any wrenches or other small tools used should be tied by means of a long piece of cord to the tripod so that if they are accidentally dropped

in the well, they can easily be removed. Since the soil of the Ban Me Thuot area would stick to the auger, it was necessary to keep a small amount of water in the hole at all times for lubrication.

### Emptying the Auger:

Each time the auger is rammed down and rotated, it should be noted how much penetration has been obtained. Starting with an empty auger the penetration is greatest on the first stroke and becomes successively less on each following one as the earth packs more and more tightly inside the auger. When progress becomes too slow it is time to raise the auger to the surface and empty it. Depending on the material being penetrated, the auger may be completely full or have 30cm (1') or less of material in it when it is emptied. A little experience will give one a "feel" for the most efficient time to bring up the auger

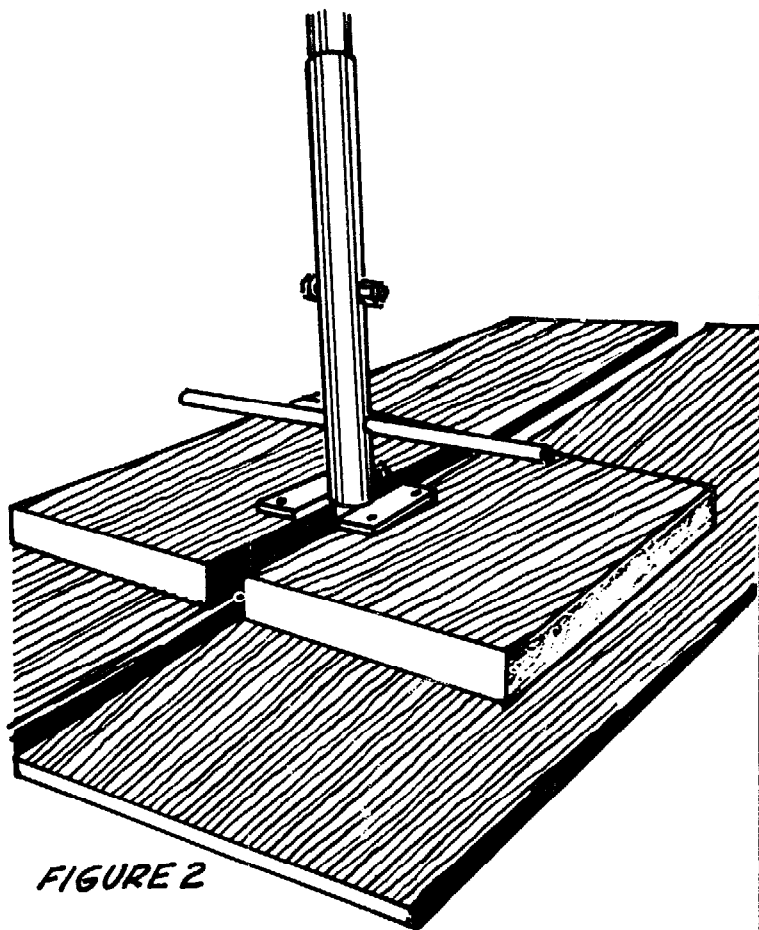


FIGURE 2

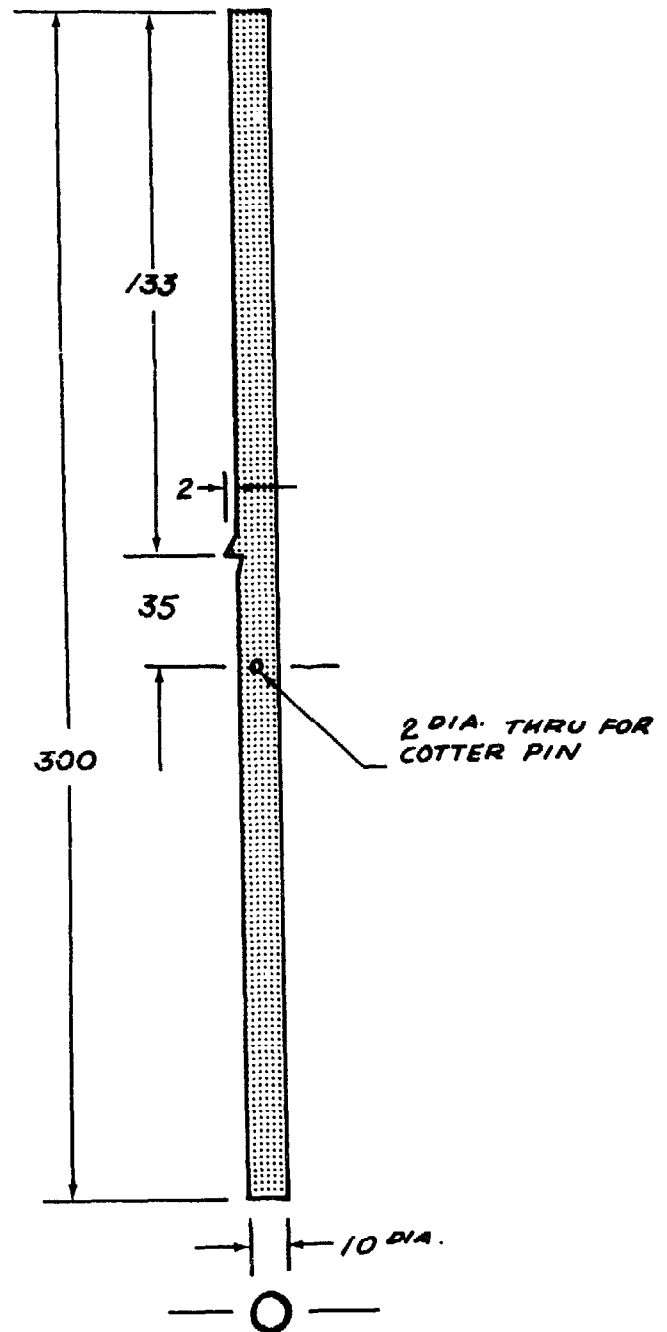
for emptying. Since the material in the auger is hardest packed at the bottom, it is usually easiest to empty the auger by inserting the auger cleaner through the slot in the side of the auger partway down and pushing the material out through the top of the auger in several passes. When the auger is brought out of the hole for emptying, it is usually leaned up against the tripod, since this is faster and easier than trying to lay it down.

### Coupling and Uncoupling Extensions

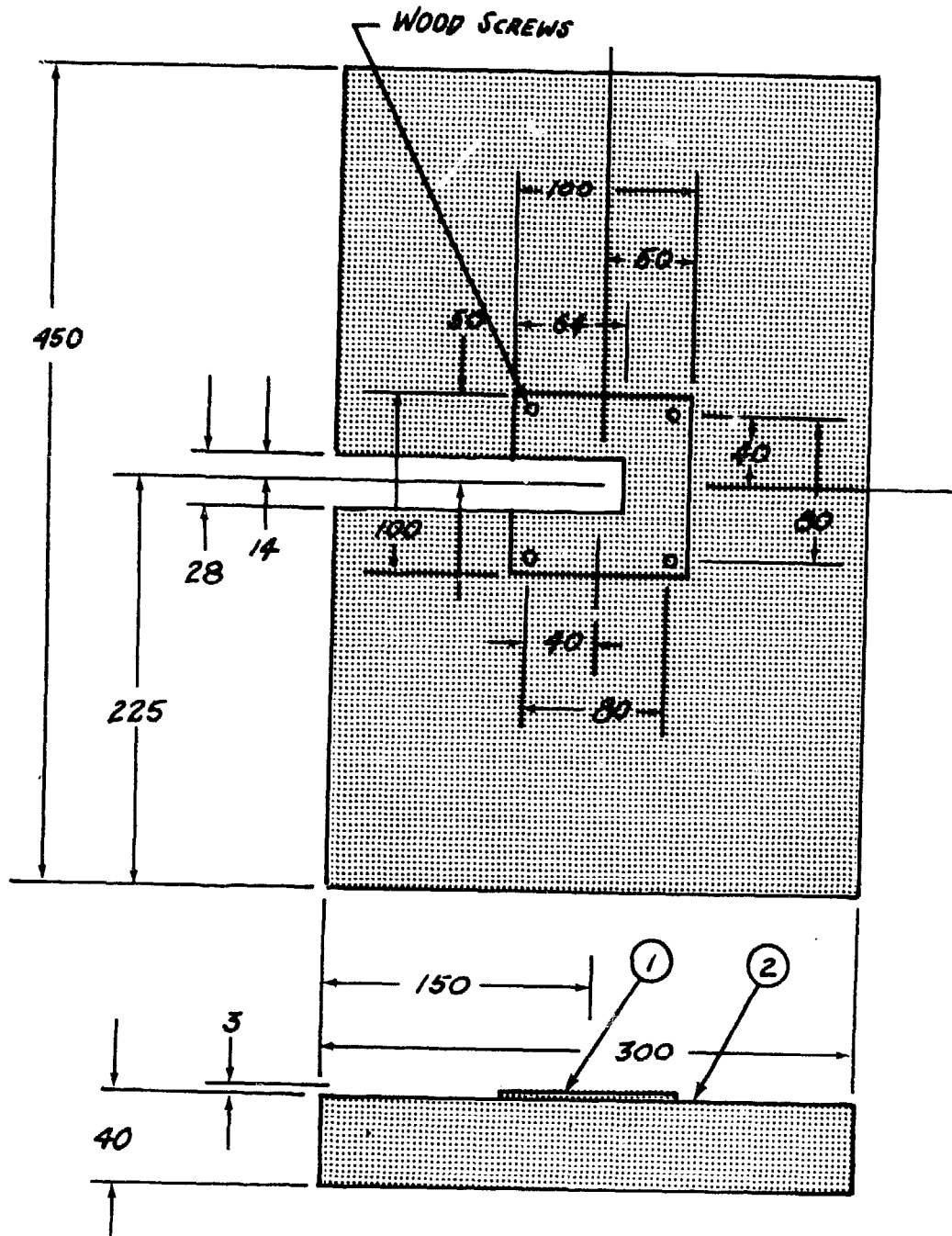
The extensions are coupled by merely slipping the small end of one into the large end of the other and pinning them together with a 10mm (3/8") bolt. It has been found sufficient and time-saving to just tighten the nut finger-tight instead of using a wrench.

Each time the auger is brought up for emptying, the extensions must be taken apart. For this reason the extensions have been made as long as possible to minimize the number of joints. Thus at a depth of 18.3 meters (60'), there are only two joints to be uncoupled in bringing up the auger.

For the sake of both safety and speed, use the following procedure in coupling and uncoupling. When bringing up the auger, raise it until a joint is just above the ground and slip the auger support (see Figures 2 and 3) into place, straddling the extension so that the bottom of the coupling can rest on the small metal plate. The next step is to put the safety rod (see Figure 4) through the lower side in the coupling and secure it with either a cotter pin or a piece of wire. The purpose of the safety rod is to keep the auger from falling into the well if it should be knocked off the auger support or dropped while being raised.



**FIGURE 4 SAFETY ROD**  
SCALE: 1/2 SIZE MATL: MILD STEEL

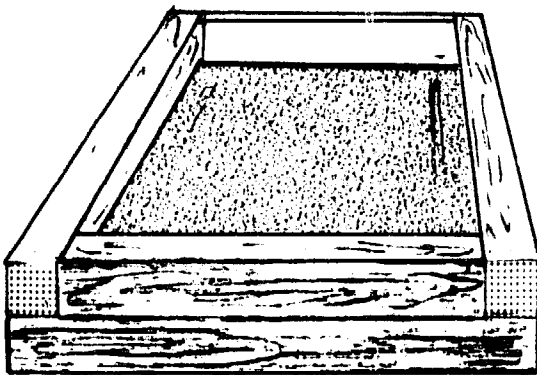


**FIGURE 3 - AUGER SUPPORT**

SCALE: 1/4 SIZE MAT'L: (1) MILD STEEL  
 (2) HARDWOOD

Once the safety rod is in place, remove the coupling bolt and slip the upper extension out of the lower. Lean the upper end of the extension against the tripod between the two wooden pegs in the front legs, and rest the lower end in the tool tray (see Figures 5 and 6). The reason for setting the extensions in the tool tray is to keep dirt from sticking to the lower ends and making it difficult to put the extensions together and take them apart.

To couple the extensions after emptying the auger, the procedure is the exact reverse of uncoupling.



*FIGURE 5 TOOL TRAY*

### Drilling Rock

When stone or other substances which the auger cannot penetrate are met, a heavy drilling bit must be used.

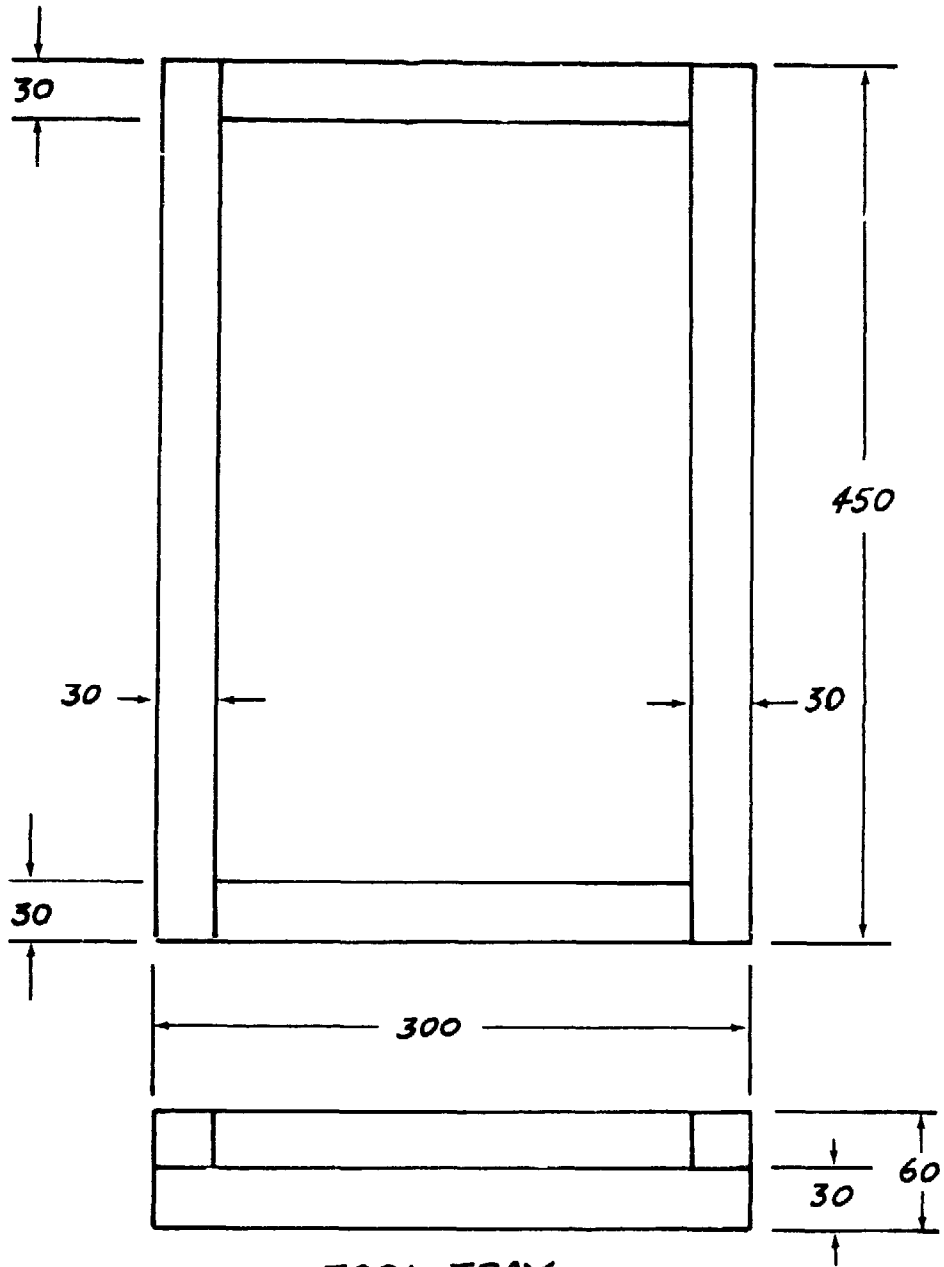
### Depth of Well

The rate at which water can be taken from a well is roughly proportional to the depth of the well below the water table as long as it keeps going into water-bearing ground. However, in village wells where water can only be raised slowly by hand pump or bucket, this is not usually of major importance. The important point is that in areas where the water table varies from one time of year to the next the well must be deep enough to give sufficient water at all times.

Information on the water table variation may be obtained from already existing wells, or it may be necessary to drill a well before any information can be obtained. In the latter case the well must be deep enough to allow for a drop in the water table.

### Sources:

Report by Richard G. Koegel, International Voluntary Services, Ban Me Thuot, Vietnam, 1959 (mimeo).



**TOOL TRAY**

SCALE: 1/4 SIZE MAT'L: WOOD

**FIGURE 6**

## Equipment

The following section gives construction details for the equipment used with Method B for well-drilling:

1. Auger, Extensions and Handle
2. Auger Cleaner
3. Demountable Reamer
4. Tripod and Pulley
5. Bailing Bucket
6. Bit for Drilling Rock

### Auger, Extensions and Handle

The auger is hacksawed out of standard-weight steel pipe about 10cm (4") in diameter (see Figure 8). Light-weight tubing is not strong enough. The extensions (see Figure 9) and handle (see Figure 10) make it possible to bore deep holes.

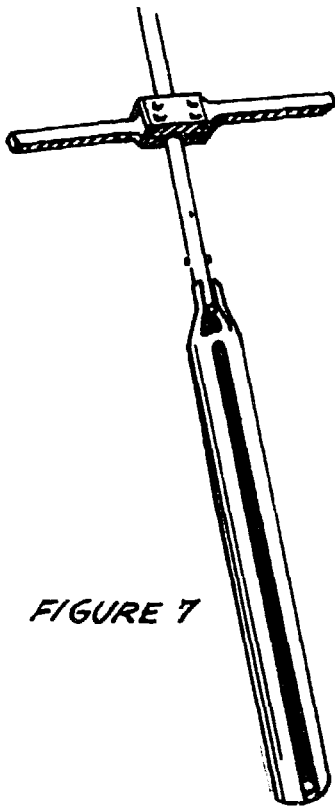


FIGURE 7

## Tools and Materials

Pipe: 10cm (4") in diameter, 120cm (47 1/4") long, for auger

Pipe: 34mm outside diameter (1" inside diameter); 3 or 4 pieces 30cm (12") long, for auger and extension socket

Pipe: 26mm outside diameter (3/4" inside diameter); 3 or 4 pieces 6.1 or 6.4 meters (20' or 21') long, for drill extensions

Pipe: 18mm outside diameter (1/2" inside diameter); 3 or 4 pieces 6cm (2 3/8") long

Hardwood: 4cm x 8cm x 50cm (1 1/2" x 3 1/8" x 19 3/4"), for handle

Mild steel: 3mm x 8cm x 15cm (1/8" x 3 1/8" x 6")

4 bolts: 1cm (3/8") in diameter and 10cm (4") long

4 Nuts

Hand tools and welding equipment

In making the auger, a flared-tooth cutting edge is cut in one end of the 10cm pipe. The other end is cut, bent and welded to a section of 34mm outside-diameter (1" inside-diameter) pipe, which forms a socket for the drill line extensions. A slot which runs nearly the length of the auger is used for removing soil from the auger. Bends are made stronger and more easily and accurately when the steel is hot. At first, an auger with two cutting lips similar to a post-hole auger was used; but it became plugged up and did not cut cleanly. In some soils, this type of auger may be more effective.



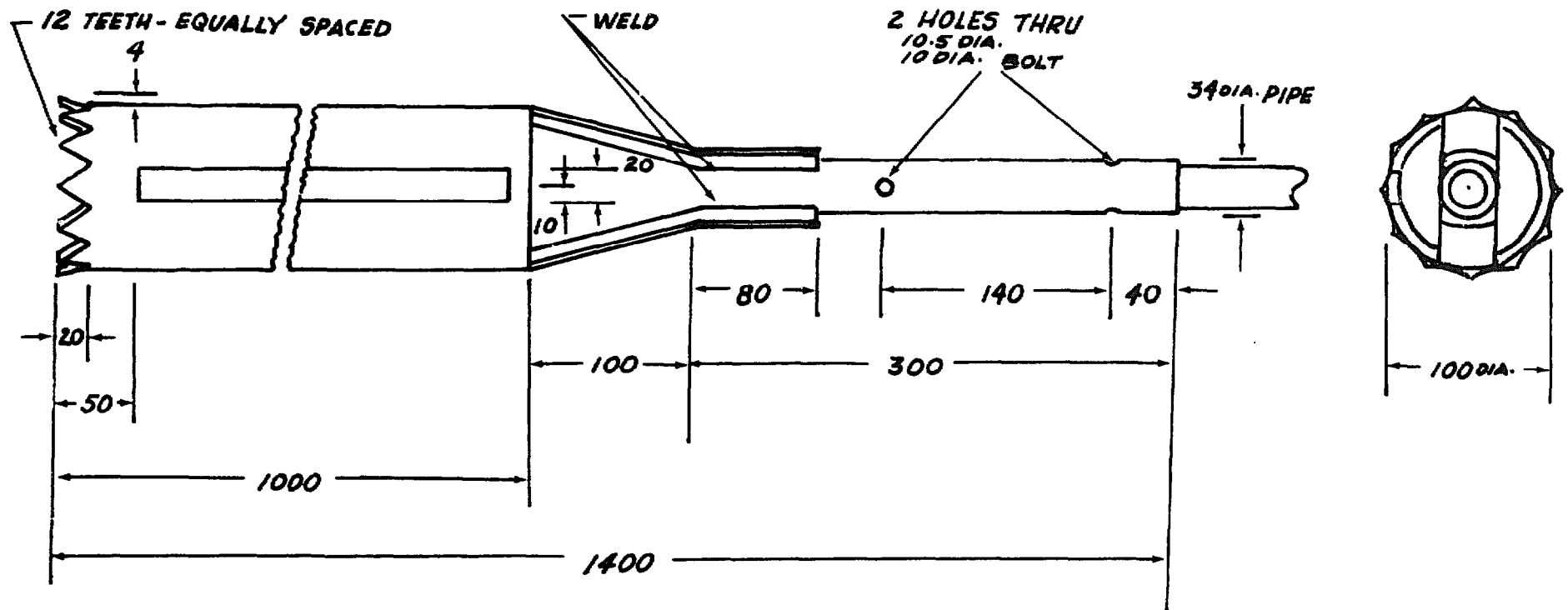
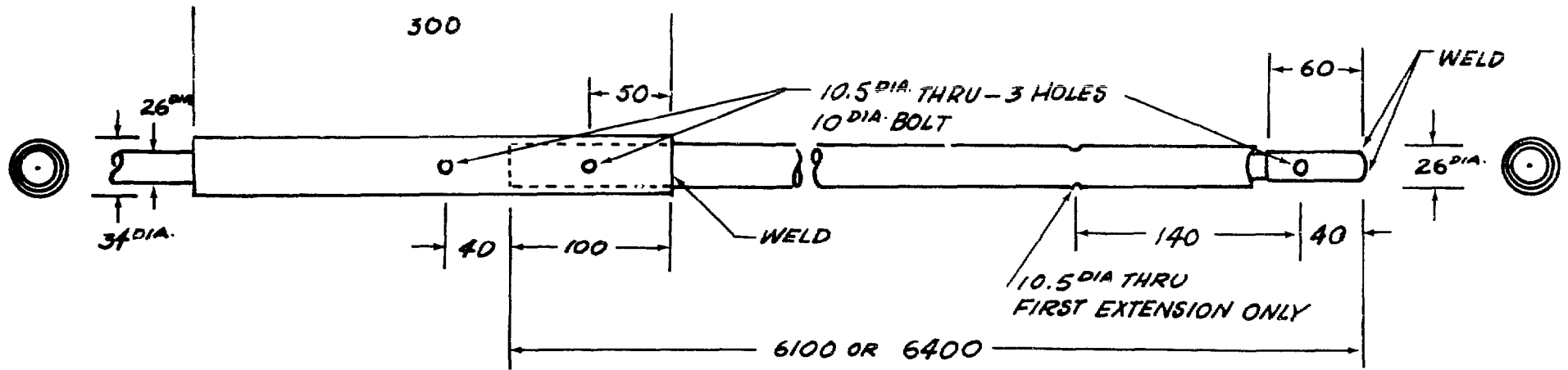


FIGURE 8, CUTTING HEAD, WELL DRILLING AUGER

SCALE:  $\frac{1}{4}$  SIZE MAT'L: MILD STEEL



**FIGURE 9 EXTENSION, WELL DRILLING AUGER**

SCALE: 1/4 SIZE MAT'L: MILD STEEL

NOTE: 3 1/4" DIA. COUPLING MAY BE OMITTED ON LAST EXTENSION

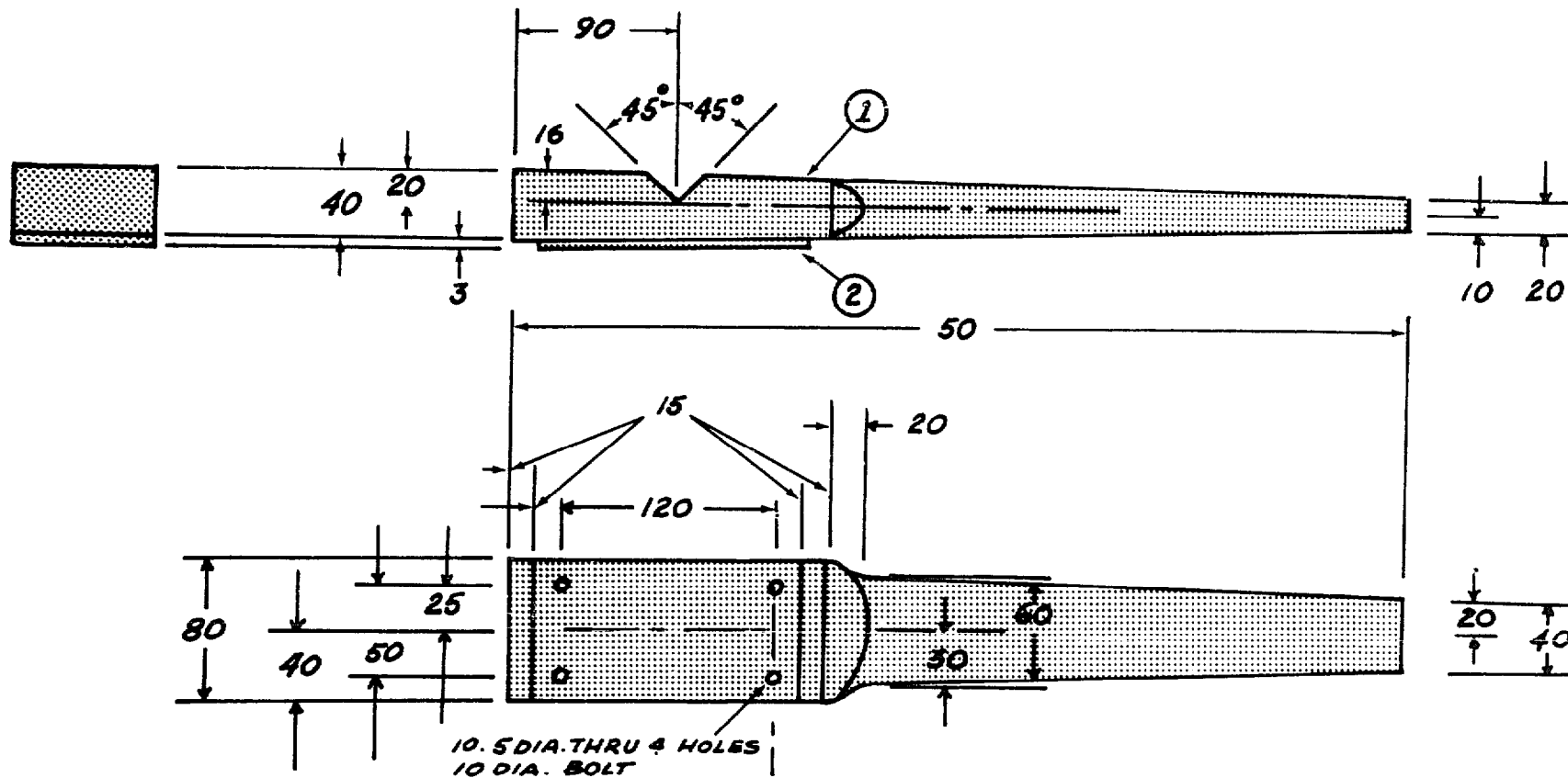


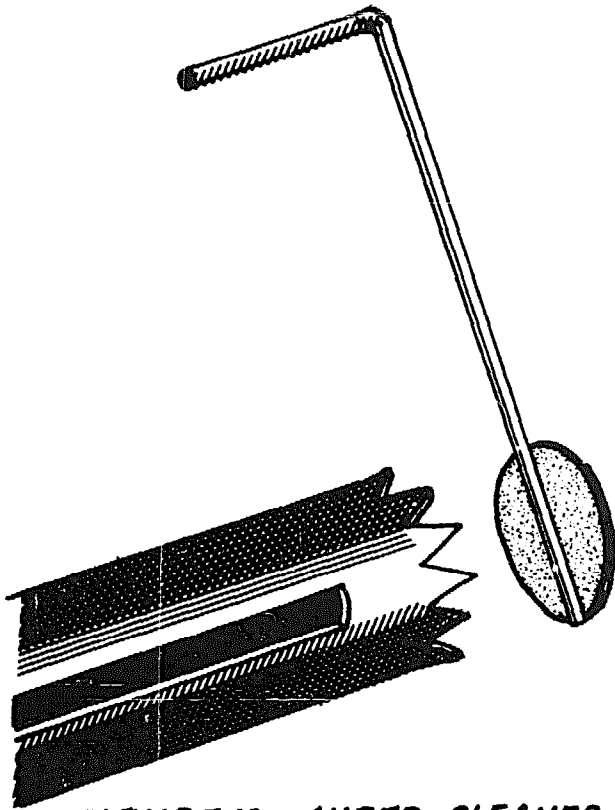
FIGURE 10, HANDLE, WELL DRILLING AUGER

NOTE: 2 REQUIRED PER SET

SCALE: 1/4 SIZE MAT'L: (1) HARDWOOD  
(2) MILD STEEL

## Auger Cleaner

Soil can be removed rapidly from the auger with this auger cleaner (see Figure 11). Figure 12 gives construction details.



**FIGURE 11 AUGER CLEANER**

### Tools and Materials

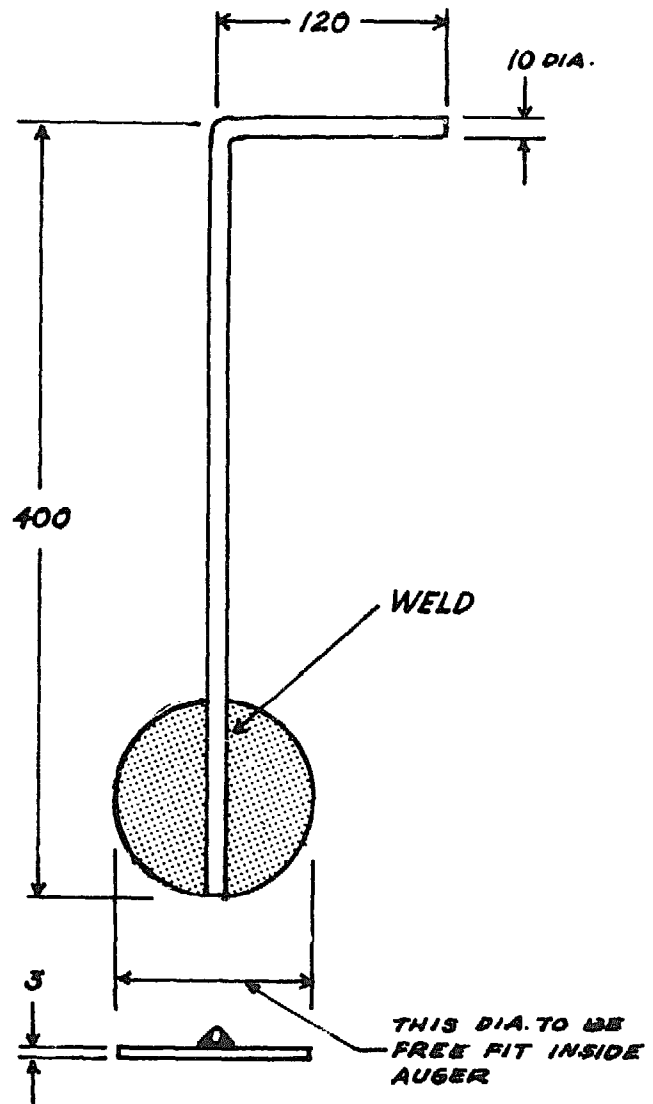
Mild steel: 10cm (4") square and 3mm (1/8") thick

Steel rod: 1cm (3/8") in diameter and 52cm (20 1/2") long

Welding equipment

Hacksaw

File



**FIGURE 12**

SCALE: 1/4 SIZE MAT'L: MILD STEEL

## Demountable Reamer

If the diameter of a drilled hole has to be made bigger, the demountable reamer described here can be attached to the auger.

### Tools and Materials

Mild steel: 20cm x 5cm x 6mm (8" x 2" x 1/4"), to ream a well diameter of 19cm (7 1/2")

2 Bolts: 8mm (5/16") in diameter and 10cm (4") long

Hacksaw

Drill

File

Hammer

Vise

The reamer is mounted to the top of the auger with two hook bolts (see Figure 13). It is made from a piece of steel 1cm (1/2") larger than the desired well diameter (see Figure 14).

After the reamer is attached to the top of the auger, the bottom of the auger is plugged with some mud or a piece of wood to hold the cuttings inside the auger.

In reaming, the auger is rotated with only slight downward pressure. It should be emptied before it is too full so that not too many cuttings will fall to the bottom of the well when the auger is pulled up.

Because the depth of a well is more important than the diameter in determining the flow and because doubling the diameter means removing four times the amount of earth, larger diameters should be considered only under special

circumstances. (See "Well Casing and Platforms," page 12.)

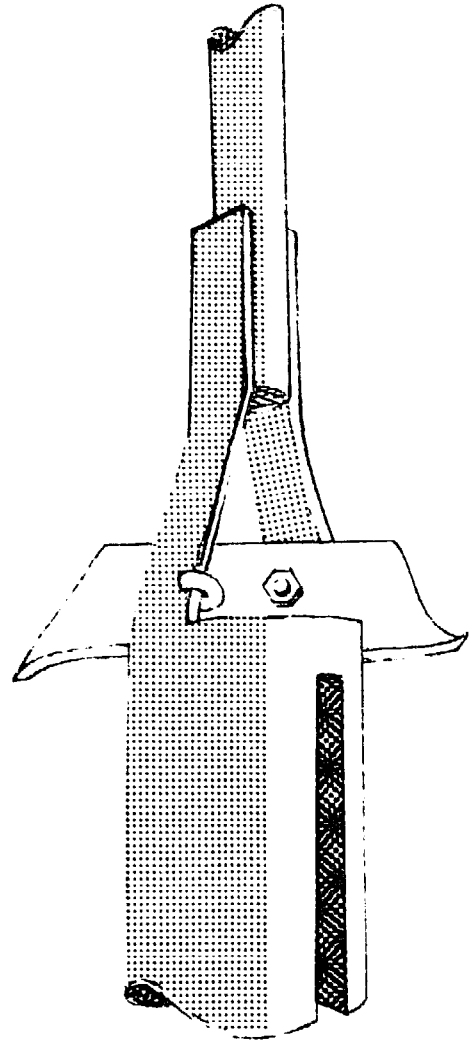
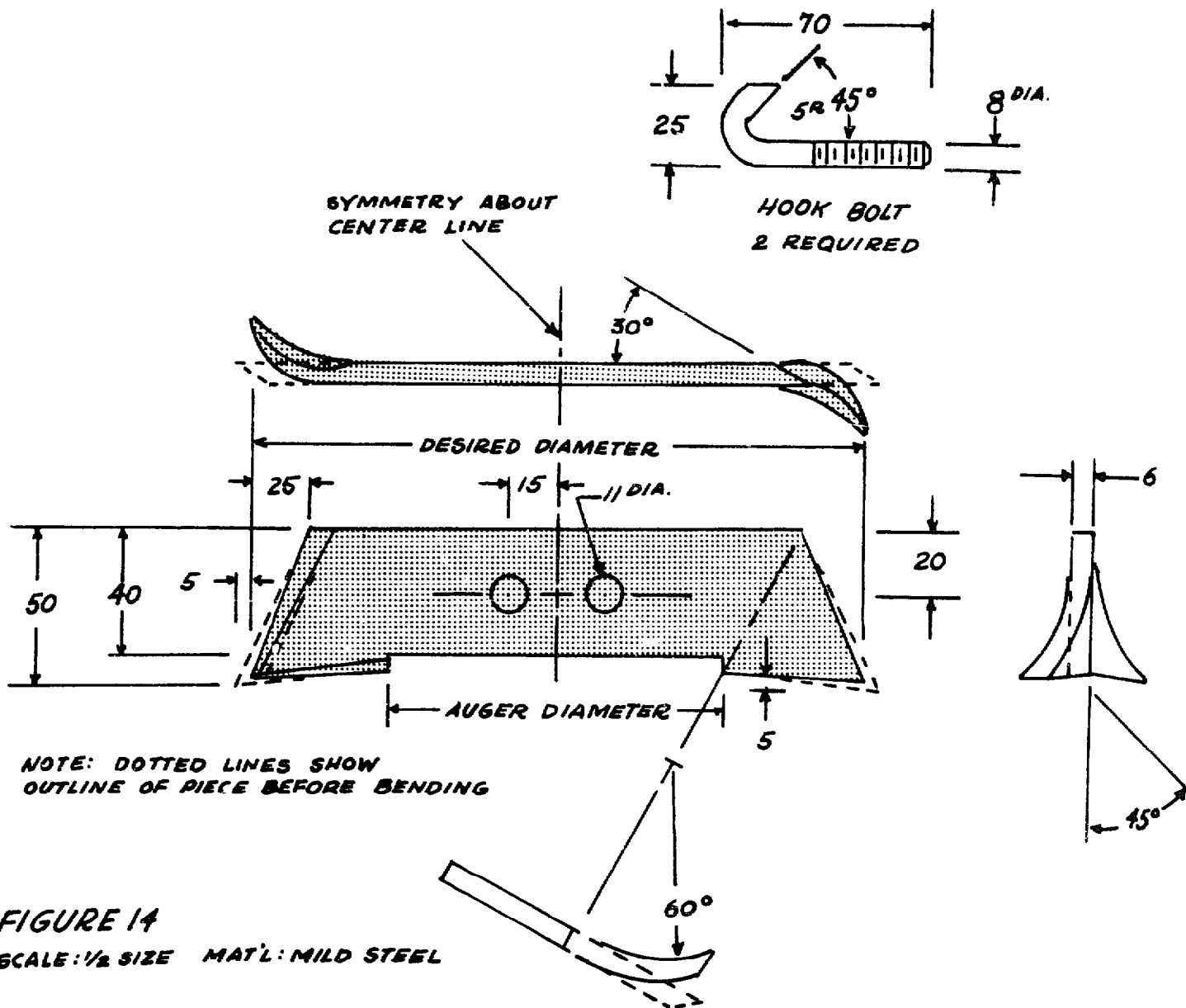


FIGURE 13



## Tripod and Pulley

The tripod (see Figures 15 and 16), which is made of poles and assembled with 16mm (5/8") bolts, serves three purposes: (1) to steady the extension of the auger when it extends far above ground; (2) to provide a mounting for the pulley (see Figures 17 and 19) used with the drill bit and bailing bucket; and (3) to provide a place for leaning long pieces of casing, pipe for pumps or auger extensions while they are being put into or taken out of the well.

When a pin or bolt is put through the holes in the two ends of the "L"-shaped pulley bracket (see Figures 15 and 18) which extend horizontally beyond the front of the tripod crossbar, a loose guide for the upper part of the auger extension is formed.

To keep the extensions from falling when they are leaned against the tripod, two 30cm (12") long wooden pegs are driven into drilled holes near the top of the tripod's two front legs (see Figure 19).

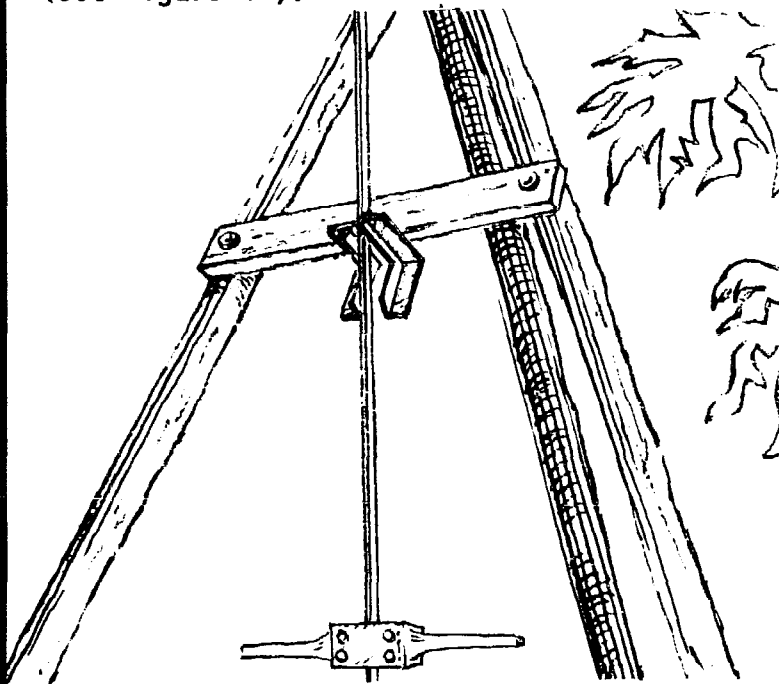


FIGURE 15

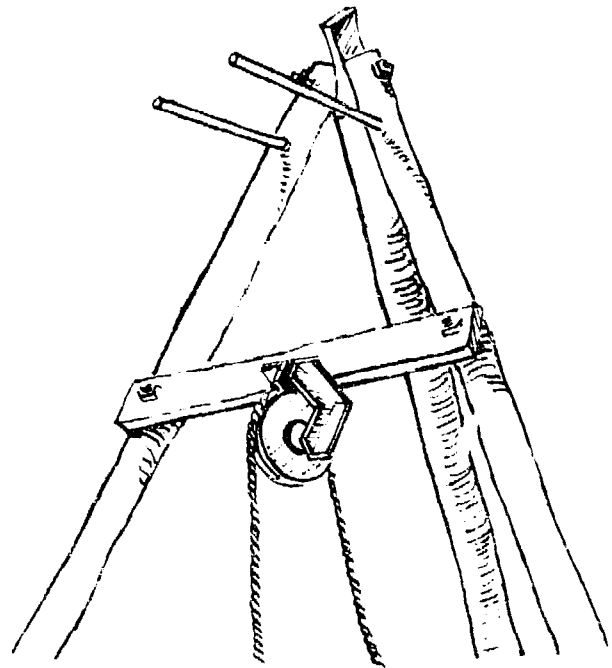


FIGURE 16

### Tools and Materials

3 Poles: 15cm (3") in diameter and 4.25 meters (14') long

Wood for cross bar: 1.1 meter (43 1/2") x 12cm (4 3/4") square

For pulley wheel:

Wood: 25cm (10") in diameter and 5cm (2") thick

Pipe: 1.25cm (1/2") inside diameter, 5cm (2") long

Axle bolt: to fit close inside 1.25cm (1/2") pipe

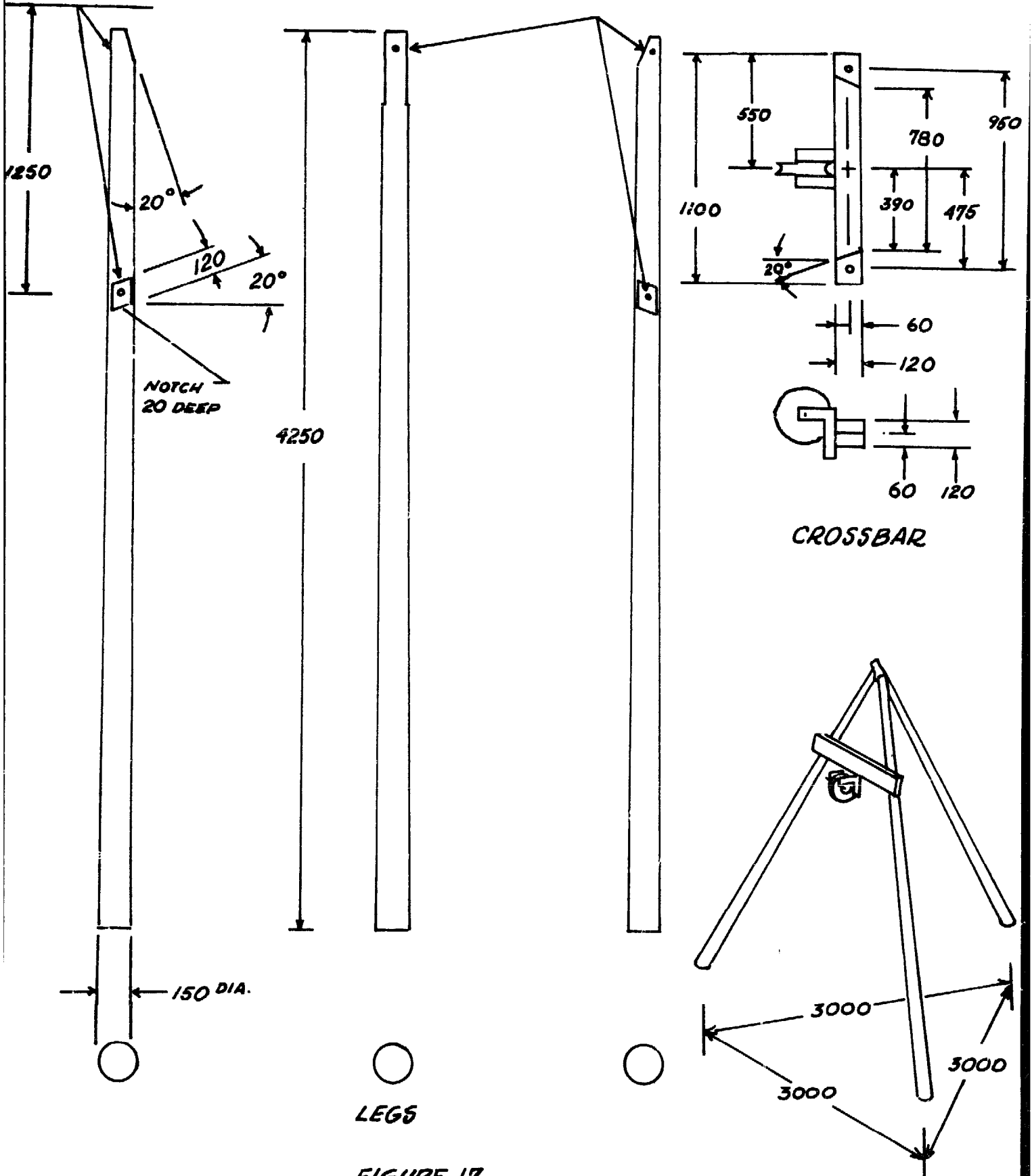
Angle iron: 80cm (31 1/2") long, 50cm (19 3/4") webs, 5mm (3/16") thick

4 Bolts: 12mm (1/2") in diameter, 14cm (5 1/2") long; nuts and washers

Bolt: 16mm (5/8") in diameter and 40cm (15 3/4") long; nuts and washers

2 Bolts: 16mm (5/8") in diameter and 25cm (9 7/8") long; nuts and washers

Bore 5 places thru center of poles for assembly with 16 DIA. bolts

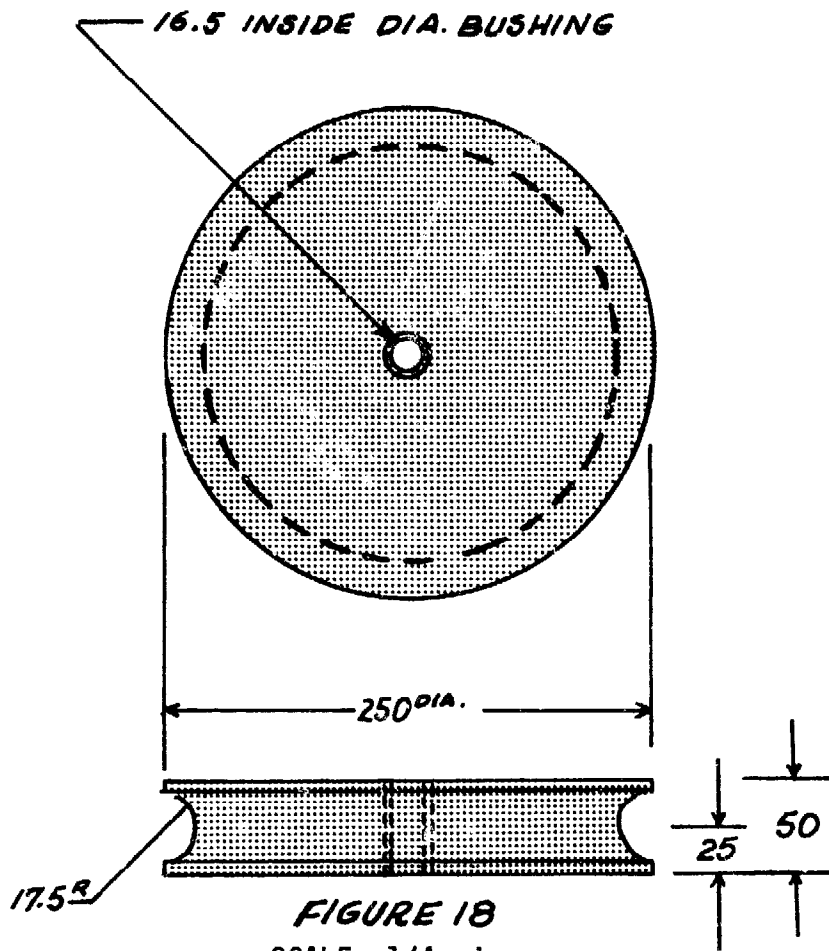


LEGS

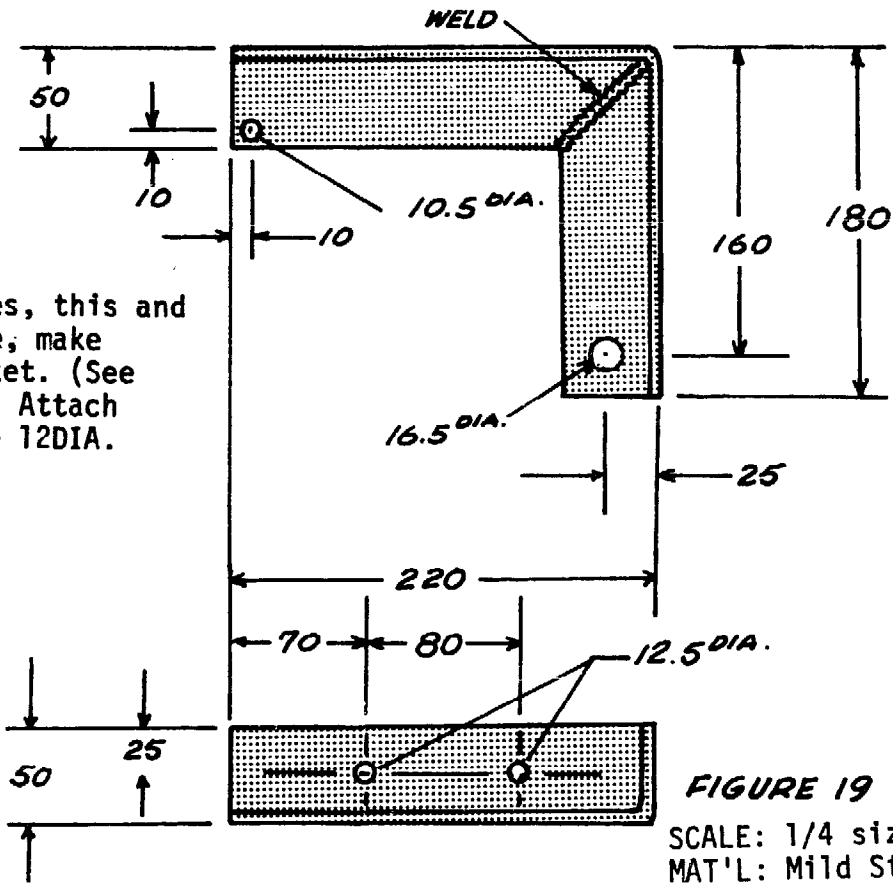
CROSSBAR

FIGURE 17





**FIGURE 18**  
 SCALE: 1/4 size  
 MAT'L: HARDWOOD

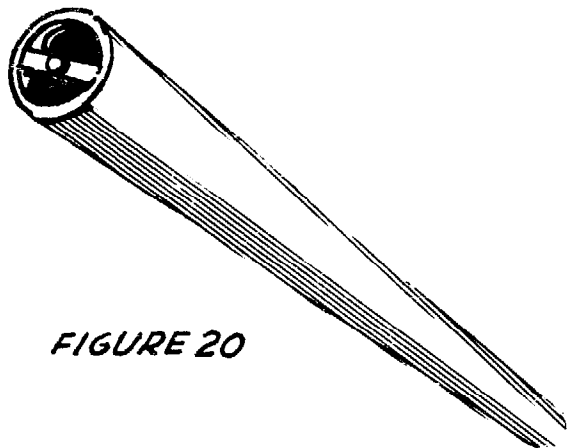


NOTE: Two pieces, this and its mirror image, make one pulley bracket. (See tripod drawing.) Attach to crossbar with 12DIA. Bolts.

**FIGURE 19**  
 SCALE: 1/4 size  
 MAT'L: Mild Steel

## Bailing Bucket

The bailing bucket can be used to remove soil from the well hole when cuttings are too loose to be removed with the auger.



*FIGURE 20*

### Tools and Materials

Pipe: about 8.5cm (3 3/8") in diameter 1 to 2 cm (1/2" to 3/4") smaller in diameter than the auger, 180cm (71") long

Steel rod: 10mm (3/8") in diameter and 25cm (10") long; for bail (handle)

Steel plate: 10cm (4") square, 4mm (5/32") thick

Steel bar: 10cm x 1cm x 5mm (4" x 3/8" x 3/16")

Machine screw: 3mm (1/8") in diameter; 16mm (5/8") long; nut and washer

Truck innertube: 4mm (5/32") thick, 10mm (3/8") square

Welding equipment

Drill, hacksaw, hammer, vise, file

Rope

Both standard weight pipe and thin-walled tubing were tried for the bailing bucket. The former, being heavier, was harder to use, but did a better job and stood up better under use. Both the steel bottom of the bucket and the rubber valve should be heavy because they receive hard usage. The metal bottom is reinforced with a crosspiece welded in place (see Figures 20 and 21).

### Using the Bailing Bucket

When water is reached and the cuttings are no longer firm enough to be brought up in the auger, the bailing bucket must be used to clean out the well as work progresses.

For using the bailing bucket the pulley is mounted in the pulley bracket with a 16mm (5/8") bolt as axle. A rope attached to the bailing bucket is then run over the pulley and the bucket is lowered into the well. The pulley bracket is so designed that the rope coming off the pulley lines up vertically with the well, so that there is no need to shift the tripod.

The bucket is lowered into the well, preferably by two men, and allowed to drop the last meter or meter and one-half (3 to 5 feet) so that it will hit the bottom with some speed. The impact will force some of the loose soil at the bottom of the well up into the bucket. The bucket is then repeatedly raised and dropped 1 to 2 meters (3 to 6 feet) to pick up more soil. Experience will show how long this should be continued to pick up as much soil as possible before raising and emptying the bucket. Two or more men can raise the bucket, which should be dumped far enough from the well to avoid messing up the working area.

If the cuttings are too thin to be brought up with the auger but too thick to enter the bucket, pour a little water down the well to dilute them.

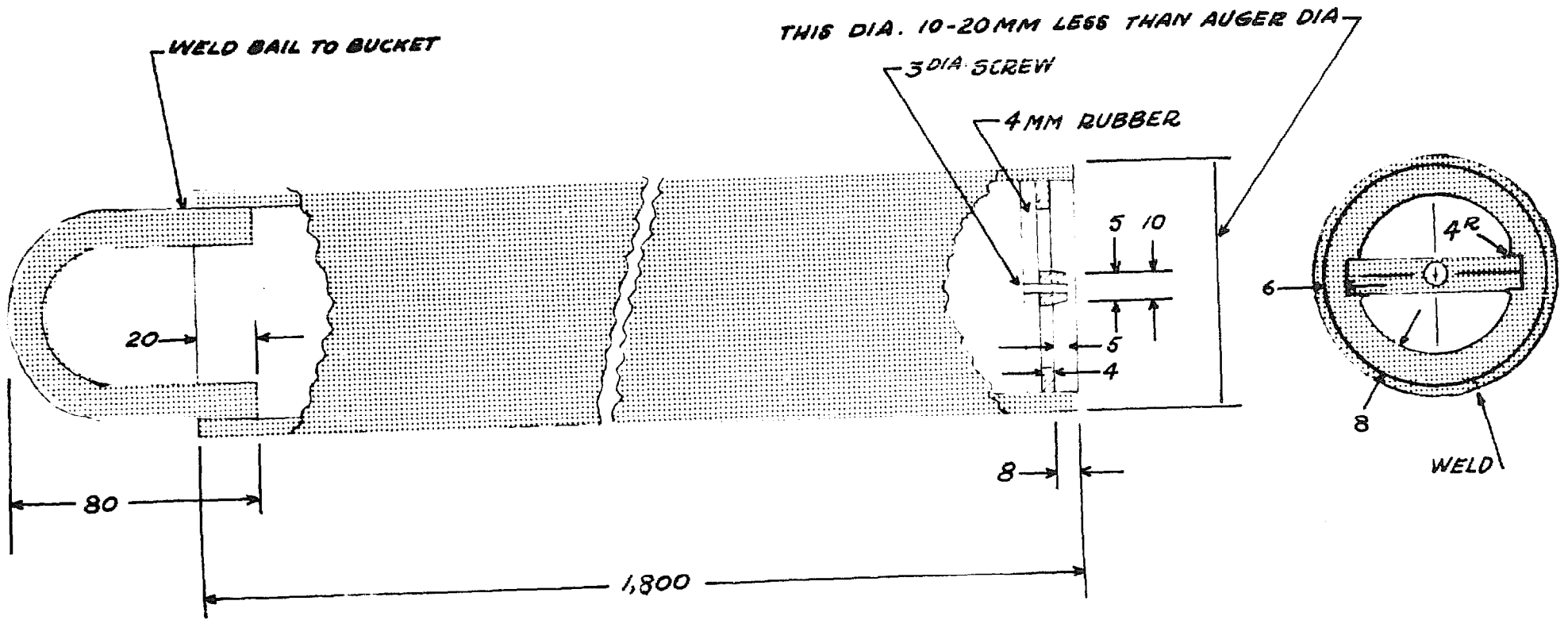
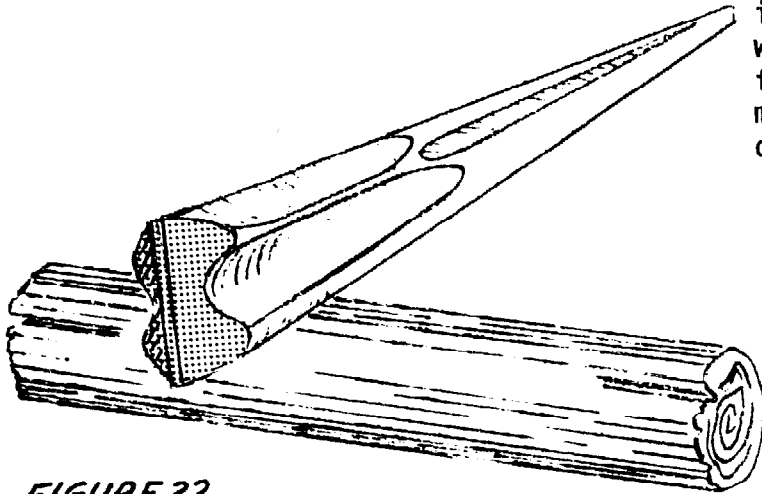


FIGURE 21  
 SCALE: 1/2 SIZE      MAT'L: MILD STEEL

## Bit for Drilling Rock

The bit described here has been used to drill through layers of sedimentary stone up to 11 meters (36') thick.



**FIGURE 22**  
**HEAVY BIT FOR DRILLING ROCK**

### Tools and Materials

Mild steel bar: about 7cm (2 3/4") in diameter and about 1.5 meters (5') long, weighing about 80kg (175 pounds)

Stellite (a very hard type of tool steel) insert for cutting edge

Anvil and hammers, for shaping

Steel rod: 2.5cm x 2cm x 50cm (1" x 3/4" x 19 3/4") for bail

Welding equipment

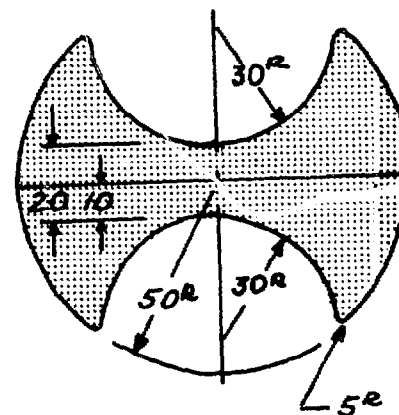
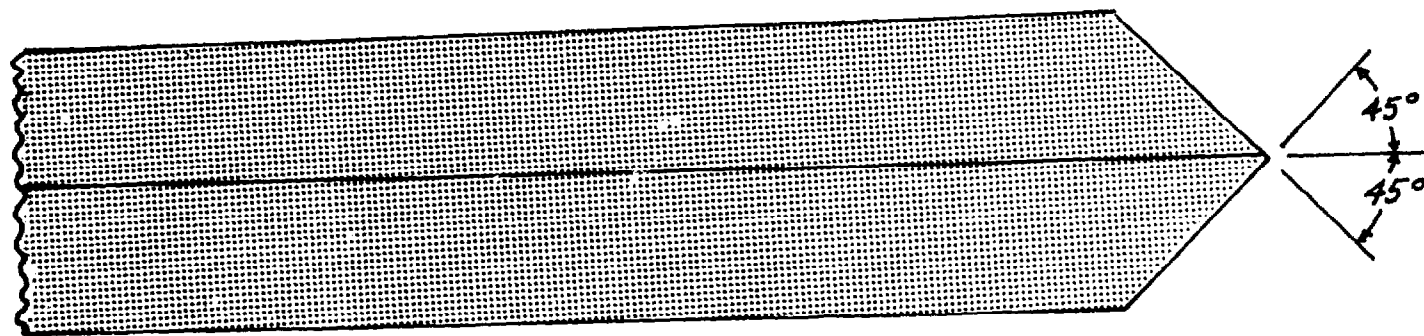
The drill bit for cutting through stone and hard formations is made from the 80kg (175-pound) steel bar (see Figures 22 and 23). The 90-degree cutting edge is hard-surfaced with stellite and a bail (or handle) for attaching a rope is welded to the top. The bail should be large enough to make "fishing" easy if the rope breaks. A 2.5cm (1") rope was used at first, but this was subject to

much wear when working in mud and water. A 1cm (3/8") steel cable was substituted for the rope, but it was not used enough to be able to show whether the cable or the rope is better. One advantage of rope is that it gives a snap at the end of the fall which rotates the bit and keeps it from sticking. A swivel can be mounted between the bit and the rope or cable to let the bit rotate.

If a bar this size is difficult to find or too expensive, it might be possible to make one by welding a short steel cutting end onto a piece of pipe which is made heavy enough by being filled with concrete. This has not been tried.

In using the drilling bit, the pulley is put in place as with the bailing bucket, and the bit is attached to its rope or cable and lowered into the well. Since the bit is heavy, wrap the rope once or twice around the back leg of the tripod so that the bit cannot "get away" from the workers with the chance of someone being hurt or the equipment getting damaged. The easiest way found to raise and drop the bit was to run the rope through the pulley and then straight back to a tree or post where it was attached at shoulder height or slightly lower. Workers line up along the rope and raise the bit by pressing down on the rope; they drop it by allowing the rope to return quickly to its original position (see Figure 24). This requires five to seven men; occasionally more helped. Frequent rests are necessary; usually after every 50 to 100 strokes. Because the work is harder near the ends of the rope than in the middle, the positions of the workers should be rotated to distribute the work evenly.

A small amount of water should be kept in the hole for lubrication and to mix with the pulverized stone to form a paste which can be removed with a bailing bucket. Too much water will



NOTE: TAPER ALL SURFACES TO BLEND INTO SURFACE OF REMAINDER OF BAR 400-500 MM BEHIND CUTTING HEAD

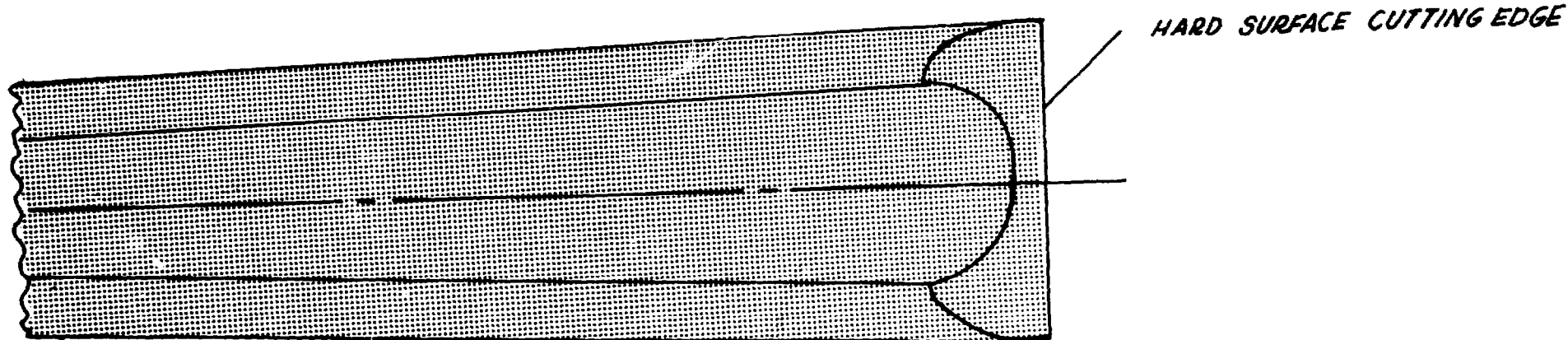


FIGURE 23

SCALE: 1/2 SIZE MATL: MILD STEEL

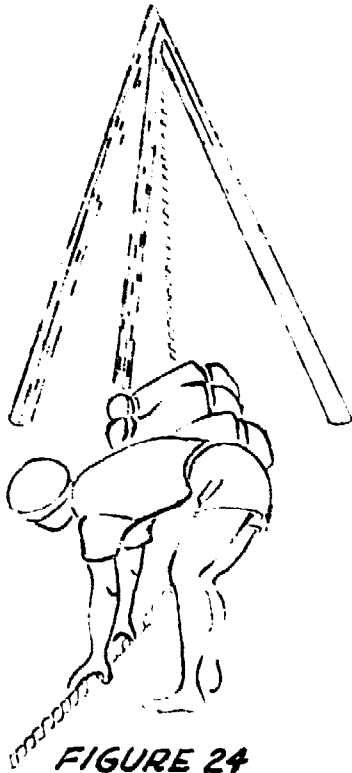


FIGURE 24

used to wrap the rope around a vertical pole pivoted on the ground and held in place by several men (see Figure 26). When the above two failed, it was necessary to borrow a chain hoist. Twice when the rope was allowed to become too worn, it was broken when trying to retrieve a stuck bit. It was then necessary to fit a hook to one of the auger extensions, attach enough extensions together to reach the desired depth, and after hooking the bit, to pull with the chain hoist. A rope or cable may also be used for this purpose, but it is considerably more difficult to hook onto the bit.

slow down the drilling.

The speed of drilling is, of course, dependent on the type of stone encountered. In the soft water-bearing stone of the Ban Me Thuot area it was possible to drill several meters (about 10 feet) per day. However, when hard stone such as basalt is encountered, progress is measured in centimeters (inches). The decision must then be made whether to continue trying to penetrate the rock or to start over in a new location. Experience in the past has indicated that one should not be too hasty in abandoning a location, since on several occasions what were apparently thin layers of hard rock were penetrated and drilling then continued at a good rate.

On occasion the bit has become stuck in the well and it has been necessary to use a lever arrangement consisting of a long pole attached to the rope to free it (see Figure 25). On other occasions a crude windlass was used consisting of a horizontal pole which was

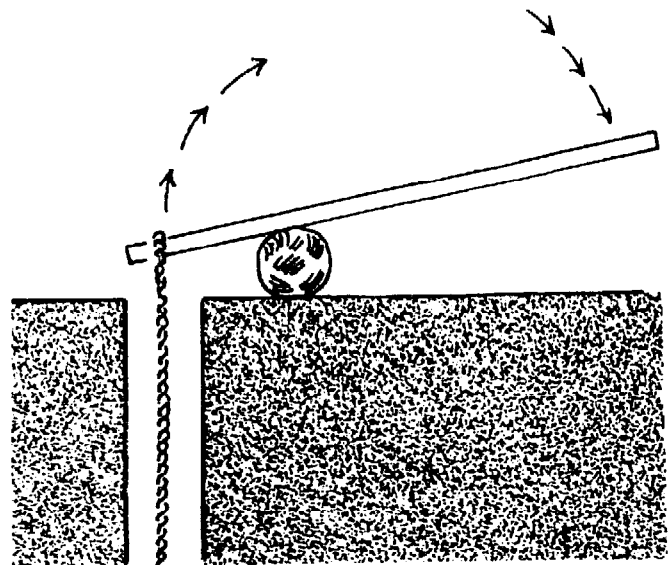
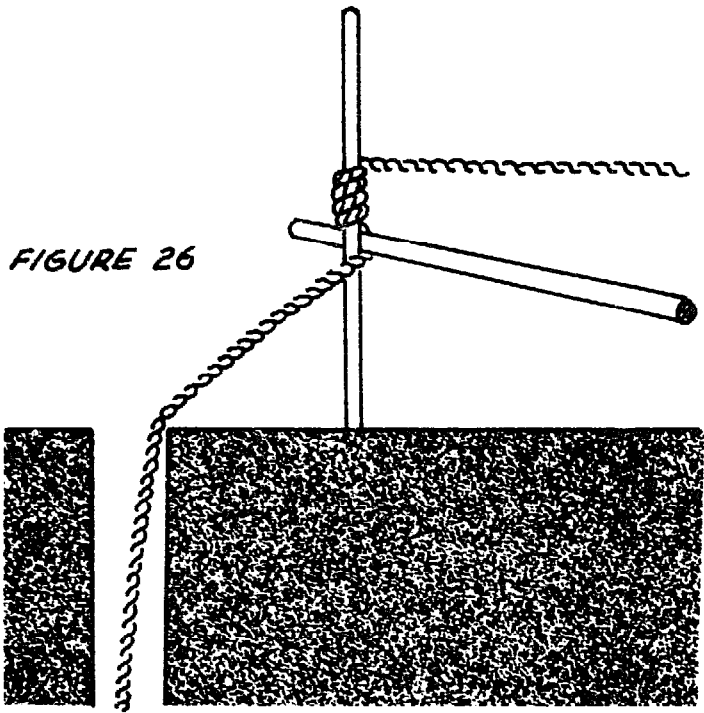


FIGURE 25

FIGURE 26



#### Drilling Mechanically

A method for raising and dropping the bit mechanically, not used on the project but used successfully elsewhere, is:

1. Jack up the rear wheel of a car and replace the wheel with a small drum.
2. Take the rope which is attached to the bit and come from the tripod on the pulley and wrap it loosely around the drum.
3. Pull the unattached end of the rope taut and set the drum in motion. The rope will move with the drum and raise the bit.
4. Let the end of the rope go slack quickly to drop the bit.

It will probably be necessary to polish and/or grease the drum.

## DRY BUCKET WELL DRILLING

The dry bucket method is a simple and quick method of drilling wells in dry soil which is free of rocks. It can be used for 5cm to 7.5cm (2" to 3") diameter wells in which steel pipe is to be installed. For wells which are wider in diameter, it is a quick method of removing dry soil before completing the bore with a wet bucket, tubewell sand bailer or tubewell sand auger.

A 19.5-meter (64') hole was dug in less than 3 hours with this method in north Florida. The method works best in sandy soil, according to the author of this entry, who has drilled 30 wells with it.

### Tools and Materials

#### Dry bucket

Rope: 16mm (5/8") or 19mm (3/4") in diameter and 6 to 9 meters (20' to 30') longer than the deepest well to be drilled

3 Poles: 10cm (4") in diameter at large end and 3.6 to 4.5 meters (12' to 15') long

Chain, short piece

Pulley

Bolt: 12.5mm (1/2") in diameter and 30 to 35cm (12" to 14") long (long enough to reach through the upper ends of the three poles )

The dry bucket is held about 10cm (several inches) above the ground, centered above the hole location and then dropped (see Figure 1). This drives a small amount of soil up into the bucket. After this is repeated two or three times, the bucket is removed, held to one side and tapped with a hammer or a piece of iron to dislodge the soil. The process is repeated until damp soil is reached and the bucket will no longer remove soil.

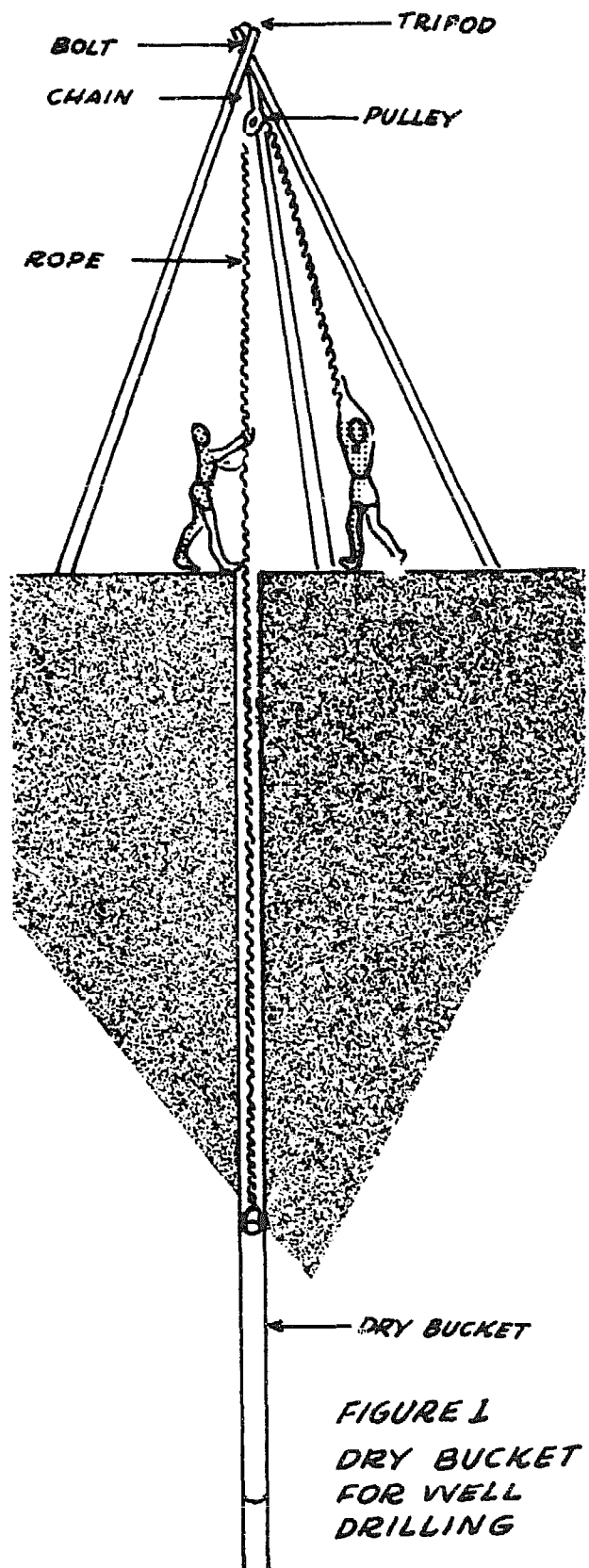
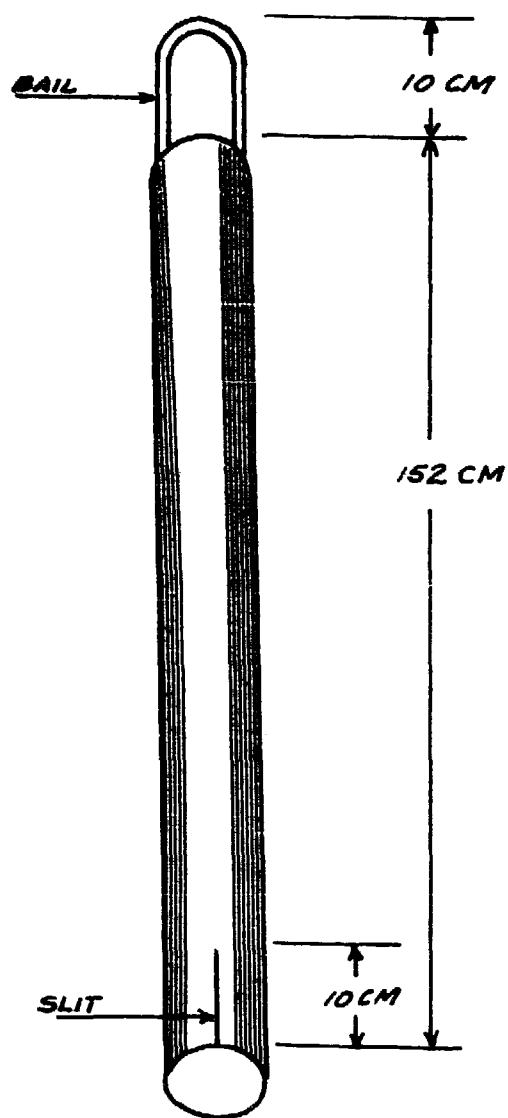


FIGURE 1  
DRY BUCKET  
FOR WELL  
DRILLING



## Dry Bucket for Well Drilling

A dry bucket is simply a length of pipe with a bail or handle welded to one end and a slit cut in the other.

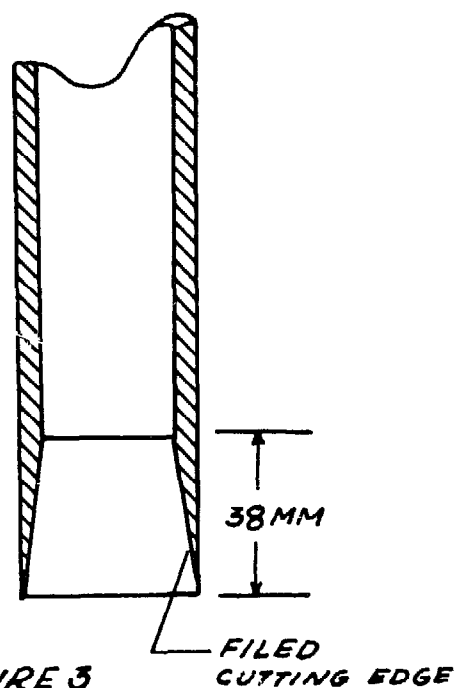


**FIGURE 2**

Bend the iron rod into a U-shape small enough to slide inside the pipe. Weld it in place as in Figure 2.

File a gentle taper on the inside of the opposite end to make a cutting edge (see Figure 3).

Cut a slit in one side of the sharpened end of the pipe (see Figure 2).



**FIGURE 3**

### Tools and Materials

Hacksaw

File

Iron rod: 10mm (3/8") or 12.5mm (1/2") in diameter and 30cm (1') long

Iron pipe: slightly larger in diameter than the largest part of casing to be put in the well (usually the coupling) and 152cm (5') long

### Source:

John Brelsford, VITA Volunteer, New Holland, Pennsylvania

## DRIVING WELLS

A pointed strainer called a well point, properly used, can quickly and cheaply drive a sanitary well, usually less than 7.6 meters (25') deep. In soils where the driven well is suitable, it is often the cheapest and fastest way to drill a sanitary well. In heavy soils, particularly clay, drilling with an earth auger is faster than driving with a well point.

### Tools and Materials

Well point and driving cap: usually obtainable from the United States for about \$10, through mail order houses (see Figure 1)

Pipe: 3cm (1") in diameter

Heavy hammer and wrenches

Pipe compound

Special pipe couplings and driving arrangements are desirable but not necessary

Driven wells are highly successful in coarse sand where there are not too many rocks and the water table is within 7 meters (23') of the surface. They are usually used as shallow wells where the pump cylinder is at ground level. If conditions for driving are very good, 10cm (4") diameter points and casings that can accept the cylinder of a deep well, can be driven to depths of 10 to 15 meters (33' to 49').

The most common types of well points are:

1. a pipe with holes covered by a screen and a brass jacket with holes. For general use, a #10 slot or 60 mesh is recommended. Fine sand requires a finer screen, perhaps a #6 slot or 90 mesh;
2. a slotted steel pipe with no covering screen, which allows more water to enter but is less rugged.

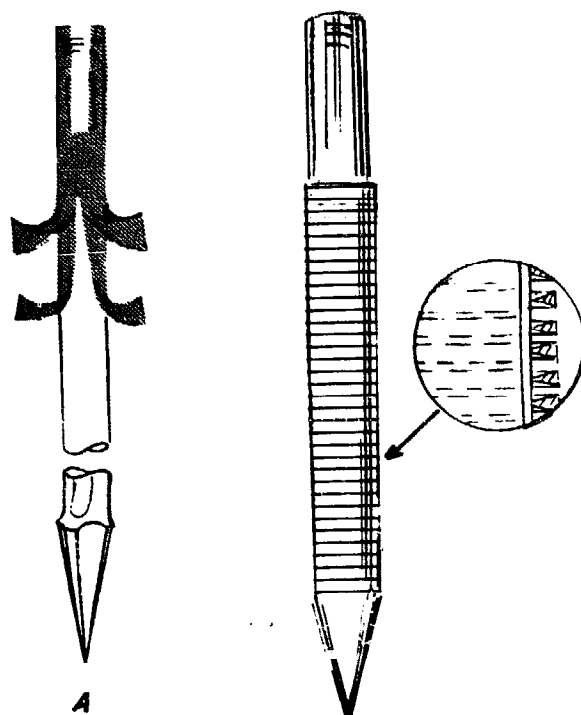


FIGURE 1

B

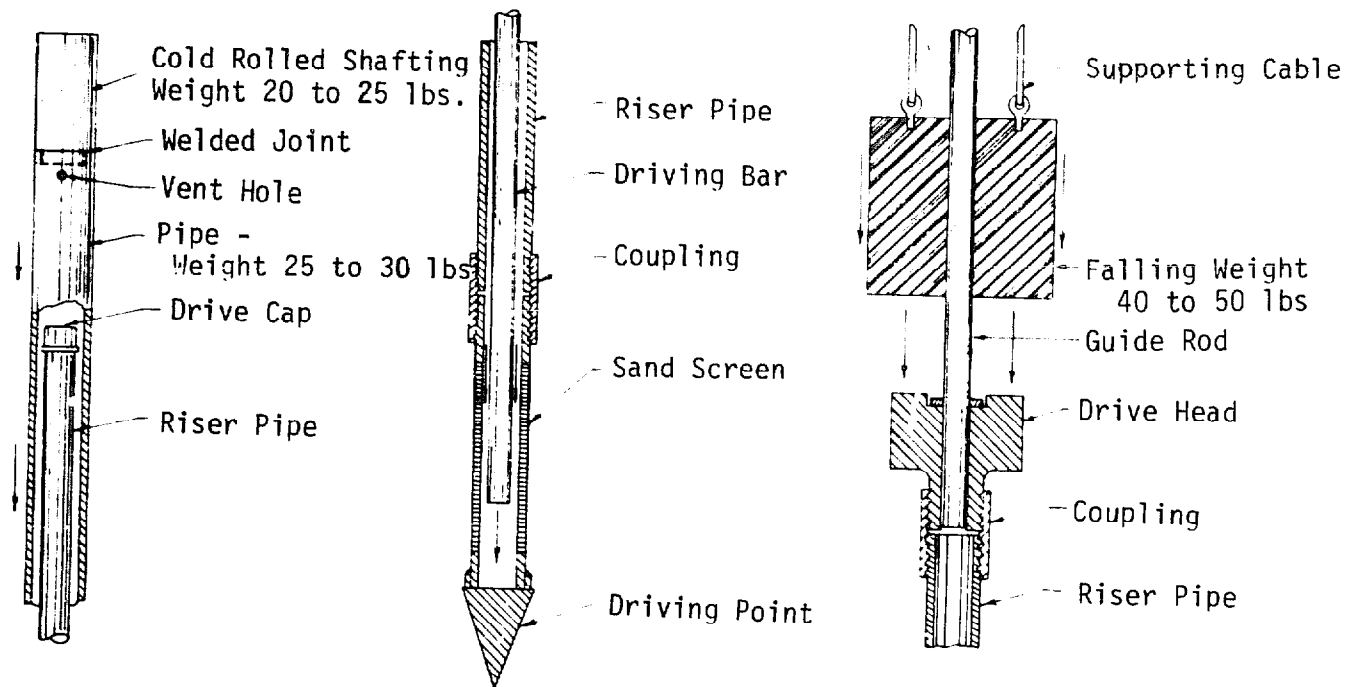
Before starting to drive the point, make a hole at the site with handtools. The hole should be plumb and should be slightly larger in diameter than the well point.

The joints must be carefully made to prevent thread breakage and assure airtight operation. Clean and oil the threads carefully and use joint compound and special drive couplings when available. To insure that joints stay tight, give the pipe a fraction of a turn after each blow, until the top joint is permanently set. Do not twist the whole string and do not twist and pound at the same time. The latter may help get past stones, but soon will break the threads and make leaky joints.

Be sure the drive cap is tight and butted against the end of the pipe (see Figure 2). Check with a plumb bob to see that the pipe is vertical. Test it occasionally and keep it straight by pushing on the pipe while driving. Hit the drive cap squarely each time or you may damage the equipment.

Several techniques can help avoid damage to the pipe. The best way is to drive with a steel bar that is dropped inside the pipe and strikes against the inside of the steel well point. It is retrieved with a cable of rope. Once water enters the well, this method does not work.

Another way is to use a driver pipe which makes sure that the drive cap is hit squarely. A guide rod can be mounted on top of the pipe and a weight dropped over it, or the pipe itself can be used to guide a falling weight which strikes a special drive-clamp (see Figure 2).



Type of formation	Driving conditions	Rate of descent	Sound of blow	Rebound	Resistance to rotation
Soft moist clay	Easy driving	Rapid	Dull	None	Slight but continuous
Tough hardened clay	Difficult driving	Slow but steady	None	Frequent rebounding	Considerable
Fine sand	Difficult driving	Varied	None	Frequent rebounding	Slight
Coarse sand	Easy driving (especially when saturated with water).	Unsteady irregular penetration for successive blows.	Dull	None	Rotation is easy and accompanied by a gritty sound
Gravel	Easy driving	Unsteady irregular penetration for successive blows.	Dull	None	Rotation is irregular and accompanied by a gritty sound
Boulder and rock	Almost impossible	Little or none	Loud	Sometimes of both hammer and pipe	Dependent on type of formation previously passed through by pipe

**FIGURE 3**

from: Wells, TM5-297/AFM 85-23, 1957  
Army Technical Manual, p. 24

Figure 3 is a table which will help identify the formations being penetrated. Experience is needed...but this may help you to understand what is happening.

When you think that the water-bearing layer has been reached, stop driving and attach a handpump to try the well. Usually, easier driving shows that the water-bearing level has been reached, especially in coarse sand. If the amount of water pumped is not enough, try driving a meter or so (a few feet) more. If the flow decreases, pull the point back until the point of greatest flow is found. The point can be raised by using a lever arrangement like a fence-post jack, or, if a drive-monkey is used, by pounding the pipe back up.

Sometimes sand and silt plug up the point and the well must be 'developed' to clear this out and improve the flow. First try hard, continuous pumping at a rate faster than normal. Mud and fine sand will come up with the water, but this should clear in about an hour. It may help to allow the water in the pipe to drop back down, reversing the flow periodically. With most pitcher pumps this is easily accomplished by lifting the handle very high; this opens the check valve, allowing air to enter and the water rushes back down the well.

If this does not clear up the flow, there may be silt inside the point. This can be removed by putting a 19mm (3/4") pipe into the well and pumping on it. Either use the pitcher pump or quickly and repeatedly raise and lower the 19mm (3/4") pipe. By holding your thumb over the top of the pipe on the upstroke, a jet of muddy water will result on each downstroke. After getting most of the material out, return to direct pumping. Clean the sand from the valve and cylinder of the pump after developing the well. If you have chosen too fine a screen, it may not be possible to develop the well successfully. A properly chosen screen allows the fine material to be pumped out, leaving a bed of coarse gravel and sand that provides a highly porous and permeable water-gathering area.

The final step is to fill in the starting borehole with puddled clay or, if clay is not available, with well-tamped earth. Make a solid, water-proof pump platform (concrete is best) and provide a place for spilled water to drain away.

Source:

Water Supply for Rural Areas and Small Communities, by E. G. Wagner and J. N. Lanoix, World Health Organization, 1959.

## DUG WELLS

A village well must often act as a reservoir, because at certain hours of the day the demand for water is heavy, whereas during the night and the heat of the day there is no call on the supply. What is suggested here is to make the well large enough to allow the water slowly percolating in to accumulate when the well is not in use in order to have an adequate supply when the demand on it is heavy. For this reason wells are usually made 183 to 213cm (6' to 7') in diameter.

Wells cannot store rainy season water for the dry season, and there is seldom any reason for making a well larger in diameter than 213cm (7').

The depth of a well is much more important than the diameter in determining the amount of water that can be drawn when the water level is low. A deep, narrow well will often provide more water than a wide shallow one.

Remember that tubewells are much easier to construct than a dug well, and should be used if your region allows their construction and an adequate amount of water can be drawn from a tubewell during the busy hours (see section on Tubewells).

Deep dug wells have several disadvantages. The masonry lining needed is very expensive. An open well is very easily contaminated by organic matter which falls in from the surface and by the buckets used to lift the water. There is an added problem of disposing of the great quantity of soil removed from a deep well.

This well has an underground concrete tank which is connected to the surface with a casing pipe, rather

than a large-diameter lining as described in the preceding entry. The advantages are that it is relatively easy to build, easy to seal, takes up only a small surface area and is low in cost.

More than 45 of these wells were installed in India by an American Friends Service Committee Team there; all performed perfectly for several years, except for one which was not dug deep enough. The total cost of an installation, excluding labor, was Rs. 230 or about U.S. \$50.

### Tools and Materials

4 reinforced concrete rings with iron hooks for lowering, 91.5cm (3') in diameter

1 reinforced concrete cover with a seating hole for casing pipe

Washed gravel to surround tank: 1.98 cubic meters (70 cubic feet)

Sand for top of well: 0.68 cubic meters (24 cubic feet)

Concrete pipe: 15cm (6") in diameter, to run from the top of the tank cover to at least 30.5cm (1') above ground

Concrete collars: for joints in the concrete pipe

Cement: 4.5kg (10 pounds) for mortar for pipe joints

Deep-well pump and pipe

Concrete base for pump

Tripod, pulleys, rope for lowering rings

Special tool for positioning casing when refilling, see "Positioning Casing Pipe," below

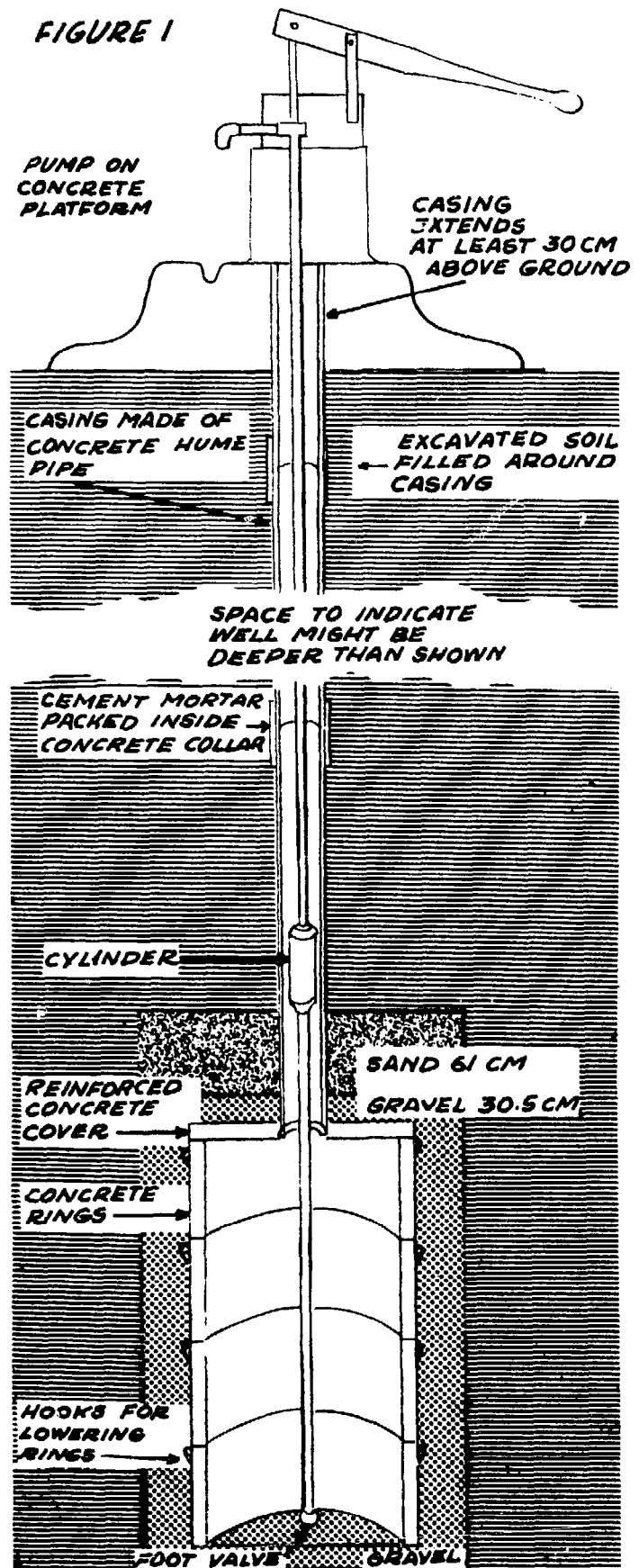
Digging tools, ladders, rope

A villager in Barpali, India, working with an American Friends Service Committee unit there suggested this radical new idea: make a masonry tank at the bottom of the well, roof it over, and draw the water from it with a pump. The resulting sealed well has many advantages:

1. It provides pure water, safe for drinking.
2. It presents no hazard of children falling in.
3. Drawing water is easy, even for small children.
4. The well occupies little space, a small courtyard can accommodate it.
5. The cost of installation is greatly reduced.
6. The labor involved is much reduced.
7. There is no problem of getting rid of excavated soil, since most of it is replaced.
8. The casing enables the pump and pipe to be easily removed for servicing.
9. The gravel and sand surrounding the tank provide an efficient filter to prevent silting, allows a large surface area for percolating water to fill the tank, and increases the effective stored volume in the tank.

On the other hand, there are three minor disadvantages: only one person can pump at one time, the pump might go out of order, and a certain amount of technical skill is required to make the parts used in the well and to install them properly.

A well is dug 122cm (4') in diameter and about 9 meters (30') deep. The digging should be done in the dry season, after the water table has



dropped to its lowest level. There should be a full 3 meter (10') re-accumulation of water within 24 hours after the well has been bailed or pumped dry. Greater depth is, of course, desirable.

Over the bottom of the well, spread 15cm (6") of clean, washed gravel or small rock. Lower the four concrete rings and cover into the well and position them there to form the tank. A tripod of strong poles with block and tackle is needed to lower the rings, because they weigh about 180kg (400 pounds) each. The tank formed by the rings and cover is 183cm (6') high and 91.5cm (3') in diameter. The cover has a round opening which forms a seat for the casing pipe and allows the suction pipe to penetrate to about 15cm (6") from the gravel bottom.

#### Positioning the Casing Pipe

The first section of concrete pipe is positioned in the seat and grouted (mortared) in place. It is braced vertically by a wooden plug with four hinged arms to brace against the sides of the wall. Gravel is packed around the concrete rings and over the top of the cover till the gravel layer above the tank is at least 15cm (6") deep. This is then covered with 61cm (2') of sand. Soil removed from the well is then shoveled back until filled within 15cm (6") of the top of the first section of casing. The next section of casing is then grouted in place, using a concrete collar made for this purpose. The well is filled and more sections of casing added until the casing extends at least 30cm (1') above the surrounding soil level.

The amount of soil which will not pack back into the well can be used to make a shallow hill around the casing to encourage spilled water to drain away from the pump. A concrete cover is placed on the casing and a pump installed.

If concrete or other casing pipe cannot be obtained, a chimney made of burned bricks and sand-cement mortar will suffice. The pipe is somewhat more expensive, but much easier to install.

#### Source:

"A Safe Economical Well," American Friends Service Committee, Philadelphia, Pennsylvania, 1956 (mimeo).

## Deep Dug Well

Untrained workers can safely dig a deep, sanitary well with simple, light equipment, if they are well supervised. The basic method is outlined here.

### Tools and Materials

Shovels, mattocks

Buckets

Rope--deep wells require wire rope

Forms--steel, welded and bolted together

Tower with winch and pulley

Cement

Reinforcing rod

Sand

Aggregate

Oil

The hand dug well is the most widespread of any kind of well. Unfortunately, most of these wells were dug by uninformed people and now are infected by parasitic and bacterial disease. By using modern methods and materials, dug wells can safely be made 60 meters (196.8') deep and will give a permanent source of pure water.

Experience has shown that for one man, the average width of a round well for best digging speed is 1 meter (3 1/4'). However 1.3 meters (4 1/4') is best for two men digging together and they dig more than twice as fast as one man. Thus, two men in the larger hole is usually best.

Dug wells always need a permanent lining (except in solid rock, where the best method is usually to drill a tubewell).

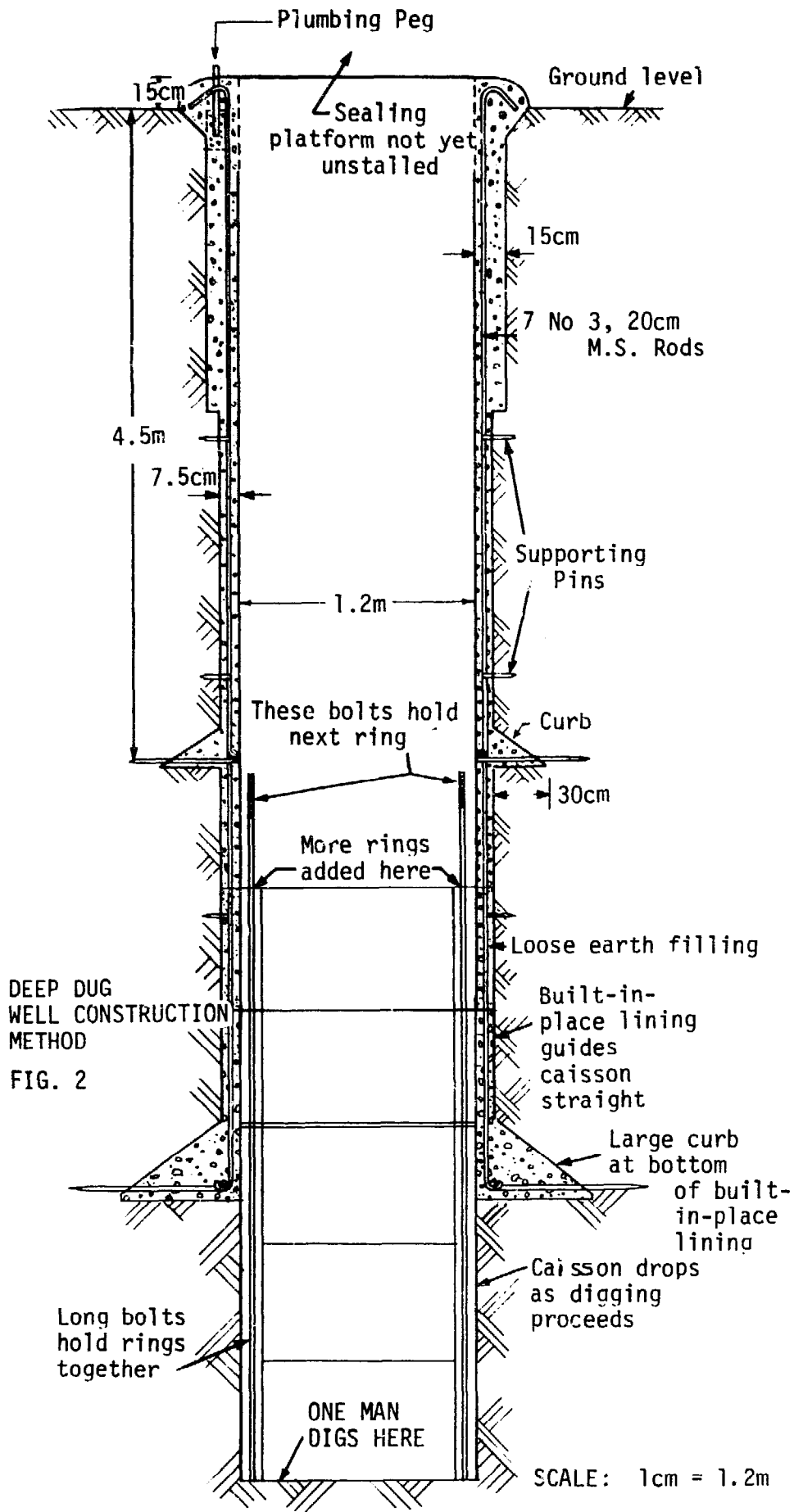
The lining prevents collapse of the hole, supports the pump platform, stops entrance of contaminated surface water, and supports the well intake which is the part of the well through which water enters. It is usually best to build the lining while digging, since this avoids temporary supports and reduces danger of cave-ins.

Dug wells are lined in two ways: (1) where the hole is dug and the lining is built in its permanent place and (2) where sections of lining are added to the top and the whole lining moves down as earth is removed from beneath it. The second method is called caissoning. Often a combination of both is best, as shown in Figure 2.

If possible, use concrete for the lining because it is strong, permanent, made mostly of local materials, and can be handled by unskilled workers with good speed and results. (See section on Concrete Construction).

Masonry and brickwork are widely used in many countries and can be very satisfactory if conditions are right. In bad ground, however, unequal pressures can make them bulge or collapse. Building with these materials is slow and a thicker wall is required than with concrete. There is also always the danger of movement during construction in loose sands or swelling shale before the cement has set firmly between the bricks or stones. This danger is prevented with concrete by leaving the form in place to support the lining, until the concrete is hard. Also, there may not be any skilled masons in the area; suitable stone or well-fired brick may not be readily available.





Wood and steel are not good for lining wells. Wood requires bracing, tends to rot and hold insects; sometimes it will make the water taste badly. Worst of all, it will not make the well watertight against contamination. Steel is seldom used because it is expensive, rusts quickly and usually is subject to bulging and bending.

The general steps in finishing the first 4.6 meters (15') are:

- . set up a tripod winch over cleared, level ground and reference points for plumbing and measuring the depth of the well.
- . two men dig the well while another raises and unloads the dirt until the well is exactly 4.6 meters (15') deep.
- . the hole is accurately trimmed to size using a special jig mounted on the reference points.
- . the forms are carefully placed and filled one by one with tamped concrete.

After this is done, dig to 9.1 meters (30'), trim and line this part also with concrete. A 12.5cm (5") gap between the first and second of these sections is filled with pre-cut concrete which is grouted (mortared) in place. Each lining is self-supporting as it has a curb. The top of the first section of lining is thicker than the second section and extends above the ground to make a good foundation for the pump housing and to make a safe seal against ground water.

This method is used until the water-bearing layer is reached where an extra-deep curb is constructed. From this point on, caissoning is used.

Caissons are concrete cylinders fitted with bolts for attaching them together. They are cast and cured on the surface in special molds, prior to use. Several caissons are lowered into the well and assembled together. Then a workman digs and the caissons drop lower as earth is removed from beneath them. The concrete lining guides the caissons.

If the water table is high when the well is dug, extra caissons are bolted in place so that the well can be finished by a small amount of digging and without concrete work, during the dry season.

#### Evaluation

Details on plans and equipment for this process are found in Water Supply for Rural Areas and Small Communities, by E. G. Wagner and J. N. Lanoix, World Health Organization, 1959.

#### Source :

Water Supply for Rural Areas and Small Communities, Wagner and Lanoix.

## Reconstructing Dug Wells

Open dug wells are not very sanitary, but they can often be rebuilt by re-lining the top 3 meters (10') with a watertight lining, digging and cleaning the well and covering it; this method is to install a buried concrete slab; see Figure 3 for construction details.

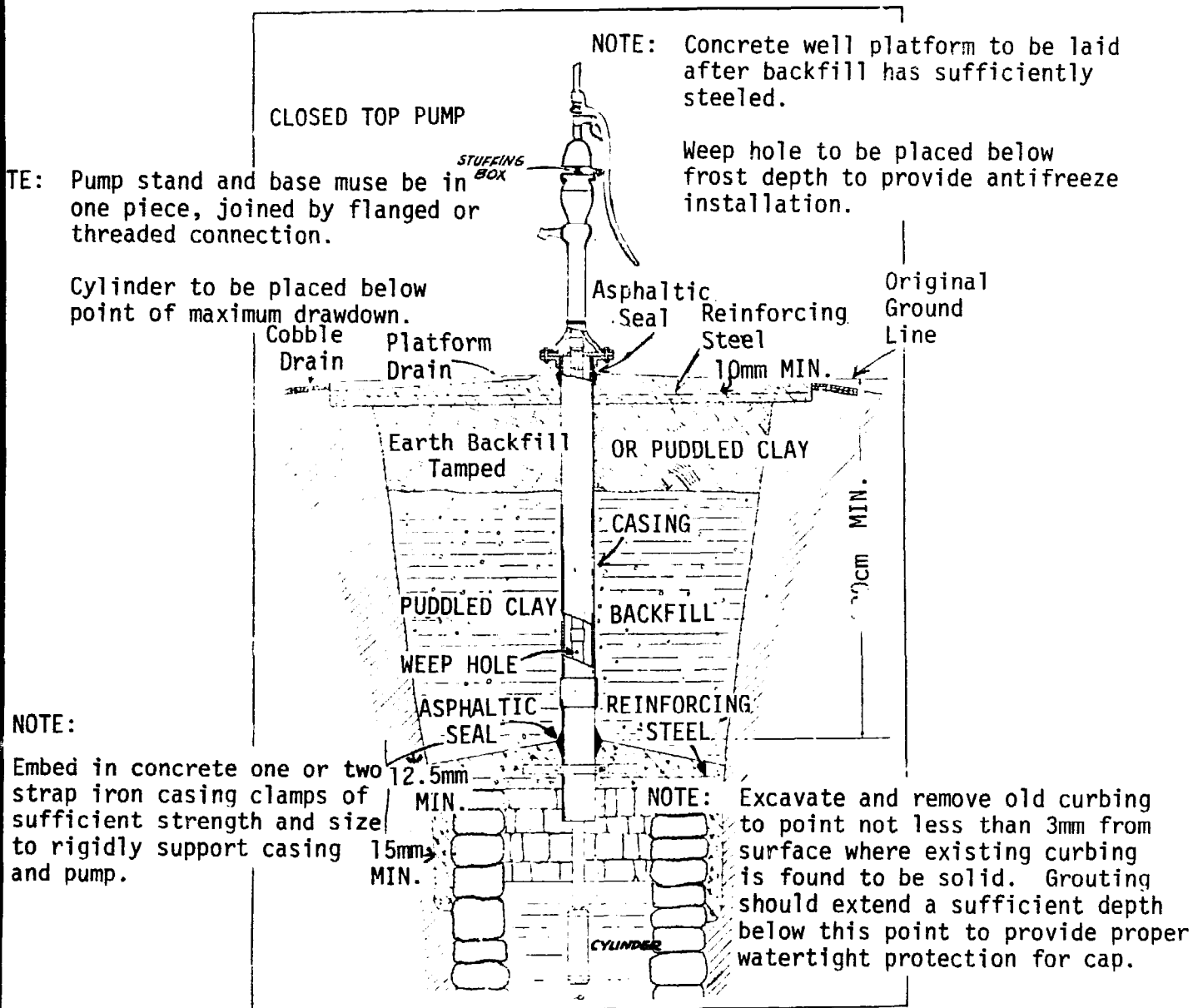
## Tools and Materials

Tools and materials for reinforced concrete

A method for entering the well

Pump and drop pipe

Fig 3



### Before starting, check the following:

- . Is the well dangerously close to a privy or other source of contamination? Is it close to a water source? Is it desirable to dig a new well elsewhere instead of cleaning this one? Could a privy be moved, instead?
- . Has the well ever gone dry? Should you deepen it as well as clean it?
- . Surface drainage should generally slope away from the well and there should be effective disposal of spilled water.
- . What method will you use to remove the water and what will it cost?
- . Before entering the well to inspect the old lining, check for a lack of oxygen by lowering a lantern or candle. If the flame remains lit, it is reasonably safe to enter the well. If the flame goes out, the well is dangerous to enter. When the well is entered, have a rope tied to the person and two strong men to pull him out in case of accident.

### Relining the Wall

The first job is to prepare the upper 3 meters (10') of the lining for concrete by removing loose rock and chipping away old mortar with a chisel, as deep as possible (see Figure 4). The next task is to clean out and deepen the well, if that is necessary. All organic matter and silt should be bailed out. The well may be dug deeper, particularly during the dry season, with the methods outlined in the article on "Deep Dug Wells." One way to increase the water yield is to drive a well point deeper into the water-bearing soil. This normally will not raise the level of water in the well, but may make the water flow into the well faster. The well point can be piped directly to the pump, but this

will not make use of the reservoir capacity of the dug well.

The material removed from the well can be used to help form a mound around the well so water will drain away from the well site. Usually, additional soil will be needed for this mound. A drain lined with rock should be provided to take spilled water away from the concrete apron that covers the well.

Reline the well with concrete troweled in place over wire mesh reinforcement. The largest aggregate should be pea-sized gravel and the mix should be fairly rich with concrete, using no more than 5 1/2 to 6 gallons of water to a 94-pound sack of cement. Extend the lining 70cm (27 1/2 inches) above the original ground surface.

### Installing the Cover and Pump

Cast the well cover so that it makes a watertight seal with the lining to keep surface impurities out. The cover will also support the pump. Extend the slab out over the mound about a meter (a few feet) to help drainage away from the site. Make a manhole and space for the drop pipe of the pump. Mount the pump off center so there is room for the manhole. The pump is mounted on bolts cast into the cover. The manhole must be 10cm (4") higher than the surface of the slab. The manhole cover must overlap by 5cm (2") and should be fitted with a lock to prevent accidents and contamination. Be sure that the pump is sealed to the slab.

### Disinfecting the Well

Disinfect the well by using a stiff brush to wash the walls with a very strong solution of chlorine. Then add enough chlorine in the well to make it about half the strength of the solution used on the walls. Sprinkle this last solution all over the surface of the well to distribute it

evenly. Cover the well and pump up the water until the water smells strongly of chlorine. Let the chlorine remain in the pump and well for one day and then pump it until the chlorine is gone.

### Testing the Water

Have the well water tested several days after disinfection to be sure that it is pure. If it is not, repeat the disinfection and testing. If it is still not pure, get expert advice.

### Sources:

Water Supply for Rural Areas and Small Communities, by E. G. Wagner and J. N. Lanoix, World Health Organization, 1959.

Manual of Individual Water Supply Systems, U.S. Department of Health, Education and Welfare, Public Health Service Publication No. 24.

# Water Lifting and Transport

Once a source of water has been found and developed, four basic questions must be answered:

1. What is the rate of flow of water needed in your situation?
2. Between what points must the water be transported?
3. What kind and size of piping is needed to transport the required flow?
4. What kind of pump, if any, is necessary to produce the required flow?

The information in this section will help you to answer the third and fourth questions, once you have determined the answers to the first two.

## Water Transport

The first three entries are equations and alignment charts (also called nomographs) which give simple methods of estimating the flow of water under the force of gravity, that is, without pumping. The fourth tells how to measure flow by observing the spout from a horizontal pipe.

## Pipe Size

You will note that in these and other alignment charts, the term "nominal diameter, incl. S. U.S. Schedule 40" is used along with the alternate term, "inside diameter in centimeters," in referring to pipe size.

Pipes and fittings are usually manufactured to a standard schedule of sizes. U.S. Schedule 40, the most common in the United States, is also widely used in other countries. When one specifies "2 inch Schedule 40", one automatically specifies the pressure rating of the pipe and its inside and outside diameters

(neither of which, incidentally, is actually 2"). If the schedule is not known, measure the inside diameter and use this for flow calculations.

## Water Lifting

The next four entries follow the steps required to design a water-pumping system with piping.

The first entry in this group, "Pump Selection" presents all factors that must be considered in selecting a pump. One should fill out the form included in the entry and make a piping sketch whether he plans to send it to a consultant for help or do the design and selection himself.

The next three entries enable the reader to design his own piping system and specify his own pump.

## Selecting a Pump

The first information needed for selecting pump type and size is: (1) the flow rate of water needed and (2) the "head" or pressure to be overcome by the pump. This "head" is composed of two parts, (a) the height the liquid must be raised and (b) the resistance to flow created by the pipe walls (friction-loss).

The friction-loss "head" is the most difficult factor to measure. The entry, "Determining Pump Size and Horsepower Requirement," page 82 describes how to select the economic pipe size(s) for the flow desired. With the pipe(s) selected one must then calculate the friction-loss head. The entry "Estimating Flow Resistance of Pipe Fittings" makes it possible to estimate extra friction caused by constrictions of pipe fittings. With this information and the length of pipe, it is possible to estimate the pump power requirement using the entry, "Determining Pump Size and Horsepower Requirement."

These four entries have another very important use. You may already have a pump and wonder "Will it do this job?" or "What size motor should I buy to do this job with the pump I have?". The entry "Pump Selection" can be used to collect all the information on the pump and on the job you want it to do. With this information, you can ask a consultant or VITA if the pump can be used or not.

### Pumps

There are many varieties of pumps for lifting water from where it is to where it is to be delivered. But, for any particular job, there are probably one or two kinds of pumps which will serve better than others. We will discuss here only two broad classes of pumps: lift pumps and force pumps.

#### Lift Pumps

A lift or suction pump is located at the top of a well and raises water by suction. Even the most efficient suction pump can create a negative pressure of only 1 atmosphere: theoretically, it could raise a column of water 10.3m (34') at sea level. But because of friction losses and the effects of temperature, a suction pump at sea level can actually lift water only 6.7m to 7.6m (22' to 25'). The entry on "Lift Pump Capability" explains how to find out the height a lift pump will raise water at different altitudes with different water temperatures.

#### Force Pumps

When a lift pump is not adequate, a force pump must be used. With a force pump, the pumping mechanism is placed at or near the water level and pushes the water up. Because it does not depend on atmospheric pressure, it is not limited to a 7.6m (25') head.

### Construction Details

Construction details are given on two irrigation pumps which can be made at the village level. An easy-to-maintain pump handle mechanism is described. Suggestions are also given on using bamboo for piping.

Further details on pumps are given in:

Water Lifting Devices for Irrigation, by Aldert Molenaar, Food and Agriculture Organization of the United Nations, Rome, 1956.

Small Water Supplies, The Ross Institute, The London School of Hygiene and Tropical Medicine, London, 1967.

Water Supply for Rural Areas and Small Communities, by Edmund G. Wagner and J. N. Lanoix, World Health Organization, Geneva, 1959.

Wells, TM 5-297/Armed Forces Manual 85-23, Government Printing Office, Washington, D.C., 1957.

## ESTIMATING SMALL STREAM WATER FLOW

A rough but very rapid method of estimating water flow in small streams is given here. In looking for water sources for drinking, irrigation or power generation, one should survey all the streams available.

If sources are needed for use over a long period, it is necessary to collect information throughout the year to determine flow changes--especially high and low flows. The number of streams that must be used and the flow variations are important factors in determining the necessary facilities for utilizing the water.

### Tools and Materials

Timing device, preferably watch with second hand

Measuring tape

Float (see below)

Stick for measuring depth

The following equation will help you to measure flow quickly:  $Q = K \times A \times V$ , where:

Q (Quantity) = flow in liters per minute

A (Area) = cross-section of stream, perpendicular to flow, in square meters

V (Velocity) = stream velocity, meters per minute

K (Constant) = a corrected conversion factor. This is used because surface flow is normally faster than average flow. For normal stages use  $K = 850$ ; for flood stages use  $K = 900$  to  $950$ .



FIGURE 1



### To Find A (Area) of a Cross-Section

The stream will probably have different depths along its length so select a place where the depth of the stream is average.

1. Take a measuring stick and place it upright in the water about 50cm from the bank.
2. Note the depth of water.
3. Move the stick 1 meter from the bank in a line directly across the stream.
4. Note the depth.
5. Move the stick 1.5 meters from the bank, note the depth, and continue moving it at 50cm intervals until you cross the stream.

Note the depth each time you place the stick upright in the stream. Draw a grid, like the one in Figure 2, and mark the varying depths on it so that a cross-section of the stream is shown. A scale of 1cm to 10cm is often used for such grids. By counting the grid squares and fractions of squares, the area of the water can be estimated. For example, the grid shown here has a little less than 4 square meters of water.

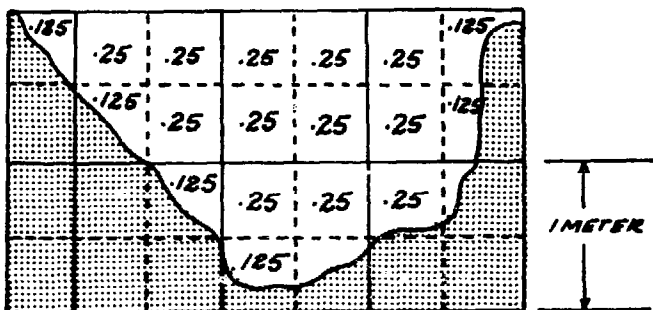


FIGURE 2



### To Find V (Velocity)

Put a float in the stream and measure the distance of travel in one minute (or fraction of a minute, if necessary.) The width of the stream should be as constant as possible and free of rapids, where the velocity is being measured.

A light surface float, such as a chip, will often change course because of wind or surface currents. A weighted float which sits upright in the water will not change course so easily. A lightweight tube or tin can, partly filled with water or gravel so that it floats upright with only a small part showing above water, will not change course so easily and makes a better float for measuring.

### Measuring Wide Streams

For a wide, irregular stream, it is better to divide the stream into 2 or 3 meter sections and measure the area and velocity of each. Q is then calculated for each section and the Qs added together to give a total flow.

Example (see Figure 2):

Cross section is 4 square meters

Velocity of float = 6 meters traveled in 1/2 minute

Stream flow is normal

$$Q = 850 \times 4 \times \frac{6 \text{ meters}}{.5 \text{ minute}}$$

$$Q = 40,800 \text{ liters per minute}$$

or

$$680 \text{ liters per second}$$

### Using English Units

If English units of measurement are used, the equation for measuring stream flow is:  $Q = K \times A \times V$ , where:

$Q$  = flow in U.S. gallons per minute

$A$  = cross-section of stream, perpendicular to flow, in square feet

$V$  = stream velocity in feet per minute

$K$  = a corrected conversion factor: 6.4 for normal stages; 6.7 to 7.1 for flood stages

The grid to be used would be similar to the one in Figure 3; a commonly used scale is 1" to 12".

Example:

Cross-section is 15 square feet

Velocity of float = 20 feet traveled in 1/2 minute

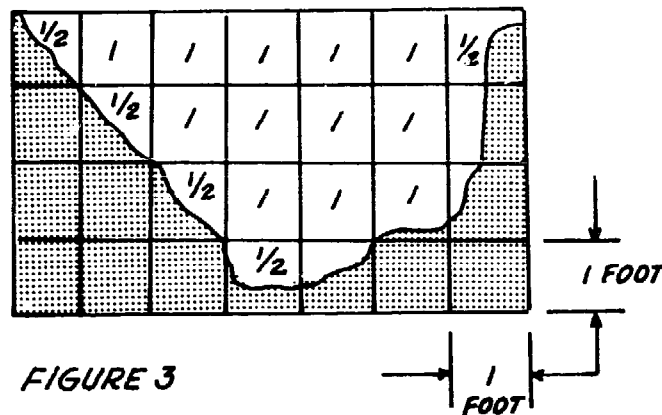
Stream flow is normal

$$Q = 6.4 \times 15 \times \frac{20 \text{ feet}}{.5 \text{ minute}}$$

$$Q = 3800 \text{ gallons per minute}$$

Source:

Design of Fishways and Other Fish Facilities by C. H. Clay, P. E. Department of Fisheries of Canada, Ottawa, 1961.



## MEASURING THE FLOW OF WATER IN PARTIALLY FILLED PIPES

The flow of water in partially-filled horizontal pipes or circular channels can be determined--if you know the inside diameter of the pipe and the depth of the water flowing--by using the alignment chart (nomograph) in Figure 2.

This method can be checked for low flow rates and small pipes by measuring the time required to fill a bucket or drum with a weighed quantity of water. A liter of water weighs 1kg (1 U.S. gallon of water weighs 8.33 pounds).

### Tools and Materials

Ruler to measure water depth (if ruler units are inches, multiply by 2.54 to convert to centimeters)

Straight edge, to use with alignment chart

The alignment chart applies to pipes with 2.5cm to 15cm inside diameters, 20 to 60% full of water, and having a reasonably smooth surface (iron, steel, or concrete sewer pipe). The pipe or channel must be reasonably horizontal if the result is to be accurate. The eye, aided by a plumb bob line to give a vertical reference, is a sufficiently good judge. If the pipe is not horizontal another method will have to be used. To use the alignment chart, simply connect the proper point on the "K" scale with the proper point of the "d" scale with the straight edge. The flow rate can then be read from the "q" scale.

q = rate of flow of water, liters per minute 8.33 pounds = 1 gallon.

d = internal diameter of pipe in centimeters.

K = decimal fraction of vertical diameter under water. Calculate K by measuring the depth of water (h) in the pipe and dividing it by the pipe diameter (d), or  $K = \frac{h}{d}$  (see Figure 1).

### Example:

What is the rate of flow of water in a pipe with an internal diameter of 5cm, running 0.3 full? A straight line connecting 5 on the d-scale with 0.3 on the K-scale intersects the q-scale at a flow of 18 liters per minute.

### Source:

Greve Bulletin, Purdue University (12, No. 5, 1928, Bulletin 32).

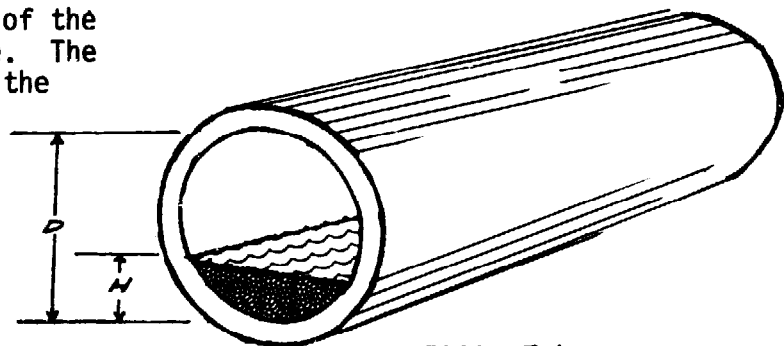
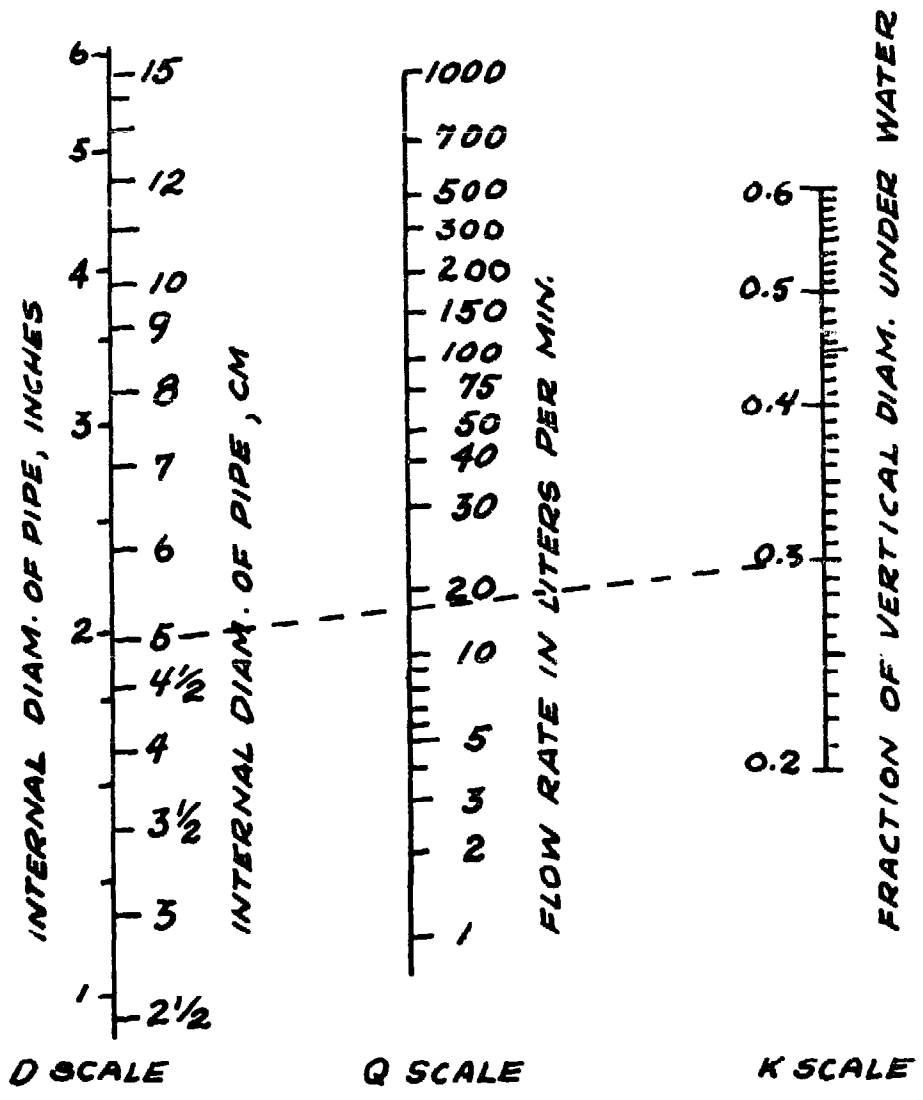


FIGURE 1

FIGURE 2



## DETERMINING PROBABLE WATER FLOW WITH KNOWN RESERVOIR HEIGHT AND SIZE AND LENGTH OF PIPE

The alignment chart in Figure 1 gives a reasonably accurate determination of water flow when pipe size, pipe length and height of the supply reservoir are known.

The example given here is for the analysis of an existing system. To design a new system, assume a pipe diameter and solve for flow-rate, repeating the procedure with new assumed diameters until one of them provides a suitable flow rate.

### Materials

Straight edge, for use with alignment chart

Surveying instruments, if available

The alignment chart was prepared for clean, new steel pipe. Pipes with rougher surfaces or steel or cast iron pipe which has been in service for a long time may give flows as low as 50 percent of those predicted by this chart.

The available head (h) is in meters and is taken as the difference in elevation between the supply reservoir and the point of demand. This may be crudely estimated by eye, but for accurate results some sort of surveying instruments are necessary.

For best results, the length of pipe (L) used should include the equivalent lengths of fittings as described in handbook entry "Flow Resistance of Pipe Fittings," p. 80. This length (L) divided by the pipe internal diameter (D) gives the necessary "L/D" ratio. In calculating L/D, note that the units of measuring both "L" and "D" must be the same, e.g.: feet divided by feet; meters divided by meters; centimeters by centimeters.

Example:

Given Available Head (h) of 10 meters, pipe internal diameter (D) of 3cm, and equivalent pipe length (L) of 30 meters = 3000cm.

$$\text{Calculate } L/D = \frac{3000\text{cm}}{3\text{cm}} = 1000$$

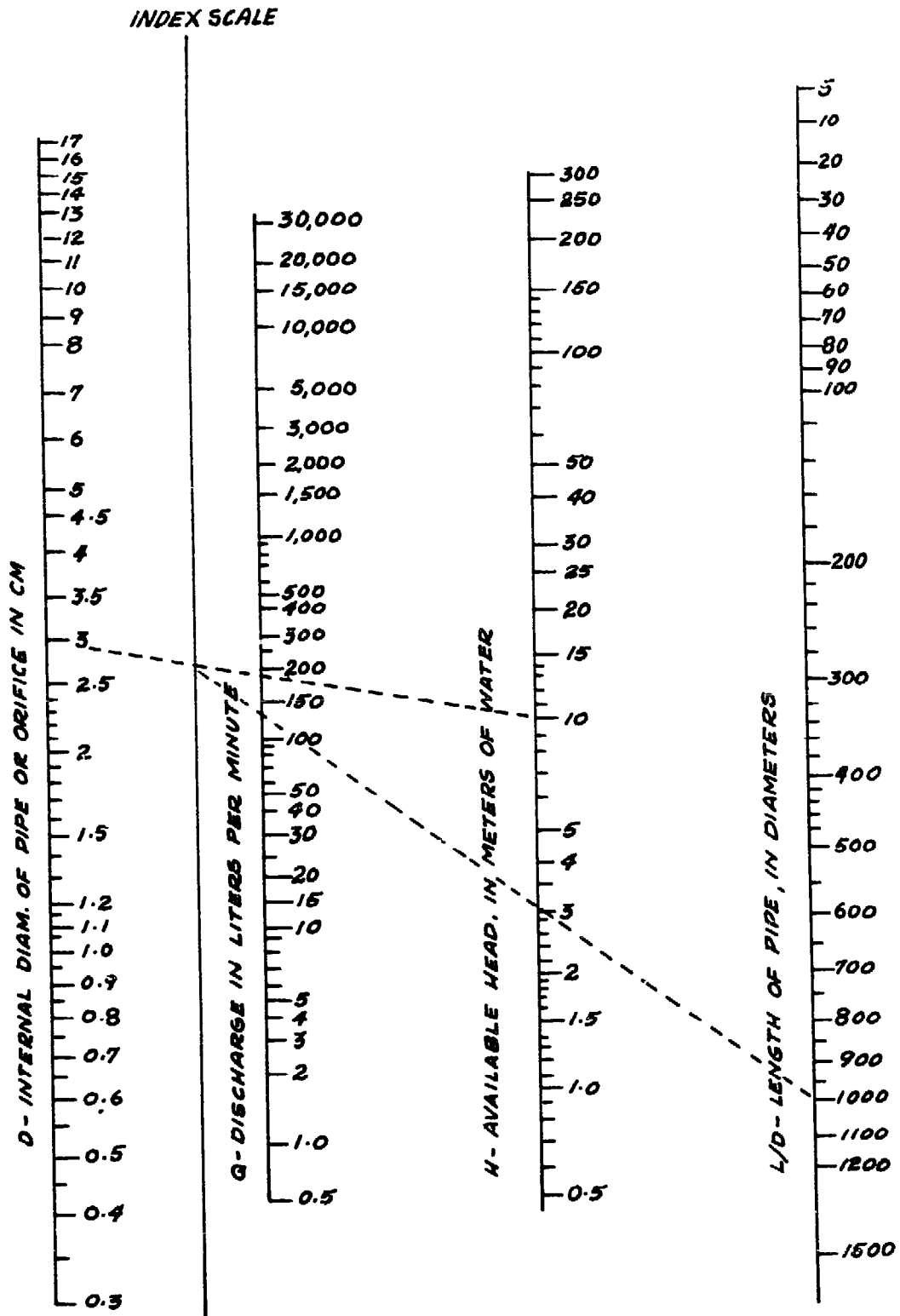
The alignment chart solution is in two steps:

1. Connect Internal Diameter 3cm to Available Head (10 meters), and make a mark on the Index Scale. (In this step, disregard "Q" scale)
2. Connect mark on Index Scale with L/D (1000), and read flow rate (Q) of approximately 140 liters per minute.

Source:

Crane Company Technical Paper #407, pages 54-55.

FIGURE 1



Alignment chart for determining probable water flow with known reservoir height and size and length of pipe.

## ESTIMATING WATER FLOW FROM HORIZONTAL PIPES

If a horizontal pipe is discharging a full stream of water, you can estimate the rate of flow from the alignment chart in Figure 2. This is a standard engineering technique for estimating flows; its results are usually accurate to within 10 percent of the actual flow rate.

### Materials

Straightedge and pencil, to use alignment chart

Tape measure

Level

Plumb bob

The water flowing from the pipe must completely fill the pipe opening (see Figure 1). The results from the chart will be most accurate when there is no constricting or enlarging fitting at the end of the pipe.

### Example:

Water is flowing out of a pipe with an inside diameter ( $d$ ) of 3cm (see Figure 1). The stream drops 30cm at a point 60cm from the end of the pipe.

Connect the 3cm inside diameter point on the "d" scale in Figure 2 with the 60cm point on the "D" scale. This line intersects the "q" scale at about 100 liters per minute, the rate at which water is flowing out of the pipe.

### Source:

"Flow of Water from Horizontal Open-end Pipes," by Clifford L. Duckworth, Chemical Processing, June 1959, p. 73.

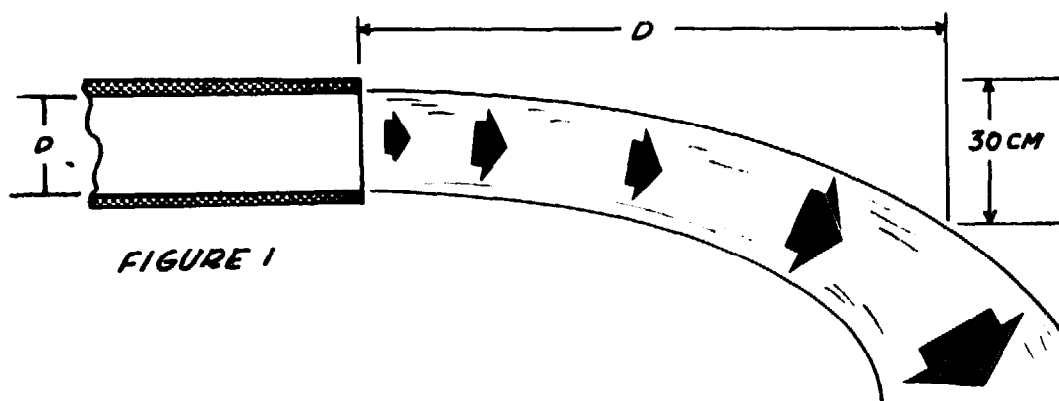


FIGURE 1

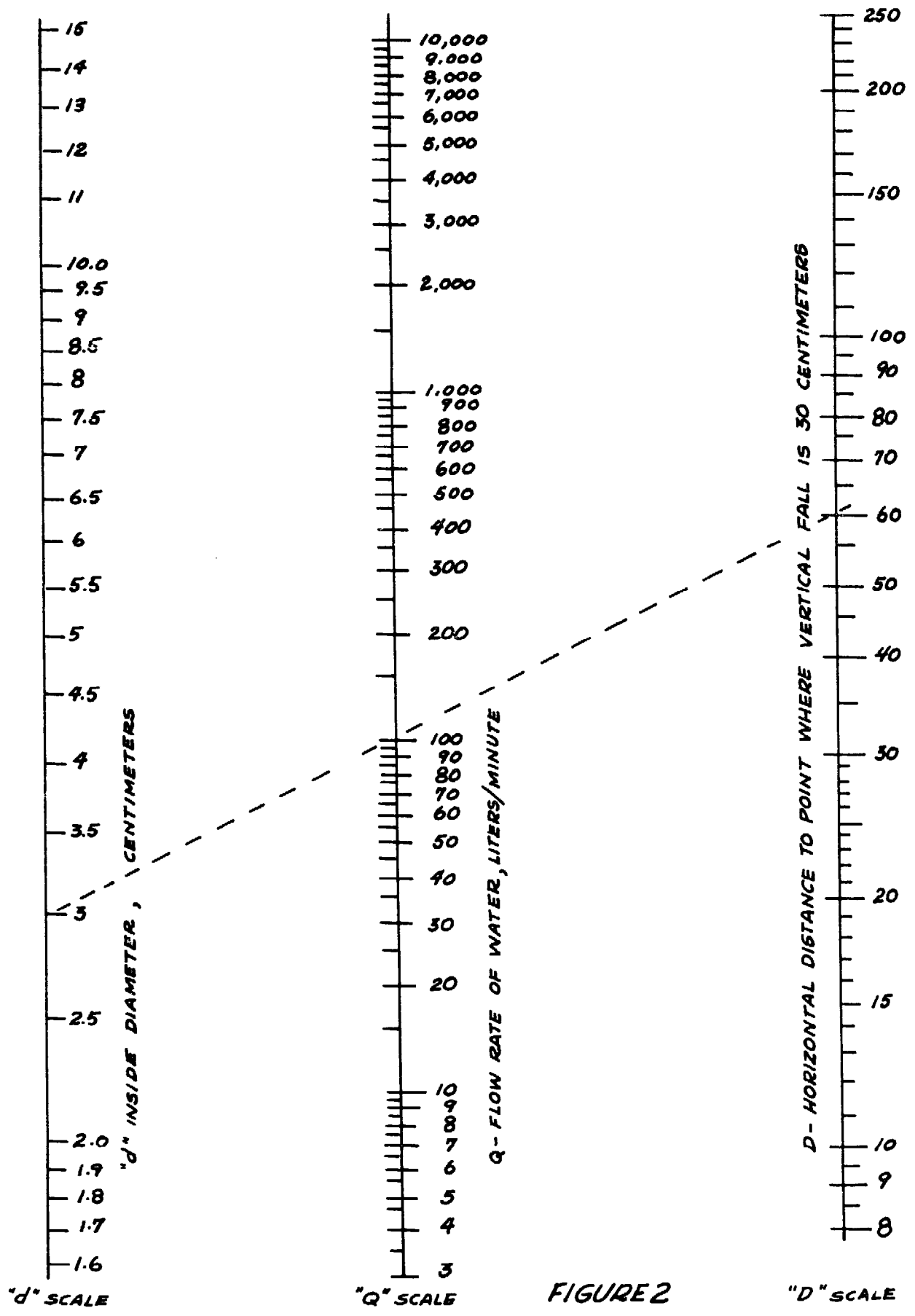


FIGURE 2

"D" SCALE



**PUMP SPECIFICATION: Choosing a Pump for a Specific Job or Evaluating an Available Pump**

The form given in Figure 1, the "Pump Application Fact Sheet," is a check list for collecting the information needed to get help in choosing a pump for a particular situation. If you have a pump on hand, you can also use the form to estimate what its capabilities are. The form is an adaptation of a standard pump specification sheet used by engineers.

If you are doubtful about how much information to give, it is better to give too much information rather than risk not giving enough. When seeking advice on how to solve a pumping problem or when asking pump manufacturers to specify the best pump for your service, give complete information on what its use will be and how it will be installed. If the experts are not given all the details, the pump chosen may give you trouble.

To give a better idea of how to use the "Pump Application Fact Sheet," it is shown filled in for a typical situation. For your own use, make a copy of the form. The following comments on each numbered item on the fact sheet will help you to complete the form adequately.

1. Give the exact composition of the liquid to be pumped: fresh or salt water, oil, gasoline, acid, alkali, etc.
2. Weight percent of solids can be found by getting a representative sample in a pail. Let the solids settle to the bottom and decant off the liquid (or filter the liquid through a cloth so that the liquid coming through is clear). Weigh the solids and the liquid, and give the weight percent of solids. If this is not possible, measure the volume of the sample (in liters, U.S. gallons, etc.) and

the volume of solids (in cubic centimeters, teaspoons, etc.) and send these figures. Describe the solid material completely and send a small sample if possible. This is important since, if the correct pump is not selected, the solids will erode and break moving parts.

Weight percent of solids =

$$\frac{100 \times \text{weight of solids in liquid sample}}{\text{weight of liquid sample}}$$

3. If you do not have a thermometer to measure temperature, guess at it, making sure you guess on the high side. Pumping troubles are often caused when liquid temperatures at the intake are too high.
4. Gas bubbles or boiling cause special problems, and must always be mentioned.
5. Give the capacity (the rate at which you want to move the liquid) in any convenient units (liters per minute, U.S. gallons per minute) by giving the total of the maximum capacity needed for each outlet.
6. Give complete details on the power source.
  - A. If you are buying an electric motor for the pump, be sure to give your voltage. If the power is A.C. (Alternating Current) give the frequency (in cycles per second) and the number of phases. Usually this will be single phase for most small motors. Do you want a pressure switch or other special means to start the motor automatically?
  - B. If you want to buy an engine driven pump, describe the type and cost of fuel, the altitude, maximum air temperature, and say whether the air is unusually wet or dusty.
  - C. If you already have an electric

PUMP APPLICATION FACT SHEET

NAME John Doe  
ADDRESS P.O. Box 393  
Canada  
Hondurama land

DATE July 14, 1969

1. Liquid to be handled: Fresh Water
2. Erosive effect of liquid:
  - (a) Weight percent of solids: 1-2 percent
  - (b) Type of solids: sand
  - (c) Size of solids: largest particle - 1mm
3. Maximum temperature of liquid entering pump: 35°C
4. Special situations (explain):
  - (a) Gases in liquid: no
  - (b) Liquid boiling: no
5. Capacity required: \_\_\_\_\_ liters per minute  
 or: 1200 kilograms per hour - made up of  
 or: 600 kg. per hour from lower outlet  
and 600 kg per hour from upper outlet
6. Power source available:
  - (a) Electrical: \_\_\_\_\_ volts  
 AC: 110 phase or: DC: \_\_\_\_\_ volts  
single cycles per second  
50
  - (b) Fuel: \_\_\_\_\_
  - (c) Other: \_\_\_\_\_
7. Differential head and suction head: See sketch
8. Pipe material: Suction: Galvanized Iron (see sketch for pipe size)  
 Discharge: Galvanized Iron (see sketch for pipe size)
9. Pump connections required: Standard pipe thread  
 Pipe size (inside diameter): Inlet: 5.25cm\* Outlet: 5.25cm\*
10. Sketch of piping (all fittings and valves shown) attached
11. Other comments: \_\_\_\_\_

Figure 1. Pump Specification Fact Sheet. Make a copy of this form for your own use.

NOTE: For advice on pump selection or application, send the completed form (keeping a copy for your own information) to a local university, a pump manufacturer or to VITA, College Campus, Schenectady, New York, 12308, U.S.A.

\* Actually this piping is the same as 2" U.S. Schedule 40.

motor or engine, give as much information about it as you can. Give the speed, sketch the machine, being especially careful to show the power shaft diameter and where it is with respect to the mounting. Describe the size and type of pulley if you intend to use a belt drive. Finally, you must estimate the power. The best thing is to copy the nameplate data completely. If the following data is available for your engine, give the number of cylinders, their size, and the stroke if possible.

7. The "head" or pressure to be overcome by the pump and the capacity (or required flow of water) determine the pump size and power. The entry "Pump Size and Horsepower Requirement", page 82, explains the calculation of simple head situations. The best approach is to explain the "heads" by drawing an accurate piping sketch (see Item 10 in the "Pump Application Fact Sheet"). Be sure to give the suction lift and piping separately from the discharge lift and piping. An accurate description of the piping is essential for calculating the friction head. See Figure 2.

8. The piping material, inside diameter, and thickness are necessary for making the head calculations and to check whether pipes are strong enough to withstand the pressure. See "Water Lifting and Transport" for comments on specifying pipe diameter.

9. Connections to commercial pumps are normally flanged or standard pipe thread.

10. In the sketch be sure to show the following:

(a) Pipe sizes; show where sizes are changed by indicating reducing fittings. (Read "Introduction" for comments on pipe diameter.)

(b) All pipe fittings--elbows, tees, valves (show valve type), etc.

(c) Length of each pipe run in a given direction. Length of each size pipe and vertical lift are the most important dimensions.

11. Give information on how the pipe will be used. Comment on such information as:

Indoor or outdoor installation?

Continuous or intermittent service?

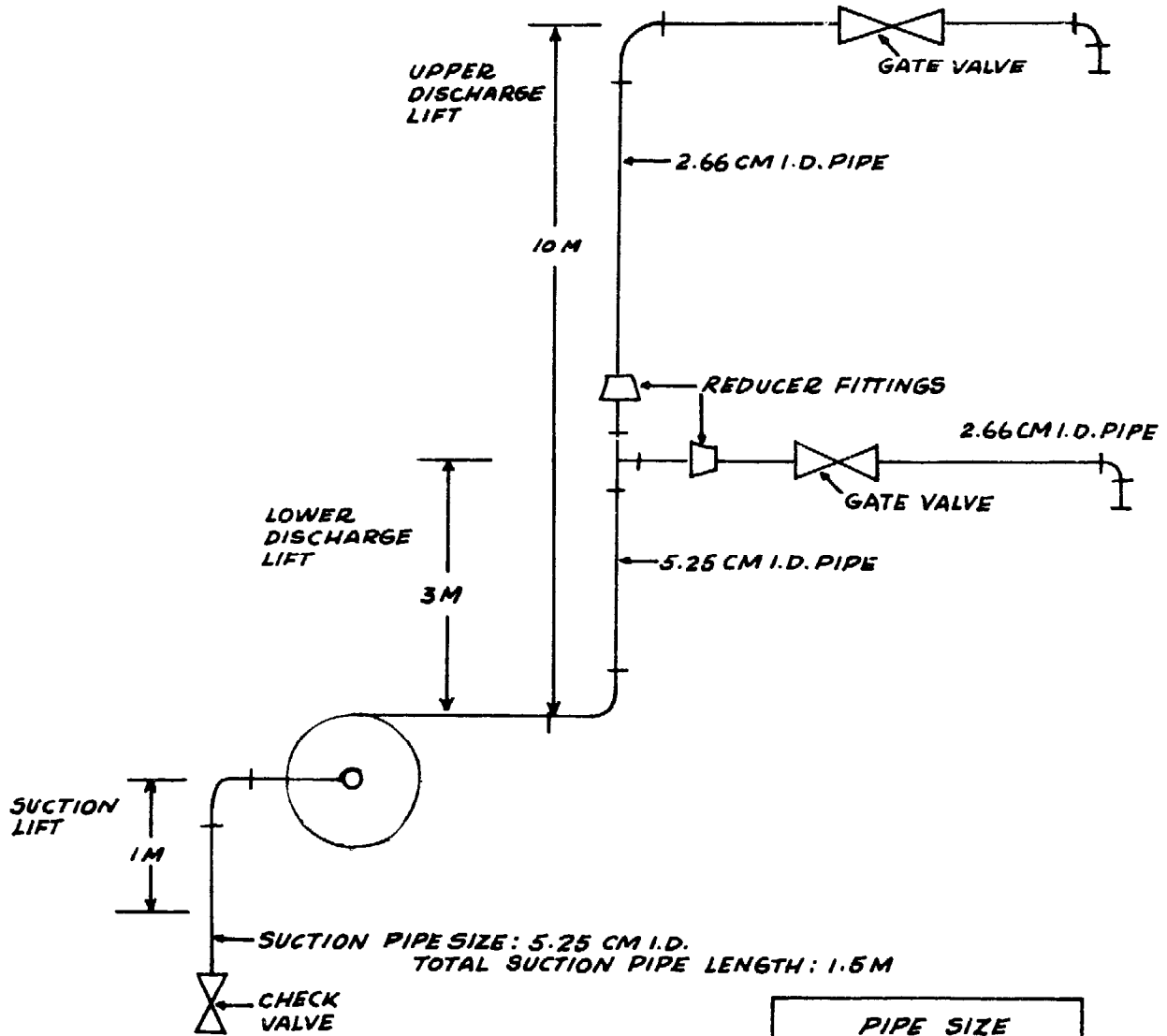
Space or weight limitations?

NOTE: For advice on pump selection or application, send a completed "Pump Application Fact Sheet" to a local university, a pump manufacturer or to VITA, College Campus, Schenectady, New York 12308, U.S.A.

Source:

Benjamin P. Coe, P.E./Executive Director,  
VITA, Schenectady, New York

**FIGURE 2**  
(NOT DRAWN TO SCALE)



PIPE SIZE	
DIAMETER IN CM	
INSIDE	OUTSIDE
2.66	3.34
5.25	6.04

## DETERMINING PIPE SIZE OR VELOCITY OF WATER IN PIPES

The choice of pipe size is one of the first steps in designing a simple water system.

The alignment chart in Figure 1 can be used to compute the pipe size needed for a water system when the water velocity is known. The chart can also be used to find out what water velocity is needed with a given pipe size to yield the required rate of flow.

### Tools and Materials

Straightedge and pencil

Practical water systems use water velocities from 1.2 to 1.8 meters per second. Very fast velocity requires high pressure pumps which in turn require high pressure pumps which in turn require large motors and use excessive power. Velocities which are too low are expensive because larger pipe diameters must be used.

It may be advisable to calculate the cost of two or more systems based on different pipe size. Remember, it is usually wise to choose a little larger pipe if higher flows are expected in the next 5 or 10 years. In addition, water pipes often build up rust and scale reducing the diameter and thereby increasing the velocity and pump pressure required to maintain flow at the original rate. If extra capacity is designed into the piping system, more water can be delivered by adding to the pump capacity without changing all the piping.

To use the chart, locate the flow (liters per minute) you need on the Q-scale. Draw a line from that point, through 1.8m/sec velocity on the V-scale to the d-scale. Choose the nearest standard size pipe.

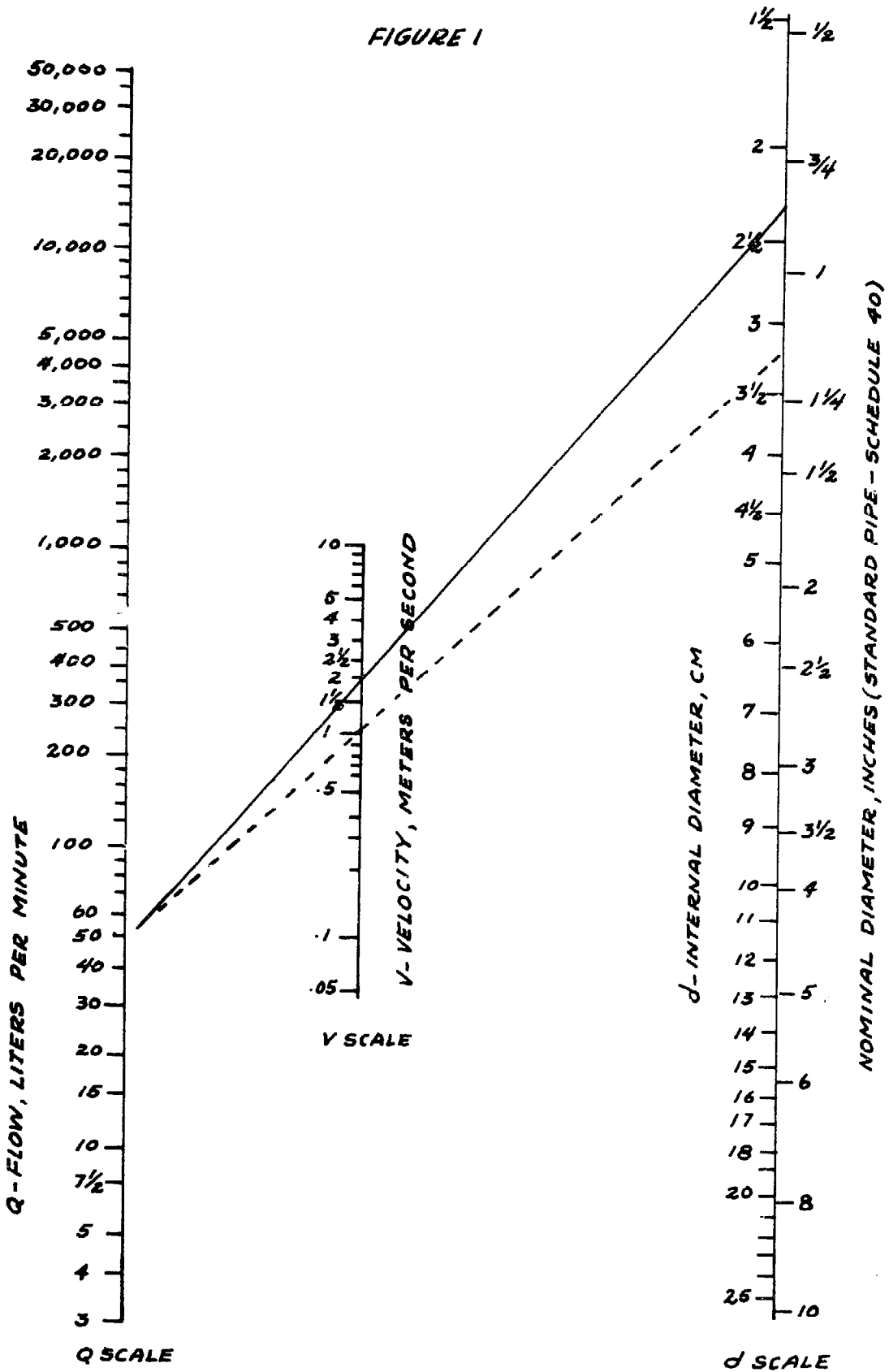
### Example:

Suppose you need a flow of 50 liters per minute at the time of peak demand. Draw a line from 50 liters per minute on the Q-scale through 1.8m/sec on the V-scale. Notice that this intersects the d-scale at about 2.25. The correct pipe size to choose would be the next largest standard pipe size: e.g. 1" nominal diameter, U.S. Schedule 40. If pumping costs (electricity or fuel) are high, it would be well to limit limit velocity to 1.2m/sec and install a slightly larger pipe size.

### Source:

Crane Company Technical Paper #409, pages 46-47.

FIGURE 1



**ESTIMATING FLOW RESISTANCE OF PIPE FITTINGS**

One of the forces which a pump must overcome to deliver water is the friction/resistance of pipe fittings and valves to the flow of water. Any bends, valves, constrictions or enlargements (such as passing through a tank) add to friction.

The alignment chart in Figure 1 gives a simple but reliable way to estimate this resistance: it gives the equivalent length of straight pipe which would have the same resistance. The sum of these equivalent lengths is then added to the actual length of pipe: this gives the total equivalent pipe length, which is used in the following entry, "Determining Pump Capacity and Horsepower Requirement," to determine total friction loss.

Rather than calculate the pressure drop for each valve or fitting separately, this chart will give the equivalent length of straight pipe.

**Valves:** Note the difference in equivalent length depending on how far the valve is open.

1. Gate Valve - full opening valve; can see through it when open; used for complete shut off of flow.
2. Globe Valve - cannot see through it when open; used for regulating flow.
3. Angle Valve - like the globe, used for regulating flow.
4. Swing Check Valve - a flapper opens to allow flow in one direction but closes when water tries to flow in the opposite direction.

Fittings

Study the variety of tees and elbows: note carefully the direction of flow through the tee. To determine the equivalent length of a fitting, (a) pick proper dot on "fitting" line, (b) connect with inside diameter of pipe, using a straight edge; read equivalent length of straight pipe in meters, (c) add the fitting equivalent length to the actual length of pipe being used.

Source:

Crane Company Technical Paper #409, pages 20-21.

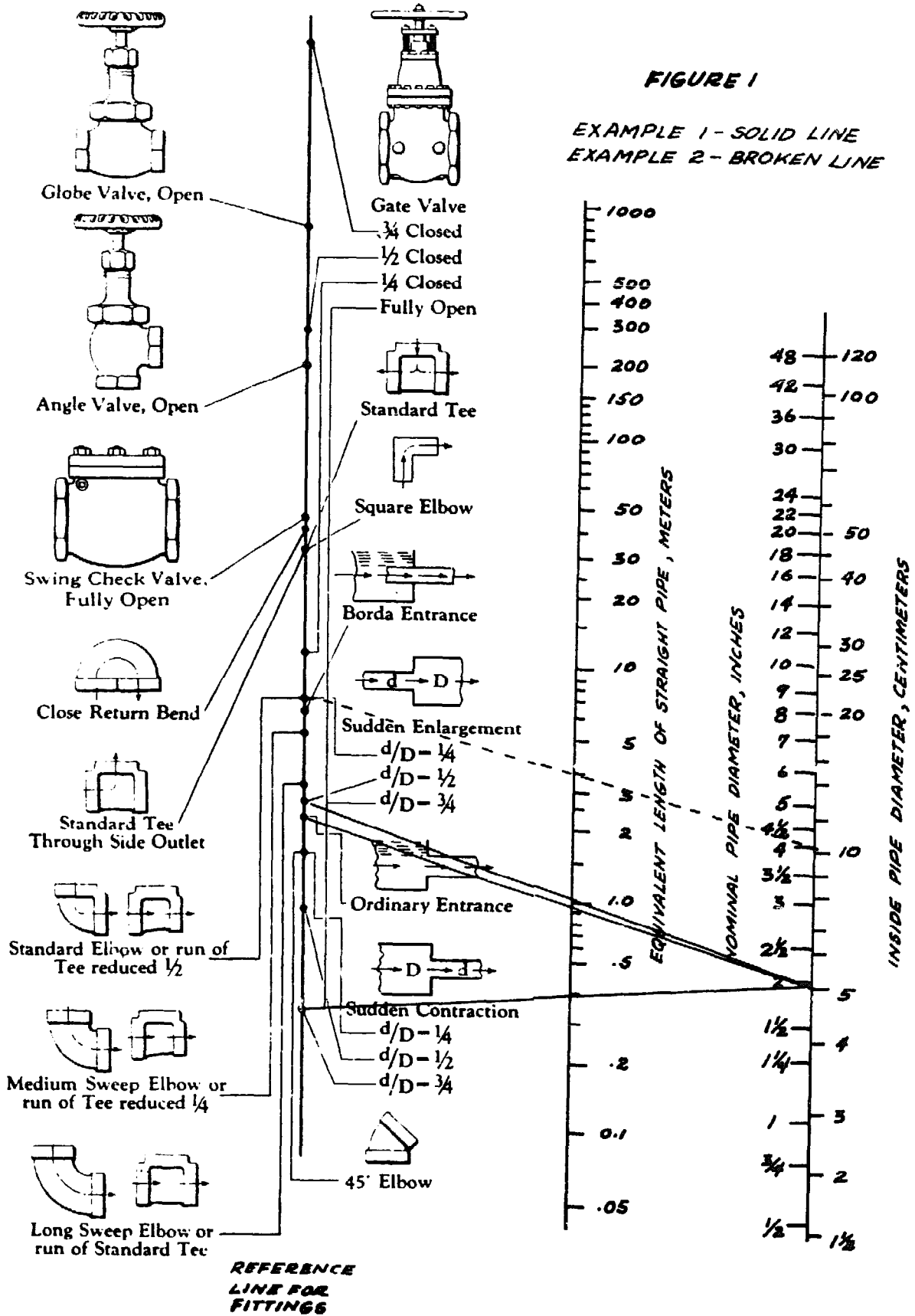
Example 1:

<u>Pipe with 5cm inside diameter</u>	<u>Equivalent Length in Meters</u>
a. Gate Valve (fully open)	.4
b. Flow into line - ordinary entrance	1.0
c. Sudden enlargement into 10cm pipe ( $d/D = 1/2$ )	1.0
d. Pipe length	<u>10.0</u>
<b>Total Equivalent Pipe Length</b>	<b>12.4</b>

Example 2:

<u>Pipe with 10cm inside diameter</u>	<u>Equivalent Length in Meters</u>
a. Elbow (standard)	4.0
b. Pipe length	<u>10.0</u>
<b>Total Equivalent Pipe Length</b>	<b>14.0</b>

# Resistance of Valves and Fittings to Flow of Fluids





## DETERMINING PUMP OUTLET SIZE AND HORSEPOWER REQUIREMENT

With the alignment chart in Figure 2, you can determine the necessary pump size (diameter of discharge outlet) and the amount of horsepower needed to power the pump. The power can be supplied by men or by motors.

A man can generate about 0.1 horsepower (HP) for a reasonably long period and 0.4 HP for short bursts. Motors are designed for varying amounts of horsepower.

### Tools

Straight edge and pencil for alignment chart

To get the approximate pump size needed for lifting liquid to a known height through simple piping, follow these steps:

1. Determine the quantity of flow desired in liters per minute.
2. Measure the height of the lift required (from the point where the water enters the pump suction piping to where it discharges).
3. Using the entry "Determining Pipe Size or Velocity of Water in Pipes," page 78, choose a pipe size which will give a water velocity of about 1.8 meters per second (6' per second). This velocity is chosen because it will generally give the most economical combination of pump and piping; Step 5 explains how to convert for higher or lower water velocities.
4. Estimate the pipe friction-loss "head" (a 3-meter "head" represents the pressure at the bottom of a 2-meter-high column of water) for the total equivalent pipe length, including suction and discharge piping and equi-

valent pipe lengths for valves and fittings, using the following equation:

$$\text{Friction-loss head} = \frac{F \times \text{total equivalent pipe length}}{100}$$

where F equals approximate friction head (in meters) per 100 meters of pipe. To get the value of F, see the table in Figure 1. For an explanation of total equivalent pipe length, see the preceding entry.

5. To find F (approximate friction head in meters per 100m of pipe) when water velocity is higher or lower than 1.8 meters per second, use the following equation:

$$F = \frac{F_{\text{at } 1.8\text{m/sec}} \times V^2}{1.8\text{m/sec}^2},$$

where V = higher or lower velocity

### Example:

If the water velocity is 3.6m per second and  $F_{\text{at } 1.8\text{m/sec}}$  is 16, then:

$$F = \frac{16 \times 3.6^2}{1.8^2} = \frac{16 \times 13}{3.24} = 64$$

6. Obtain "Total Head" as follows:  
Total Head = Height of Lift + Friction-loss Head

Pipe inside diameter: cm	2.5	5.1	7.6	10.2	15.2	20.4	30.6	61.2
inches*	1"	2"	3"	4"	6"	8"	12"	24"
F (approximate friction loss in meters per 100 meters of pipe)	16	7	5	3	2	1.5	1	0.5

Figure 1. Average friction loss in meters for fresh water flowing through steel pipe when velocity is 1.8 meters (6 feet) per second.

\*For the degree of accuracy of this method, either actual inside diameter in inches or nominal pipe size, U.S. Schedule 40, can be used.

- Using a straight edge, connect the proper point on the T-scale with the proper point on the Q-scale; read motor horsepower and pump size on the other two scales.

Example:

Desired flow: 400 liters per minute

Height of lift: 16 meters, No fittings

Pipe size: 5cm

Friction-loss head: about 1 meter

Total head: 17 meters

Solution:

Pump size: 5cm

Motor horsepower: 3HP

Note that water horsepower is less than motor horsepower (see HP-scale, Figure 2). This is because of friction losses in the pump and motor. The alignment chart should be used for rough estimate only. For an exact determination, give all information on flow and piping to a pump manufacturer or an independent expert. He has the exact data on pumps for various applications. Pump specifications can be tricky especially if suction piping is long and the suction lift is great.

Conversion to Metric Horsepower

Given the limits of accuracy of this method, metric horsepower can be considered roughly equal to the horsepower indicated by the alignment chart. Actual metric horsepower can be obtained by multiplying horsepower by 1.014.

Source:

Nomographic Charts, by C. A. Kulman, McGraw-Hill Book Co., New York, 1951, pages 108-109.

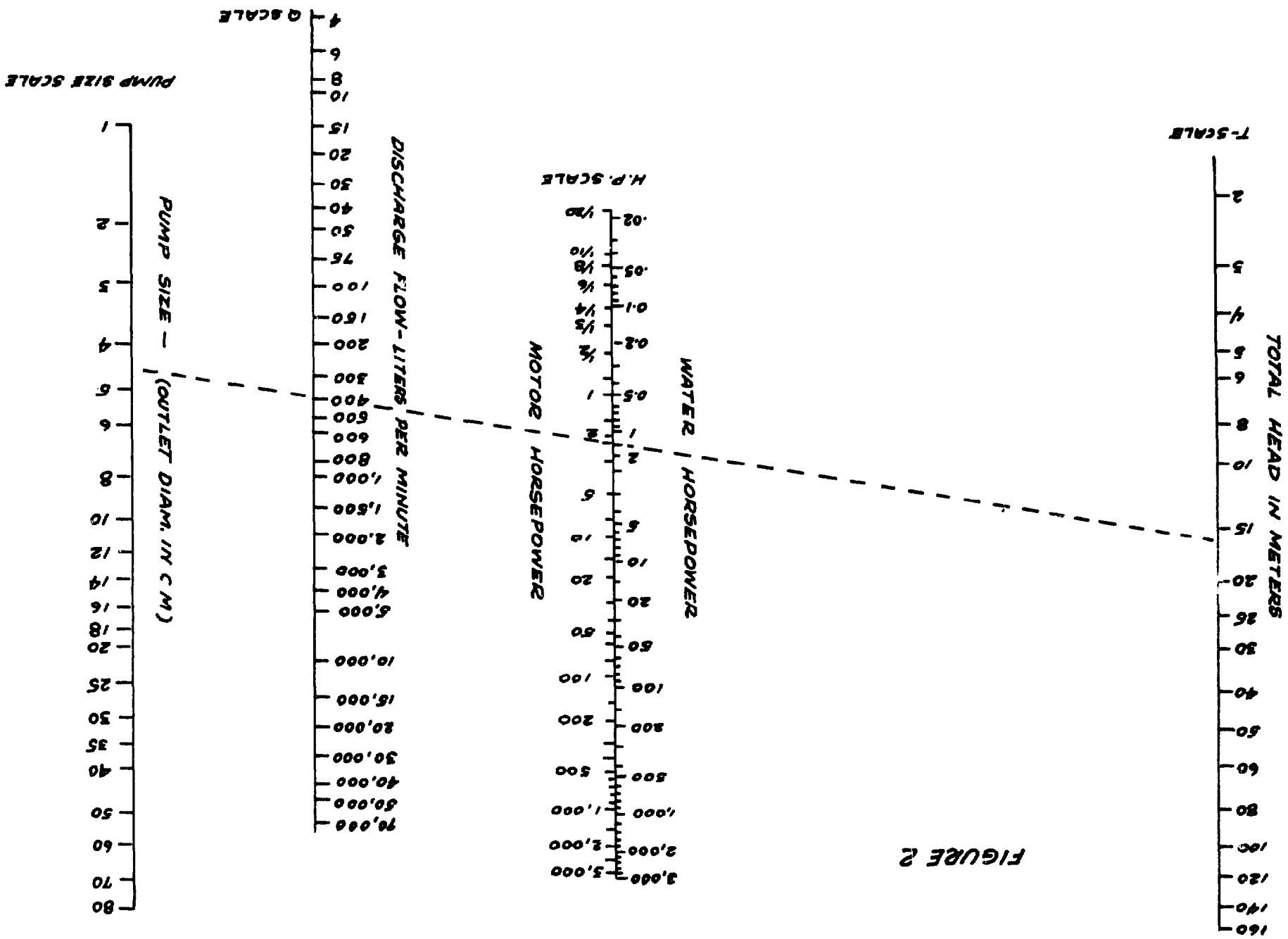


FIGURE 2

## DETERMINING LIFT PUMP CAPABILITY

The height that a lift pump can raise water depends on altitude and, to a lesser extent, on water temperature. The graph in Figure 1 will help you to find out what a lift pump can do at various altitudes and water temperatures.

### Tools

Measuring tape

Thermometer

If you know your altitude and the temperature of your water, Figure 1 will tell you the maximum allowable distance between the pump cylinder and the lowest water level expected. If the graph shows that lift pumps are marginal or will not work, then a force pump should be used. This involves putting the

cylinder down in the well, close enough to the lowest expected water level to be certain of proper functioning.

The graph shows normal lifts. Maximum possible lifts under favorable conditions would be about 1.2 meters higher, but this would require slower pumping and would probably give much difficulty in "losing the prime."

Check predictions from the graph by measuring lifts in nearby wells or by experimentation.

### Source:

Mechanical Engineer's Handbook, by Theodore Baumeister, 6th edition, McGraw-Hill Book Co., New York, copyright 1958. Used by permission. (Adapted.)

### Example:

Suppose your elevation is 2000 meters and the water temperature is 25C. The graph shows that the normal lift would be 4 meters.

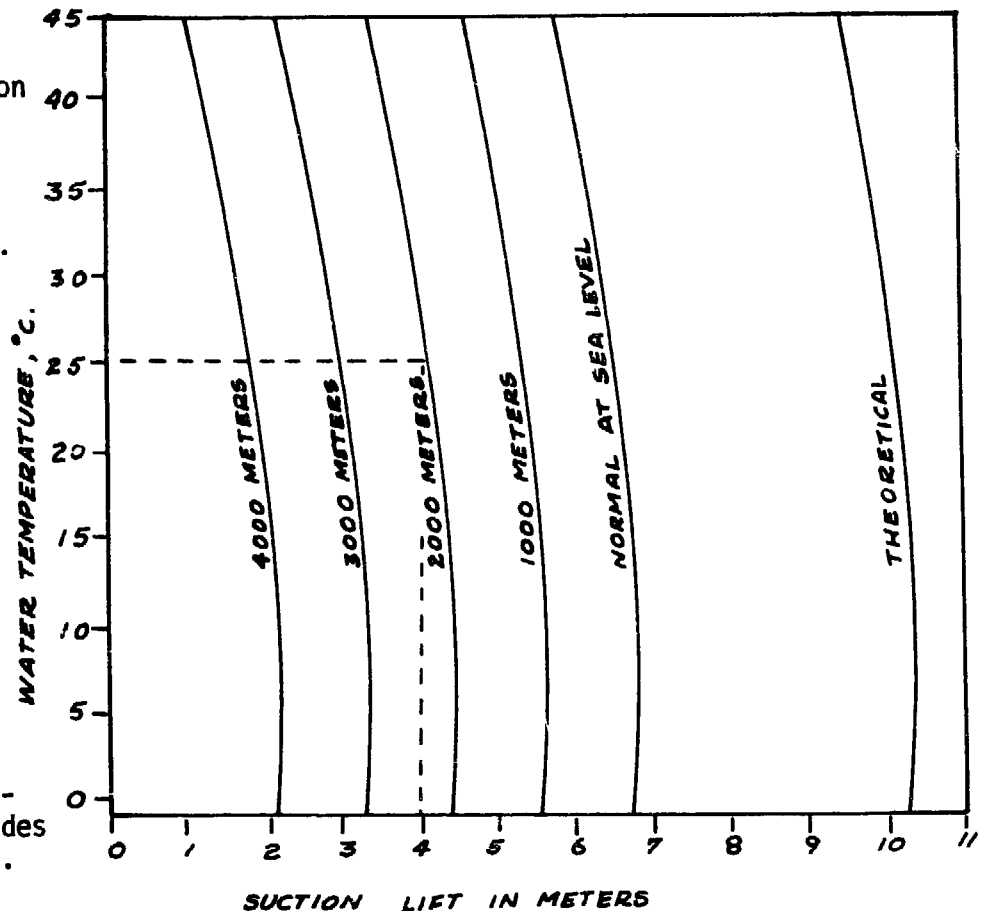


Figure 1. Graph showing lift pump capabilities at various altitudes and water temperatures. Broken lines indicate example given in text.

FIGURE 1

## BAMBOO PIPING

Where bamboo is readily available, it seems to be a good substitute for metal pipe. Bamboo pipe is easy to make with unskilled labor and local materials. The important features of the design and construction of a bamboo piping system are given here.

Bamboo pipe is extensively used in Indonesia to transport water to villages. In many rural areas of Taiwan, bamboo is commonly used in place of galvanized iron for deep wells up to a maximum depth of 150 meters (492'). Bamboos of 50mm (2") diameter are straightened by means of heat, and the inside nodes knocked out. The screen is made by punching holes in the bamboo and wrapping that section with a fibrous mat-like material from a palm tree, *Chamaerops humilis*. In fact,

such fibrous screens are also used in many galvanized iron tube wells.

### Tools and Materials

Chisels (see text and Figure 2)

Nail, cotter pin or linchpin

Caulking materials

Tar

Rope

Bamboo piping can hold pressure up to two atmospheres (about 2.1kg per square centimeter or 30 pounds per square inch). It cannot, therefore be used as pressure piping. It is most suitable in areas where the source of

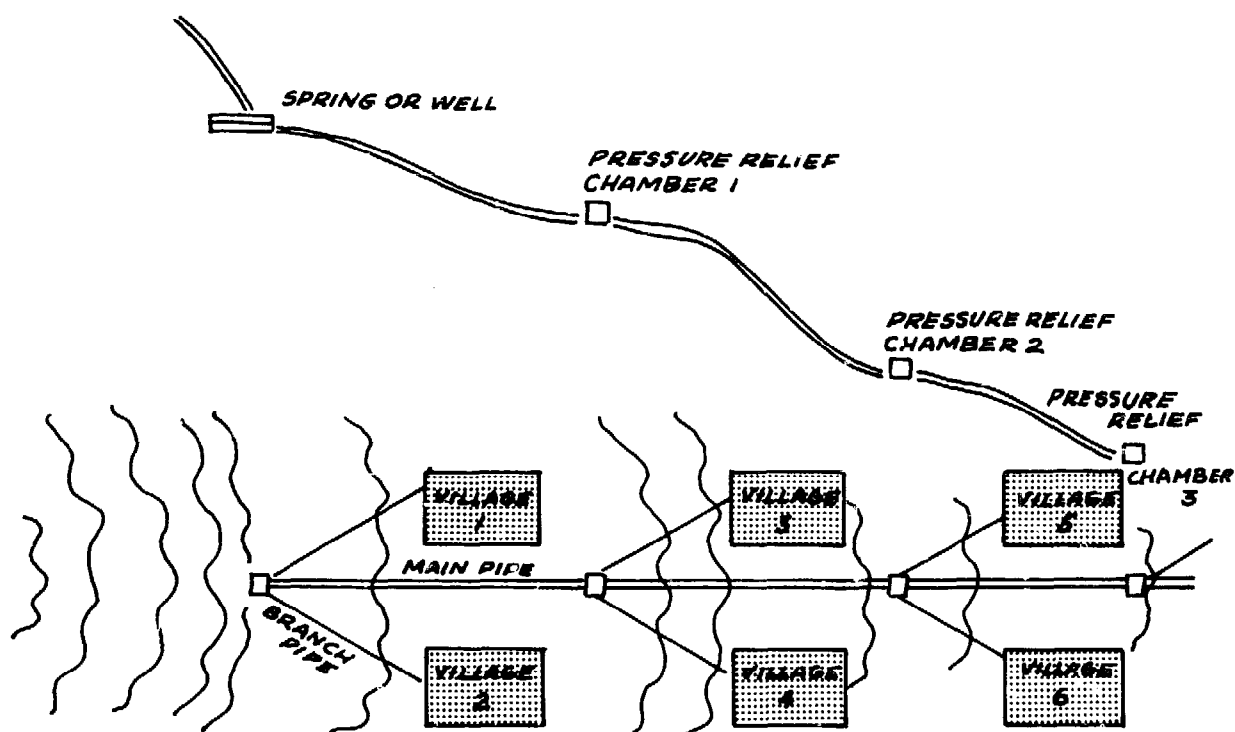


FIGURE 1

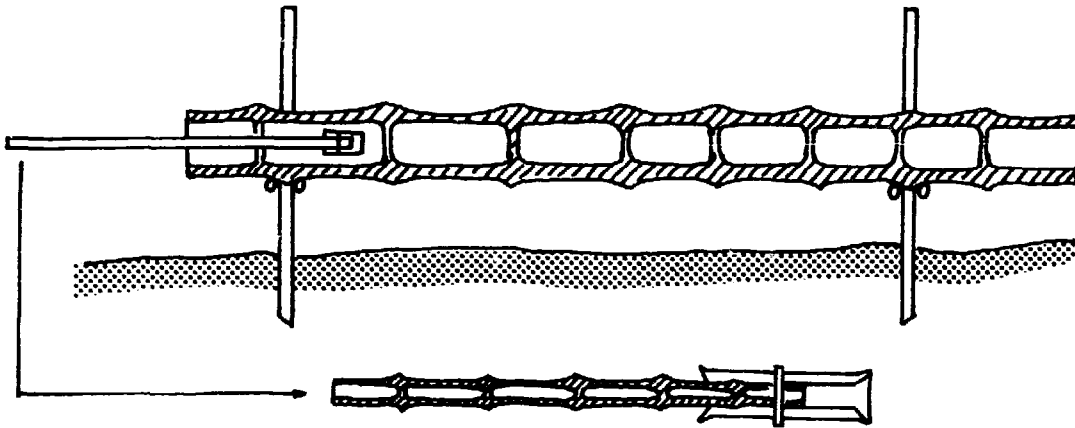


FIGURE 2

supply is higher than the area to be served and the flow is under gravity.

#### Health Aspects

If bamboo piping is to carry water for drinking purposes, the only preservative treatment recommended is boric acid: borax in a 1:1 ratio by weight. The recommended treatment is to immerse green bamboo completely in a solution of 95 percent water and 5 percent boric acid: borax.

After a bamboo pipe is put into operation it gives an undesirable odor to the water. This, however, disappears after about three weeks. If chlorination is done before discharge to the pipe, a reservoir giving sufficient contact time for effective disinfection is required since bamboo pipe removes chlorine compounds and no residual chlorine will be maintained in the pipe. To avoid possible contamination by ground water, an ever present danger, it is desirable to maintain the internal pressure within the pipe at a higher level than any external water pressure outside the pipe. Any leakage will then be from the pipe, and contaminated water will not enter the pipe.

#### Design and Construction

Bamboo pipe is made of lengths of bamboo of the desired diameter by boring out the dividing membrane at the joints. A circular chisel for this purpose is shown in Figure 2. One end of a short length of steel pipe is belled out to increase the diameter and the edge sharpened. A length of bamboo pipe of sufficiently small diameter to slide into the pipe is used as a boring bar and secured to the pipe by drilling a small hole through the assembly and driving a nail through the hole. This nail is also known as a cotter pin or linchpin. Three or more chisels ranging from smallest to the maximum desired diameter are required. At each joint the membrane is removed by first boring a hole with the smallest diameter chisel, then, progressively enlarging the hole with the larger diameter chisels.

Bamboo pipe lengths are joined in a number of ways, as shown in Figure 3. Joints are made watertight by caulking with cotton wool mixed with tar, then tightly binding with rope soaked in hot tar.

Bamboo pipe is preserved by laying

the pipe below ground level and ensuring a continuous flow in the pipe. Where the pipe is laid above ground level, it is protected by wrapping it with layers of palm fiber with soil between the layers. This treatment will give a life expectancy of about 3 to 4 years to the pipe; some bamboo will last up to 5-6 years. Deterioration and failure usually occur at the natural joints, which are the weakest parts.

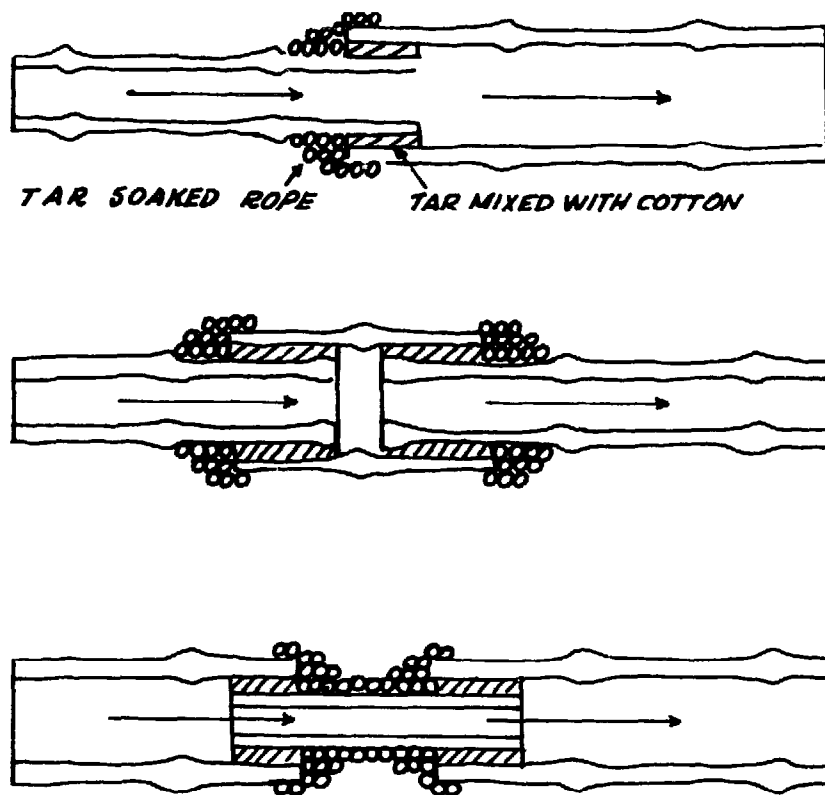
Where the depth of the pipe below the water source is such that the maximum pressure will be exceeded, pressure relief chambers must be installed. A typical chamber is shown in Figure 4. These chambers are also installed as reservoirs for branch supply lines to villages en route.

A diagrammatic sketch of a bamboo pipe water supply system for a number of villages is shown in Figure 1. Size requirements for bamboo pipe may be determined by using the pipe-capacity alignment chart in Figure 5. A design for a public fountain made from bamboo is shown in Figure 6.

Source:

"Water Supply Using Bamboo Pipe," AID-UNC/IPSED Series Item No. 3, International Program in Sanitary Engineering Design, University of North Carolina, 1966.

FIGURE 3



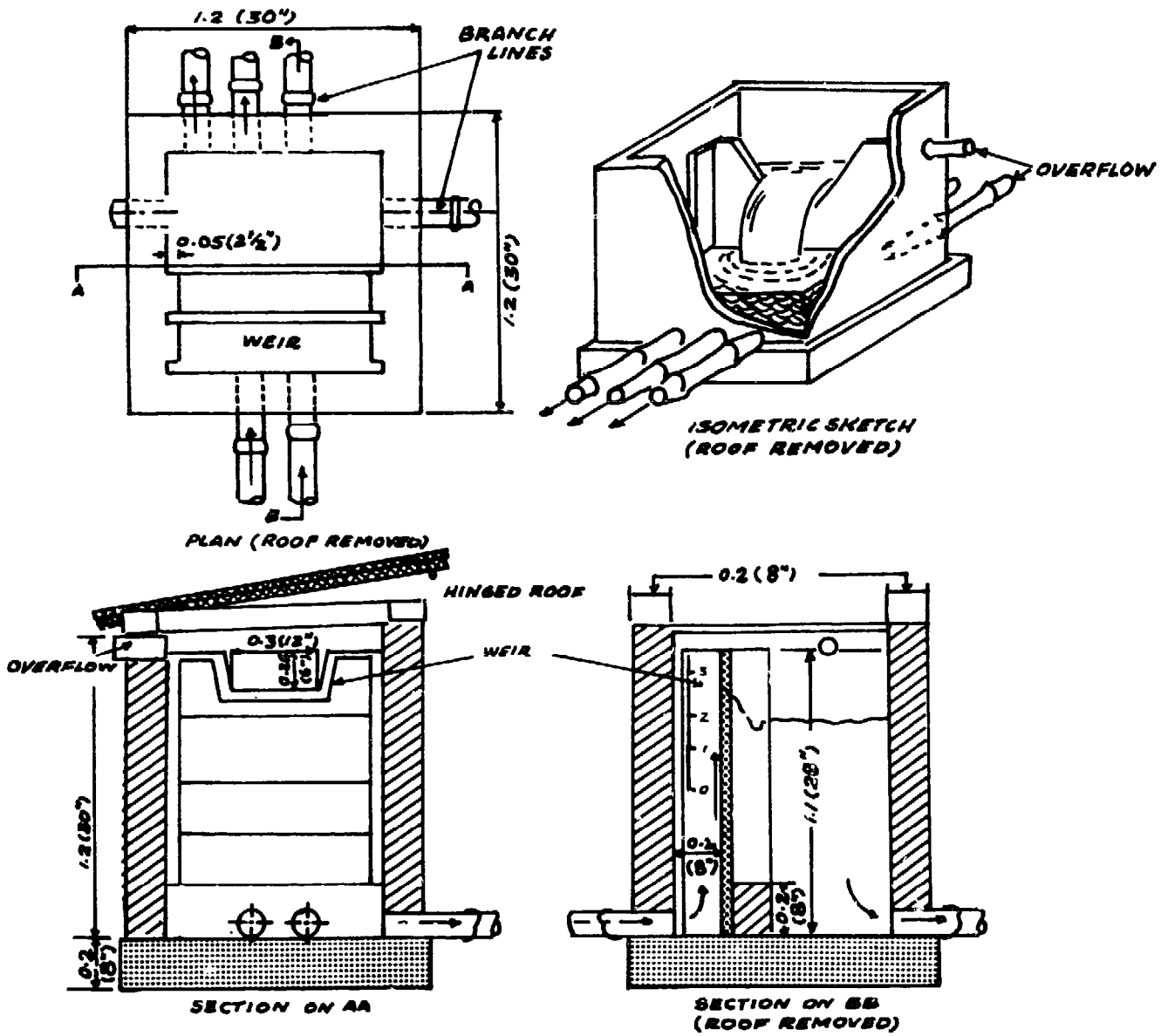
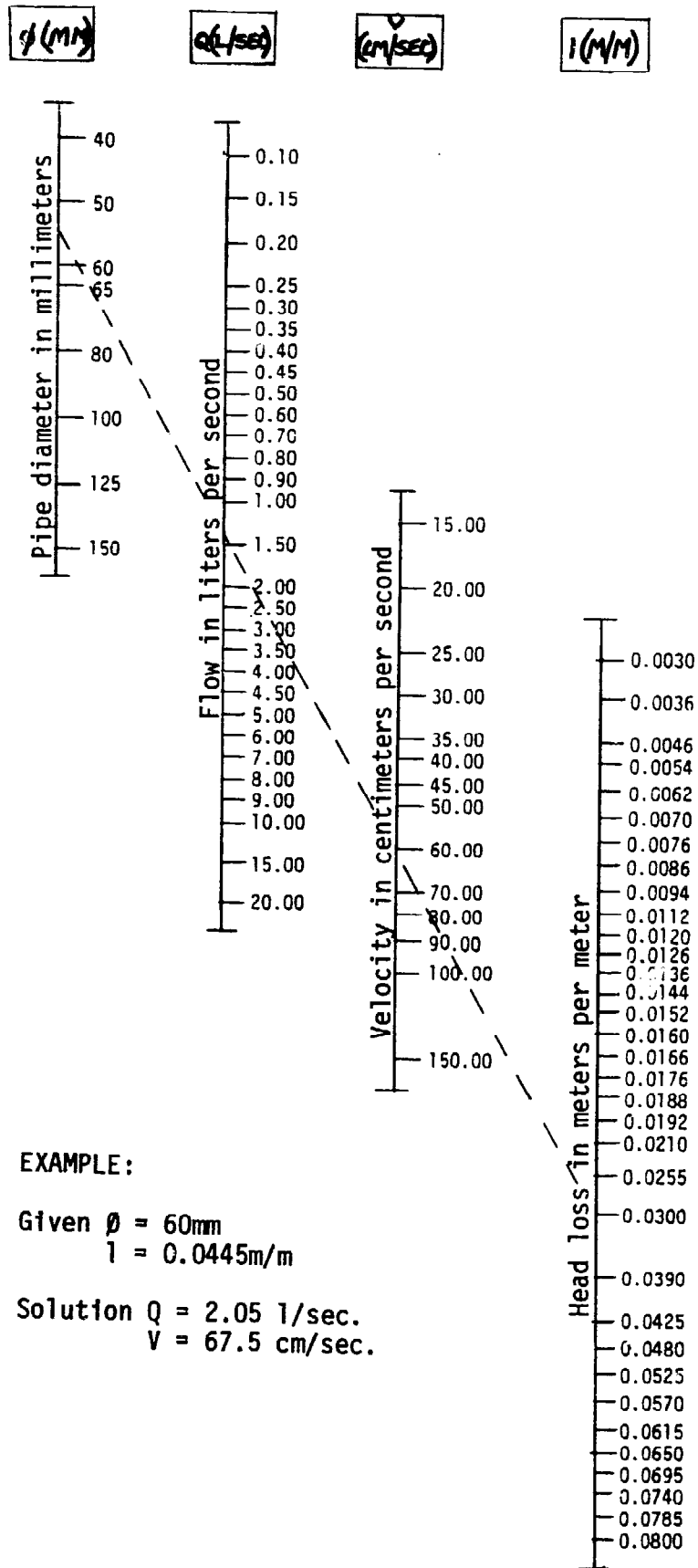


FIGURE 4



FIGURE 5  
 NOMOGRAPH FOR FLOW IN BAMBOO PIPE



EXAMPLE:

Given  $\phi = 60\text{mm}$   
 $l = 0.0445\text{m/m}$

Solution  $Q = 2.05 \text{ l/sec.}$   
 $V = 67.5 \text{ cm/sec.}$

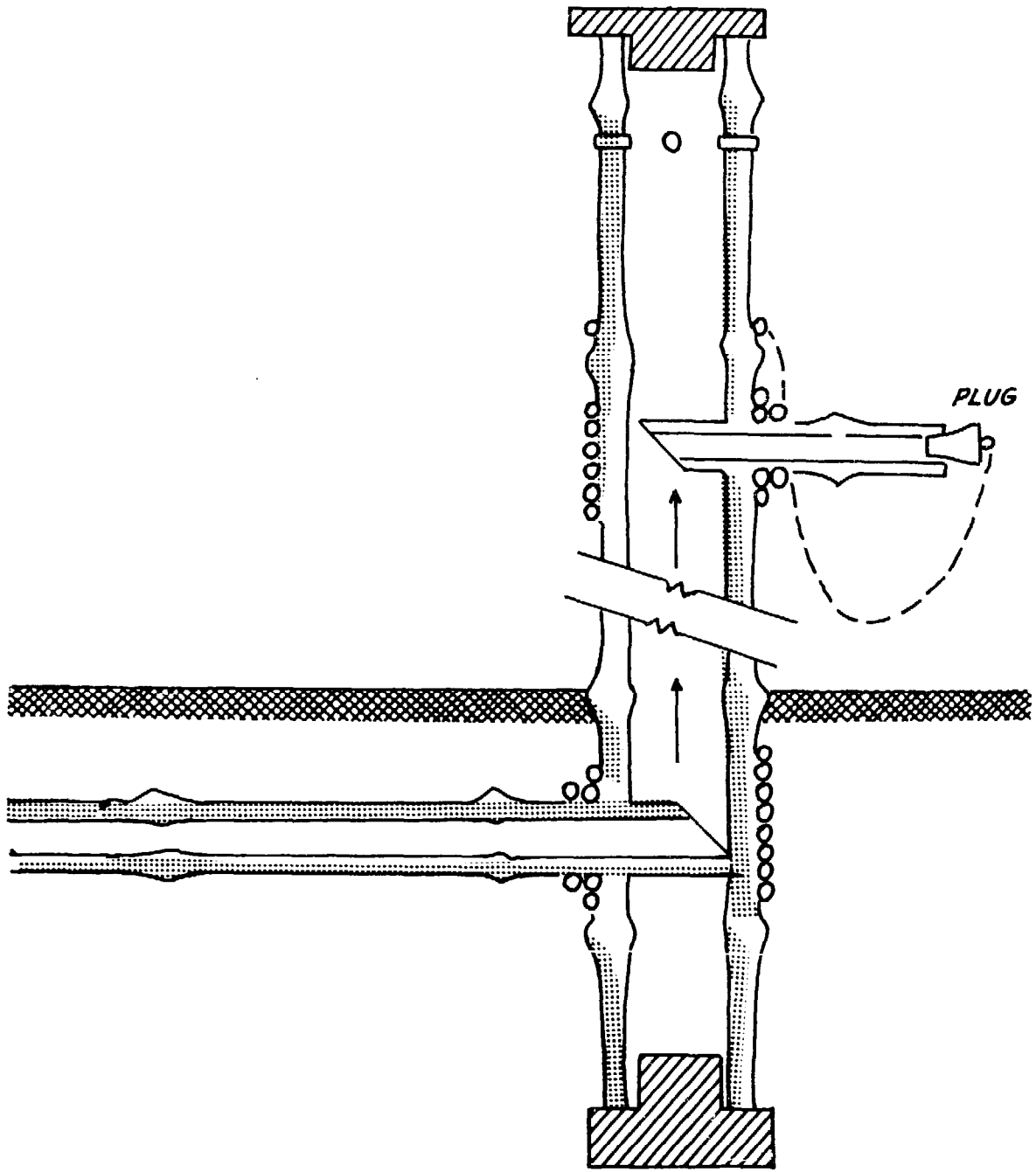


FIGURE 6 PUBLIC FOUNTAIN

## CHAIN PUMP FOR IRRIGATION

The chain pump, which can be powered by man or animal, is primarily a shallow-well pump to lift water for irrigation (see Figure 1). It works best when the lift is less than 6 meters (20'). The water source must have a depth of about 5 chain links.

Both the pump capacity and the power requirement for any lift are proportional to the square of the diameter of the tube. Figure 2 shows what can be expected from a 10cm (4") diameter tube operated by four men working in two shifts.

The pump is intended for use as an irrigation pump because it is difficult to seal for use as a sanitary pump.

### Tools and Materials

Welding or brazing equipment

Metal-cutting equipment

Woodworking tools

Pipe: 10cm (4") outside diameter,  
length as needed

5cm (2") outside diameter,  
length as needed

Chain with links about 8mm (5/16") in  
diameter, length as needed

Sheet steel, 3mm (1/8") thick

Sheet steel, 6mm (1/4") thick

Steel rod, 8mm (5/16") in diameter

Steel rod, 12.7mm (1/2") in diameter

Leather or rubber for washers

The entire chain pump is shown in Figure 3. Details of this pump can be changed to fit materials available and structure of the well.

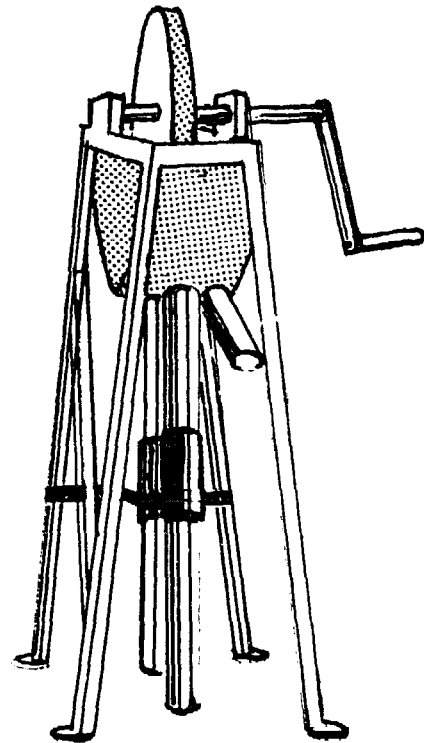


FIGURE 1

The piston links (see Figures 4, 5, 6 and 7) are made from three parts:

1. a leather or rubber washer (see Figure 4) with an outside diameter about two thicknesses of a washer larger than the inside diameter of the pipe.
2. a piston disc (see Figure 5).
3. a retaining plate (see Figure 6).

The piston link is made as shown in Figure 7. Center all three parts, clamp them together temporarily, drill a hole about 6mm (1/4") in diameter through all three parts and fasten them together with a bolt or rivet.

The winch is built as shown in Figure 3. Two steel discs 6mm (1/4") thick are welded to the pipe shaft.

**FIGURE 2**

<i>LIFT</i>	<i>QUANTITY</i>
<i>6 METERS (18 FEET)</i>	<i>11 CUBIC METERS/HOUR (2906 GALLONS/HOUR)</i>
<i>3 METERS (9 FEET)</i>	<i>20 CUBIC METERS/HOUR (5284 GALLONS/HOUR)</i>
<i>1.5 TO 2 METERS (4.5 TO 6 FEET)</i>	<i>25-30 CUBIC METERS/HOUR (6605 TO 7926 GALLONS/HOUR)</i>

Twelve steel rods, 12.7mm (1/2") thick, are spaced at equal distances, at or near the outside diameter and are welded in place. The rods may be laid on the outside of the discs, if desired.

A crank and handle of wood or metal is then welded or bolted to the winch shaft.

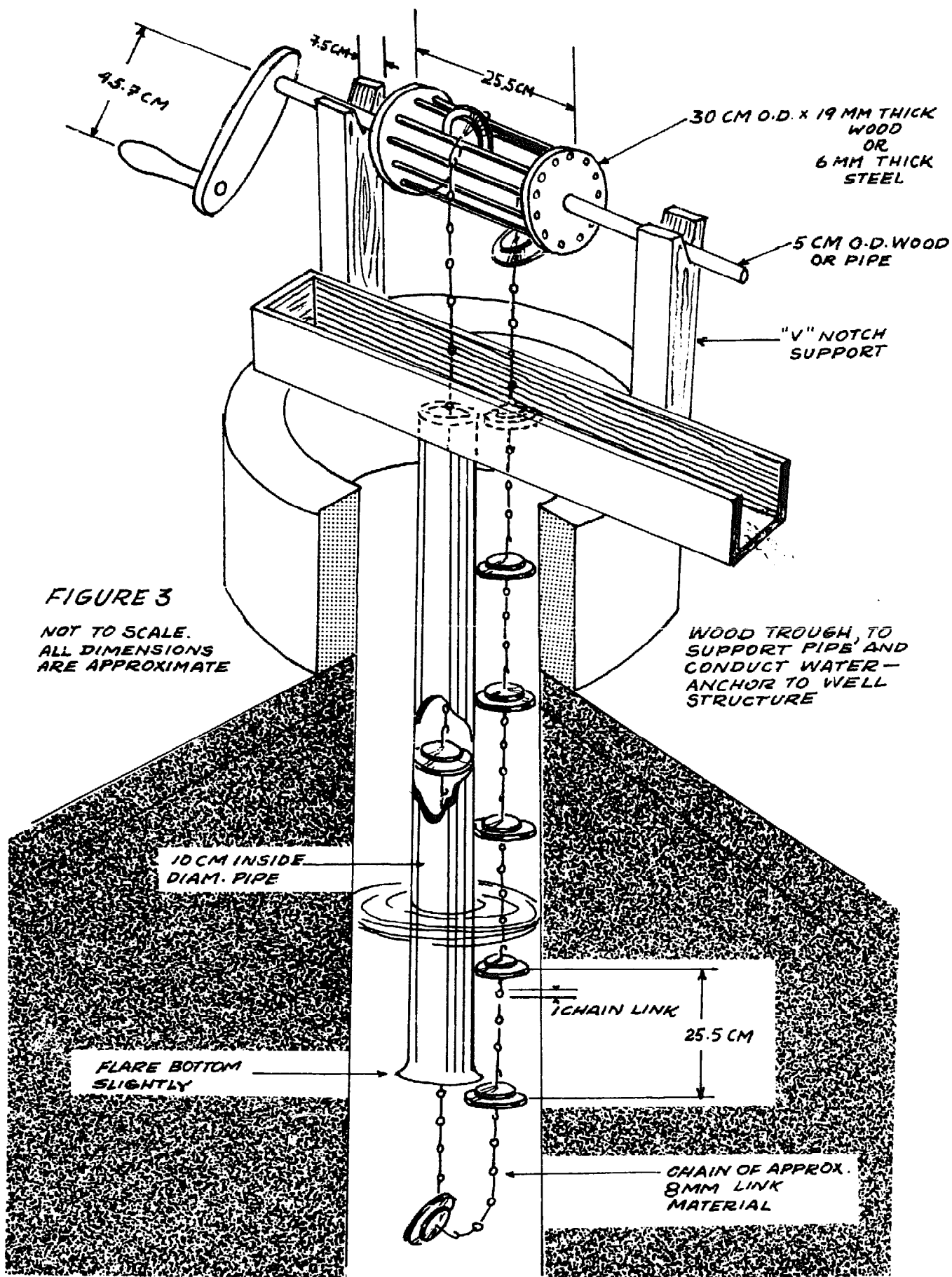
The supports for the winch shaft (see Figure 3) can be V-notched to hold the shaft, which will gradually wear its own groove. A strap or block can be added across the top, if necessary, to hold the shaft in place.

The pipe can be supported by threading or welding a flange to its upper end (see Figure 8). The flange should be 8mm to 10mm (5/16" to 3/8") thick. The pipe passes through a hole in the bottom of the trough and hangs from the trough into the well.

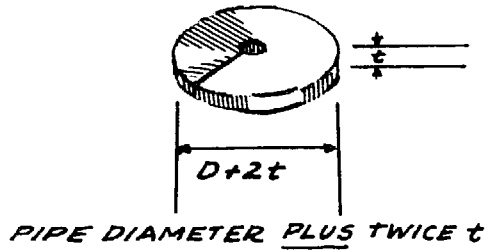
Sources:

Robert G. Young, VITA Volunteer, New Holland, Pennsylvania, Chapter

Water Lifting Devices for Irrigation, by Aldert Molenaar, Rome: Food and Agriculture Organization of the United Nations, 1956.

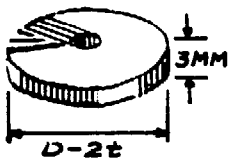


**FIGURE 4  
LEATHER WASHER**



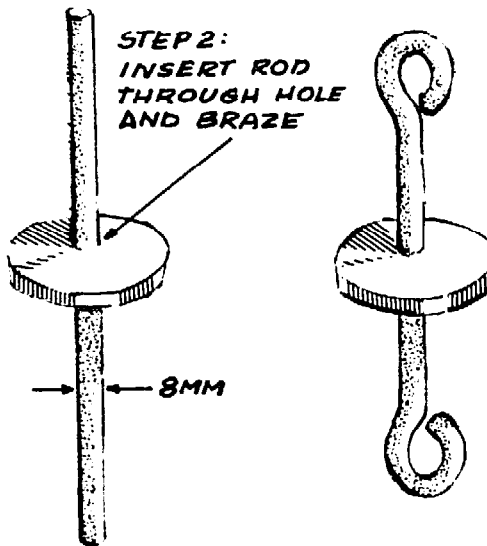
**FIGURE 5**

**STEP 1:  
CUT CIRCULAR DISK  
AND DRILL HOLE  
IN CENTER**



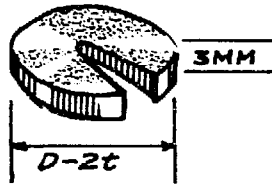
**PIPE DIAMETER  
LESS TWICE THE  
THICKNESS OF  
LEATHER WASHER**

**STEP 2:  
INSERT ROD  
THROUGH HOLE  
AND BRAZE**

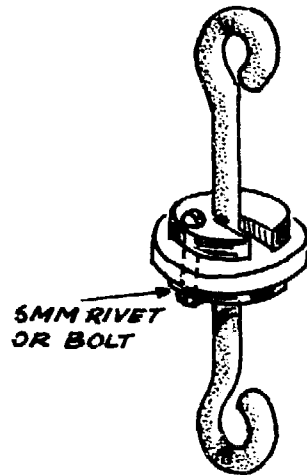


**STEP 3:  
BEND ROD  
ENDS TO  
LINK WITH  
CHAIN**

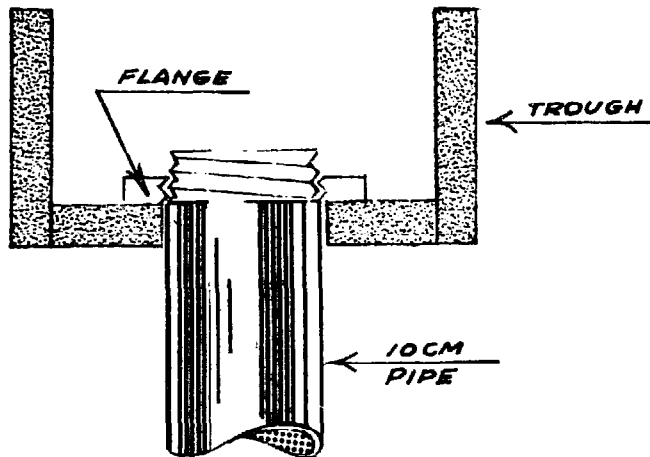
**FIGURE 6**  
**RETAINING PLATE**



**FIGURE 7**  
**PISTON LINK**  
**ASSEMBLED**



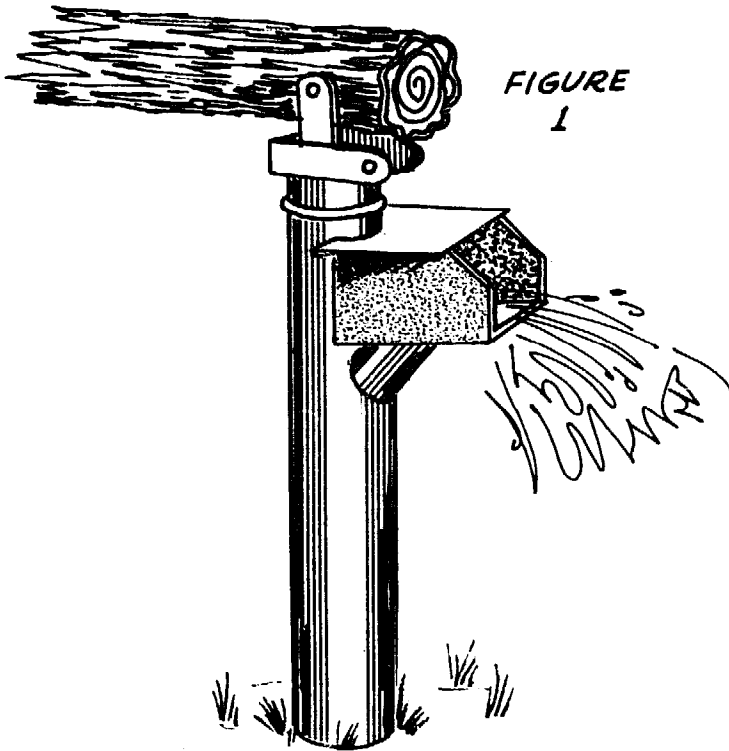
**FIGURE 8** **PIPE SUPPORT**



## INERTIA HAND PUMP

The inertia hand pump described here is a very efficient pump for lifting water short distances. It lifts water 4 meters (13') at the rate of 75 to 114 liters (20 to 30 U.S. gallons) per minute. It lifts water 1 meter (3.3') at the rate of 227 to 284 liters (60 to 75 gallons) per minute. Delivery depends on the number of persons pumping and their strength.

The pump is easily built by a tinsmith. Its three moving parts require almost no maintenance. The pump has been built in three different sizes for different water levels.



The pump is made from galvanized sheet metal of the heaviest weight obtainable which can be easily worked by a tinsmith (24 to 28-gage sheets have been used successfully). The pipe is formed and made air tight by soldering all joints and seams. The valve is made from the metal of discarded barrels and a piece of truck inner tube rubber. The bracket for attaching the handle is also made from barrel metal.

### Tools

Soldering equipment

Drill and bits or punch

Hammer

Saws

Tinsnips

Anvil (railroad rail or iron pipe)

### Materials for 1-meter (3.3') pump:

Galvanized iron (24 to 28 gage):

Shield: 61cm x 32cm, 1 piece  
(2' x 12 5/8")

Shield cover: 21cm x 22cm, 1 piece  
(8 1/4" x 8 5/8")

Pipe: 140cm x 49cm, 1 piece  
(55 1/8" x 19 1/4")

Top of pipe: 15cm x 15cm, 1 piece  
(6" x 6")

"Y" pipe: 49cm x 30cm, 1 piece  
(19 1/4" x 12")

Barrel metal:

Bracket: 15cm x 45cm, 1 piece  
(6" x 21 1/4")

Valve-bottom: 12cm (4 3/4") in diameter, 1 piece

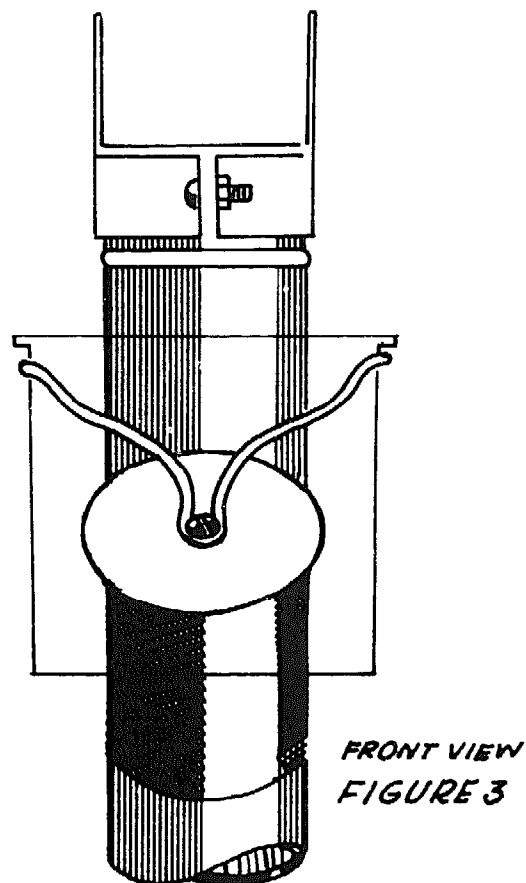
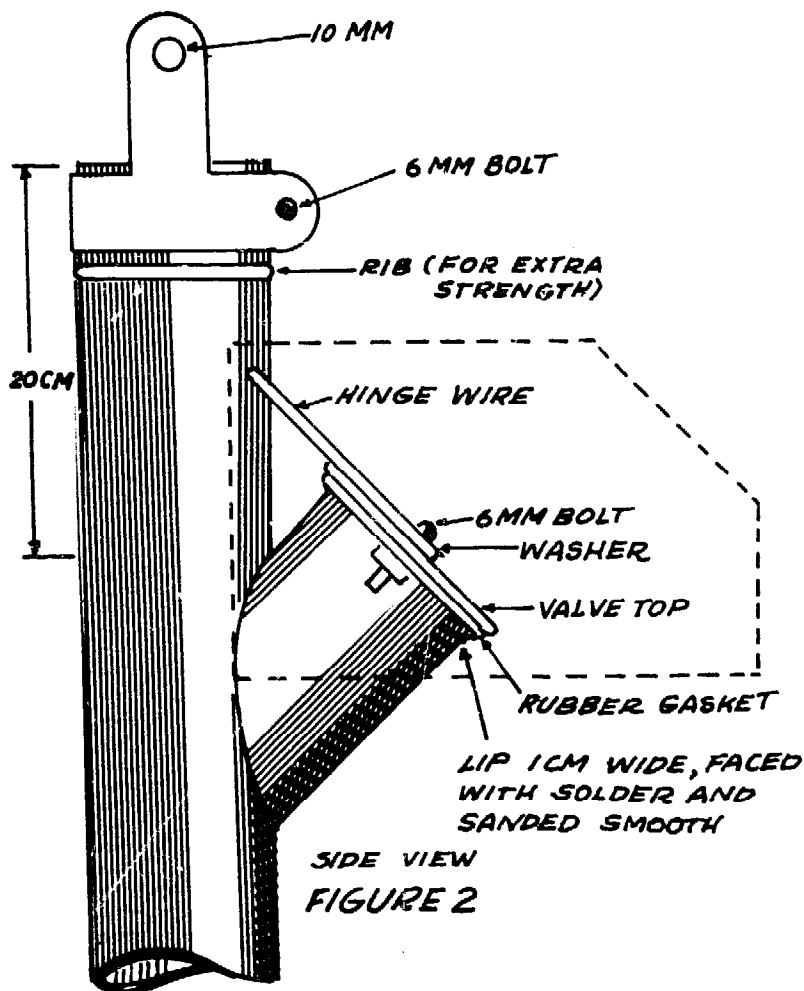
Valve-top: 18cm (7 1/8") in diameter, 1 piece

Wire:

Hinge: 4mm (5/32") in diameter,  
32cm (12 5/8") long

This pump can also be made from plastic pipe or bamboo.

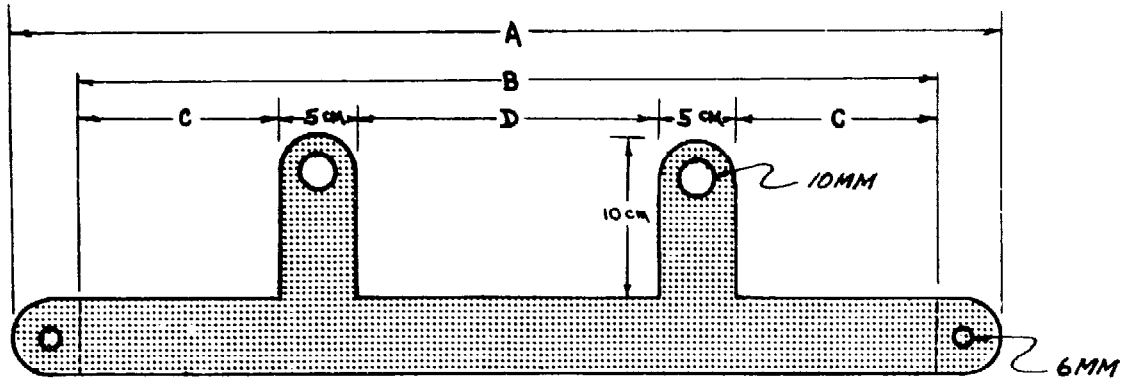




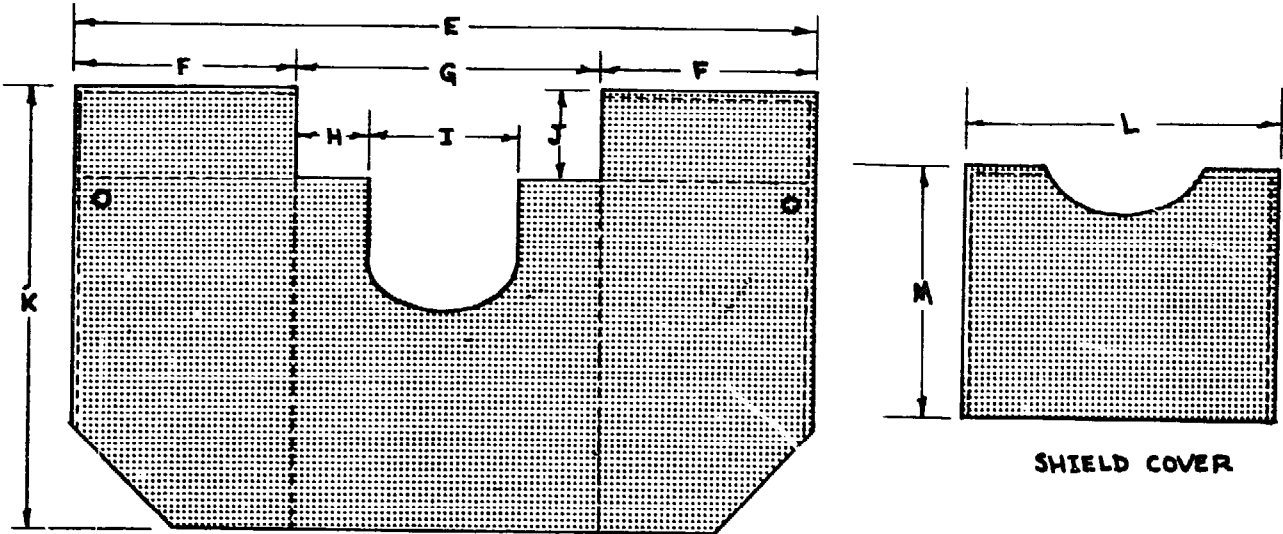
There are two points to be remembered concerning this pump. One is that the distance from the top of the pipe to the top of the hole where the short section of pipe is connected must be 20cm (8"). See Figure 2. The air which stays in the pipe above this junction serves as an air cushion (to prevent "hammering") and regulates the number of strokes pumped per minute. The second point is to remember to operate the pump with short strokes, 15 to 20cm (6" to 8") and at a rate of about 80 strokes per minute. There is a definite speed at which the pump works best and the operator will soon get the "feel" of his particular pump.

In building the two larger size pumps it is sometimes necessary to strengthen the pipe to keep it from collapsing if it hits the side of the well. It can be strengthened by forming "ribs" about every 30cm (12") below the valve or banding with bands made from barrel metal and attached with 6mm (1/4") bolts.

The handle is attached to the pump and post with a bolt 10mm (3/8") in diameter, or a large nail or rod of similar size.

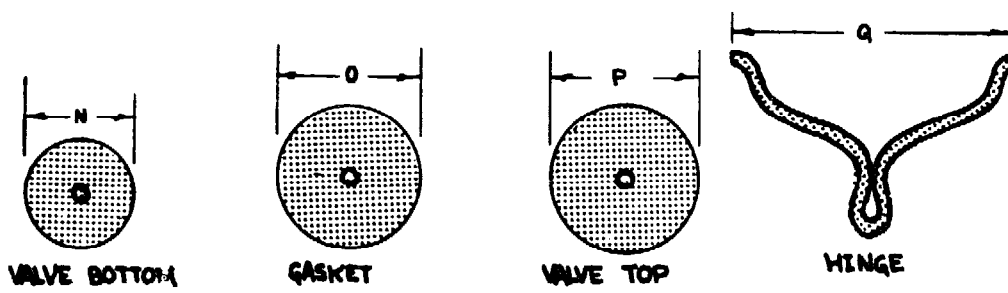


HANDLE BRACKET



SHIELD

SHIELD COVER

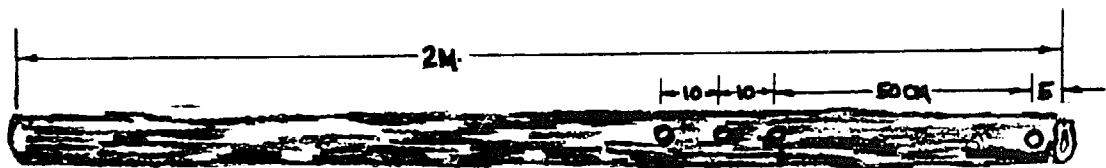


VALVE BOTTOM

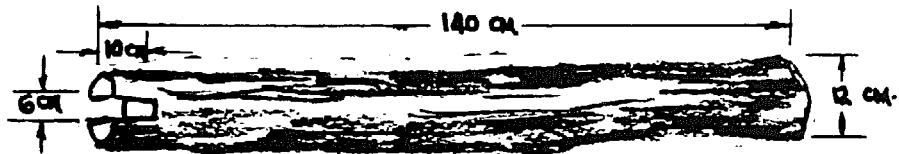
GASKET

VALVE TOP

HINGE



HANDLE



POST

FIGURE 4

**FIGURE 5**

<b>PART</b>	<b>MATERIAL</b>	<b>8 CM PIPE</b>	<b>10 CM PIPE</b>	<b>15 CM PIPE</b>
<b>HANDLE BRACKET</b>	<b>BARREL METAL</b>			
A		34 CM	40 CM	54 CM
B		24	30	44
C		3 1/2	5	8 1/2
D		7	10	17
<b>SHIELD</b>	<b>GALVANIZED TIN</b>			
E		43	49	61
F		14	16	20
G		14	16	20
H		3	3	2 1/2
I		8	10	15
J		4	4	4
K		30	30	32
<b>SHIELD COVER</b>	<b>GALVANIZED TIN</b>			
L		15	17	21
M		20	20	22
N	<b>BARREL METAL</b>	6	8	12
O	<b>INNER TUBE RUBBER</b>	11	13	18
P	<b>BARREL METAL</b>	11	13	18
Q	<b>WIRE (4 MM)</b>	16	18	22
<b>HANDLE</b>	<b>WOOD POLE</b>			
<b>POST</b>	<b>WOOD POST</b>			

**FIGURE 6**

<b>DIAMETER OF PIPE</b>	<b>LENGTH OF PIPE</b>	<b>HEIGHT OF LIFT</b>	<b>LITERS PER MINUTE AT 1830 METERS ELEVATION</b>
8 CM	450 CM	2 TO 4 METERS	75 TO 114
10 CM	270 CM	1 TO 2 METERS	114 TO 152
15 CM	140 CM	1 METER	227 TO 284

Figure 5 gives the dimensions of parts for pumps of three different sizes. Figure 6 shows the pumping capacity for each size.

Source:

Dale Fritz, VITA Volunteer,  
Washington, D.C.

## HANDLE MECHANISM FOR HAND PUMPS

The wearing parts of this durable hand-pump handle mechanism are wooden (see Figure 1). They can be easily replaced by a village carpenter. This handle has been designed to replace pump handle mechanisms which are difficult to maintain. Some have been in use for several years in India with only simple, infrequent repairs.

The mechanism shown in Figure 1 is bolted to the top flange of your pump. The mounting holes A and C in the block should be spaced to fit your pump (see Figure 6). Figure 2 shows a pump with this handle mechanism which is being manufactured by F. Humain and Bros., 28 Strand Road, Calcutta, India.

### Tools and Materials

Saw

Drill

Bits

Tap: 12.5mm (1/2")

Tap: 10mm (3/8")

Chisel

Drawknife, spokeshave or lathe

Hardwood: 86.4cm x 6.4cm x 6.4cm  
(34" x 2 1/2" x 2 1/2")

Mild steel rod: 19mm (3/4") in diameter  
and 46.5cm (16") long

Strap iron, 2 pieces: 26.7cm x 38mm  
x 6mm (10 1/2" x 1 1/2" x 1/4")

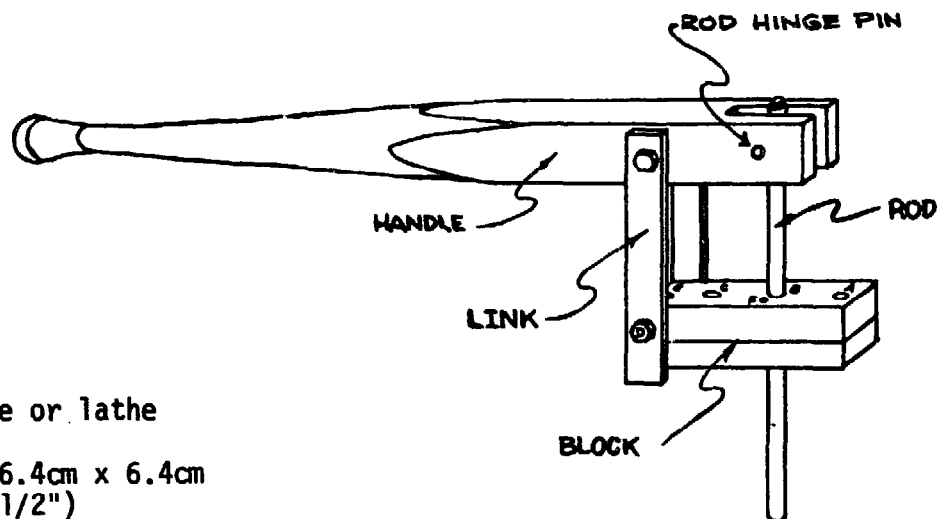


FIG 1

### BOLT HARDWARE

Number of bolts reqd.	Dia. mm	Length mm	Number of nuts reqd.	Number of lock-washers	Number of plain washers	Purpose - fastens:
1	10	38	0	0	0	76mm bolt to rod
1	10	76	0	0	2	Rod to Handle
2	12.5	89	2	4	4	Link to Handle Link to Block
2	12.5	?	2	2	2	Block to your pump
1	12.5	?	1	1	0	Rod to piston

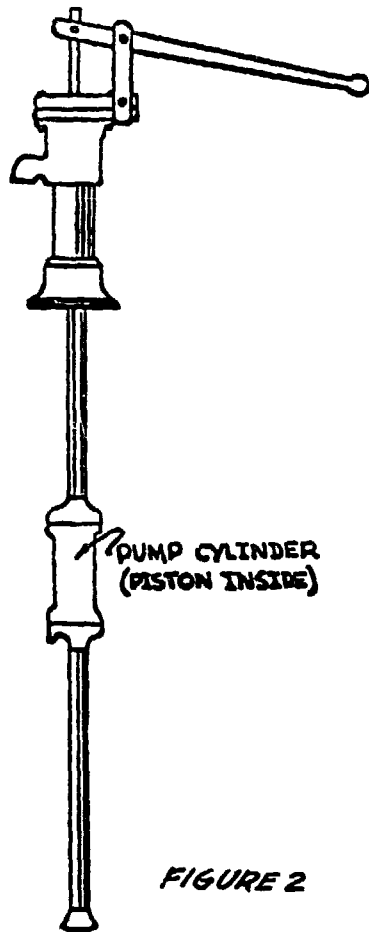


FIGURE 2

**Handle.** Make the handle of tough hardwood, shaped on a lathe or by hand shaving. The slot should be cut wide enough to accommodate the rod with two plain washers on either side. See Figure 3.

**Rod.** The rod is made of mild steel as shown in Figure 4. A 10mm (3/8") diameter machine bolt 38mm (1 1/2") long screws into the end of the rod to lock the rod hinge pin in place. The rod hinge pin is a 10mm (3/8") diameter machine bolt which connects the rod to the handle (see Figure 1). The end of the rod can be bolted directly to the pump piston with a 12.5mm bolt. If the pump cylinder is too far down for this, a threaded 12.5mm (1/2") rod should be used instead.

**Links.** The links are two pieces of flat steel strap iron. Clamp them together for drilling to make the hole spacing equal. See Figure 5.

**Block.** The block forms the base of the lever mechanism, serves as a lubricated guide hole for the rod, and provides a means for fastening the mechanism to the pump barrel. If the block is accurately made of seasoned tough hardwood without knots, the mechanism will function well for many years. Carefully square the block to 22.9cm x 6.4cm x 6.4cm (9" x 2 1/2" x 2 1/2"). Next holes A, B, C, and D are drilled

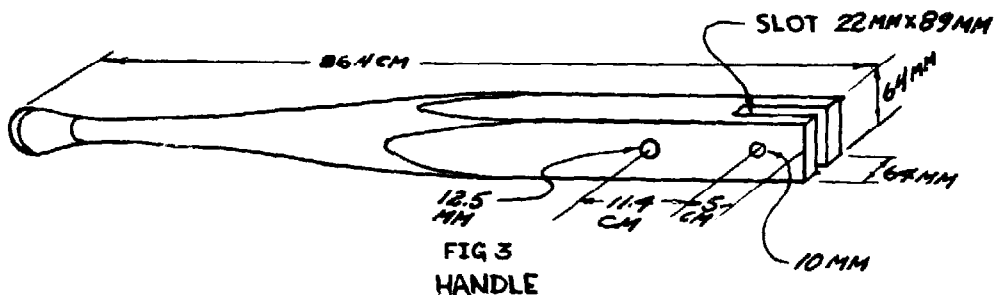


FIG 3  
HANDLE

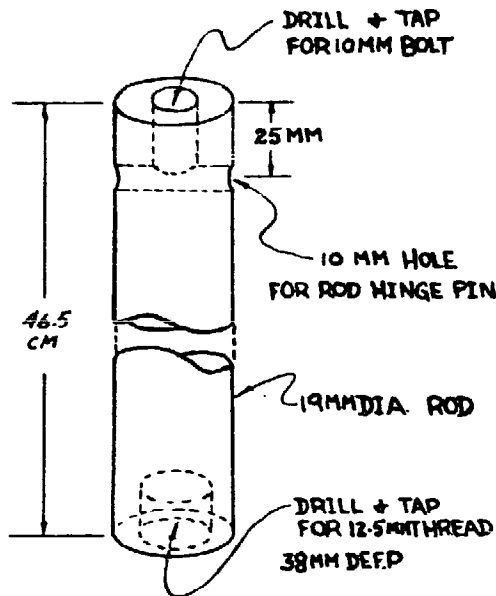


FIG 4  
ROD

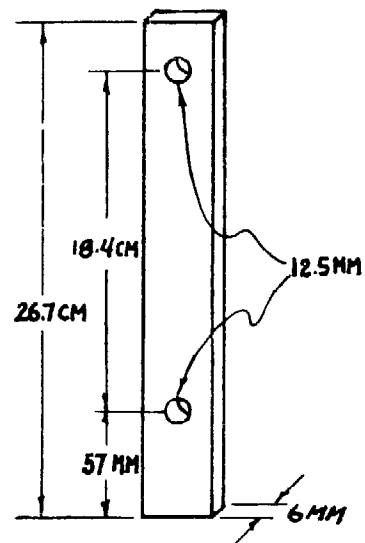


FIG 5  
LINK

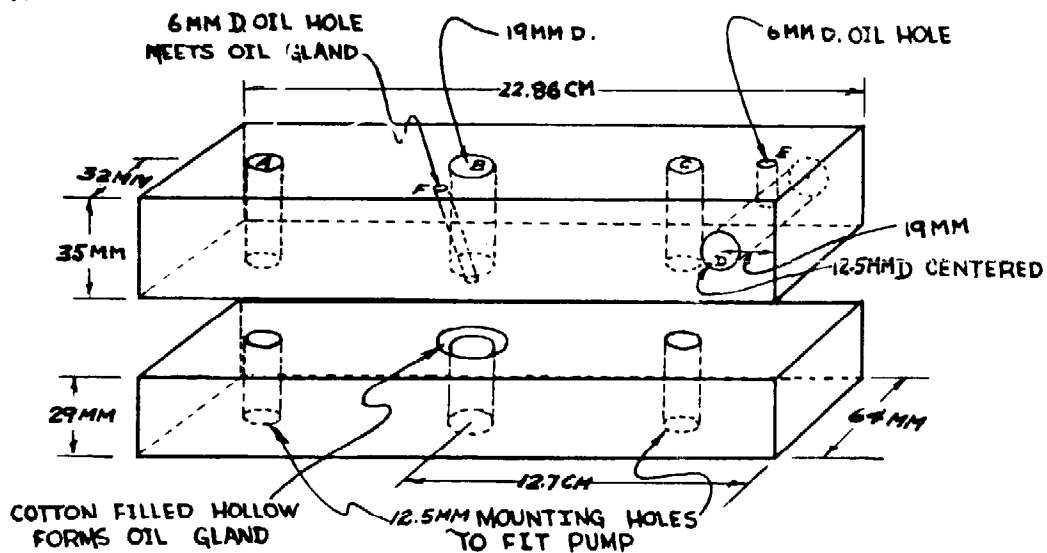


FIG 6  
BLOCK

perpendicular to the block as shown in Figure 6. The spacing of the mounting holes A and C from hole B is determined by the spacing of the bolt holes in the barrel flange of your pump. Next saw the block in half in a plane 3.5cm (1 3/8") down from the top side. Enlarge hole B at the top of the lower section with a chisel to form an oil well around the rod. This well is filled with cotton. A 6mm (1/4") hole, F, is drilled at an angle from the oil well to the surface of the block. A

second oil duct hole E is drilled in the upper section of the block to meet hole D. Use lockwashers under the head and nut of the link bolts to lock the bolts and links together. Use plain washers between the links and the wooden parts.

Source:

A Pump Designed for Village Use, by Dr. Edwin Abbott, American Friends Service Committee, Philadelphia, Pennsylvania, 1955.

## USING A HYDRAULIC RAM

A hydraulic ram is a self-powered pump which uses the energy of falling water to lift some of this water to a level above the original source. This entry explains the use of commercial hydraulic rams, which are available in some countries.

### Tools and Materials

Commercial hydraulic ram

Steel pipe and fittings

Pipe wrenches

Materials to make a small dam or reservoir

### Use of the Hydraulic Ram

A hydraulic ram can be used wherever a spring or stream of water flows with at least a 91.5cm (3') fall in altitude. The source must be a flow of at least 11.4 liters (3 gallons) a minute. Water can be lifted about 7.6 meters (25') for each 30.5cm (12") of fall in altitude. It can be lifted as high as 152 meters (500'), but a more common

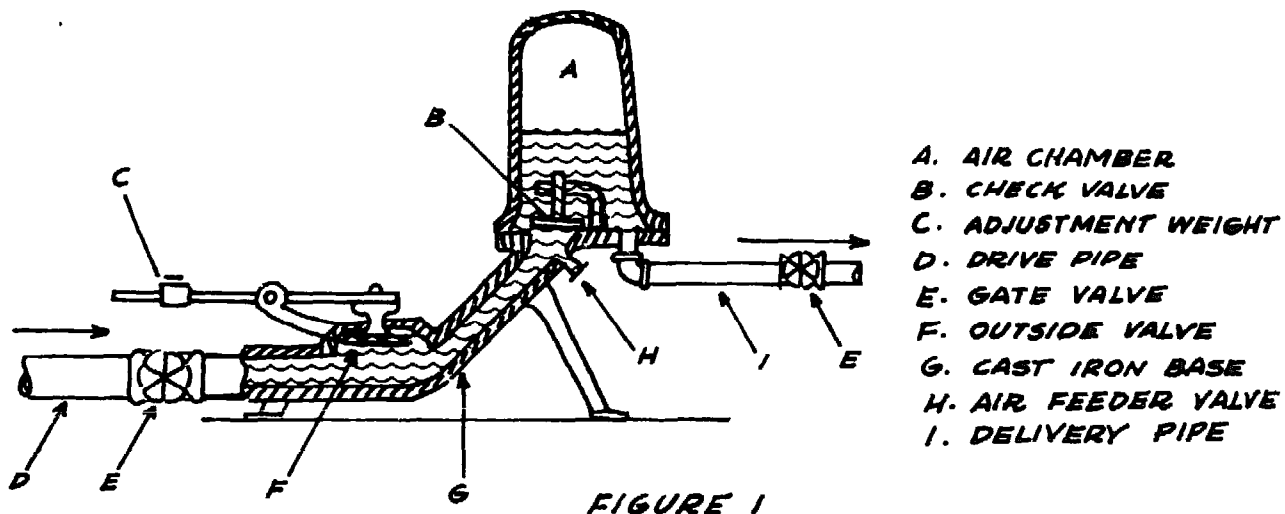
lift is 45 meters (150').

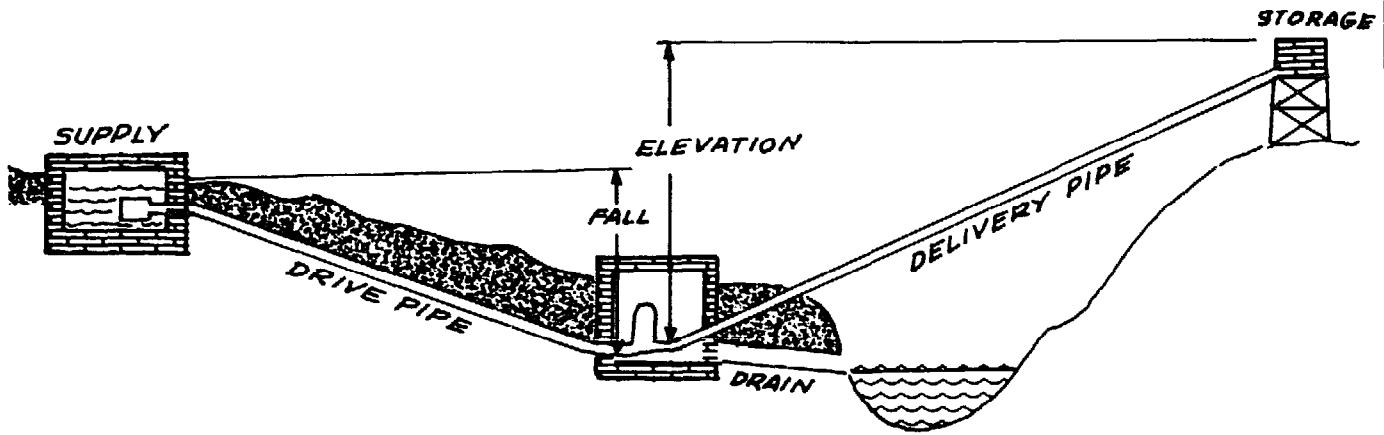
The pumping cycle (see Figure 1) is:

1. Water flows through the drive pipe (D) and out the outside valve (F).
2. The drag of the moving water closes the valve (F).
3. The momentum of water in the drive pipe (D) drives some water into the air chamber (A) and out the delivery pipe (I).
4. The flow stops.
5. The check valve (B) closes.
6. The outside valve (F) opens to start the next cycle.

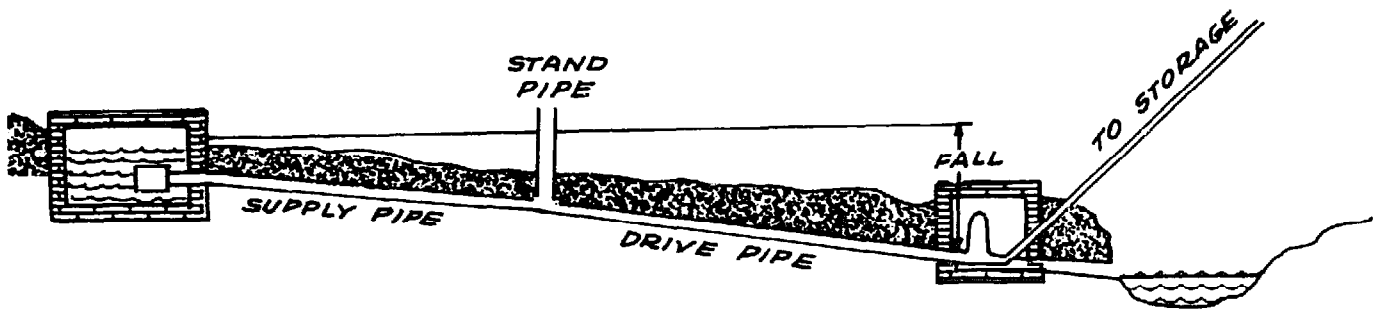
This cycle is repeated 25 to 100 times a minute; the frequency is regulated by moving the adjustment weight (C).

The length of the drive pipe must be between five and ten times the length of the fall (see Figure 2). If the

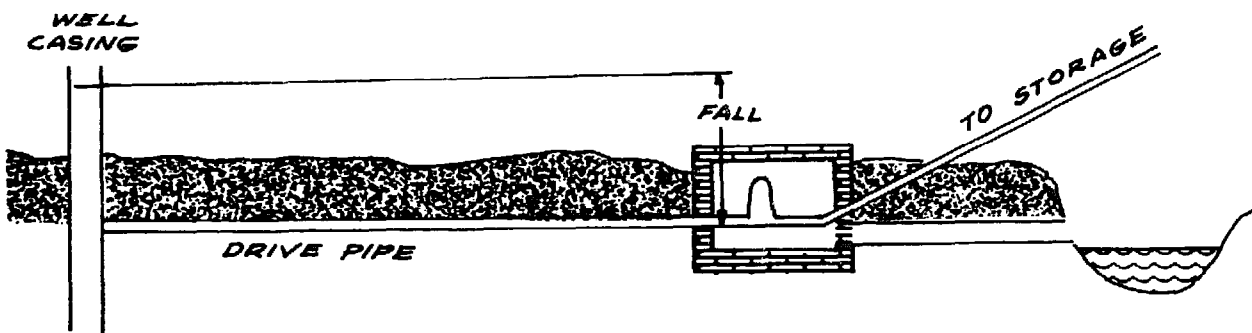




A. COMMON ARRANGEMENT OF DRIVE PIPE, RAM AND STORAGE



B. ARRANGEMENT OF DRIVE PIPE FOR A DISTANT WATER SUPPLY



C. ARTESIAN WELL OPERATING A RAM

FIGURE 2



distance from the source to the ram is greater than ten times the length of the fall, the length of the drive pipe can be adjusted by installing a stand pipe between the source and the ram (see B in Figure 2).

Once the ram is installed there is little need for maintenance and no need for skilled labor. The cost of a small ram which will raise water about 45 meters (150') is about U.S. \$150, not including the cost of the pipe and installation. Although the cost may seem high, it must be remembered that there is no further power cost and a ram will last for 30 years or more. A ram used in freezing climates must be insulated.

A double-acting ram will use an impure water supply to pump two-thirds of the pure water from a spring or similar source. A third of the pure water mixes with the impure water. A supplier should be consulted for this special application.

To calculate the approximate pumping rate, use the following equation:

$$\text{Capacity (gallons per hour)} = \frac{V \times F \times 40}{E}$$

V = gallons per minute from source

F = fall in feet

E = height the water is to be raised in feet

#### Data Needed for Ordering a Hydraulic Ram

1. Quantity of water available at the source of supply in liters (or gallons) per minute \_\_\_\_\_
2. Vertical fall in meters (or feet) from supply to ram \_\_\_\_\_
3. Height to which the water must be raised above the ram \_\_\_\_\_
4. Quantity of water required per day \_\_\_\_\_
5. Distance from the source of supply to the ram \_\_\_\_\_
6. Distance from the ram to the storage tank \_\_\_\_\_

#### Sources:

Loren G. Sadler, New Holland, Pennsylvania, VITA Chapter

Rife Hydraulic Engine Manufacturing Company, Box 367, Millburn, New Jersey, U.S.A.

The Hydraulic Ram, by W. H. Sheldon, Extension Bulletin 171, July 1943, Michigan State College of Agriculture and Applied Science.

"Country Workshop," Australian Country, September 1961, pages 32-33.

"Hydraulic Ram Forces Water to Pump Itself," Popular Science, October 1948, pages 231-233.

"Hydraulic Ram," The Home Craftsman, March-April 1963, pages 20-22.

# Water Storage and Water Power

## SPRING DEVELOPMENT

Springs, particularly in sandy soil, often make an excellent water source, but they should be dug deeper, sealed, protected by a fence and piped to the home. If fissured rock or limestone are present, get expert advice.

### Tools and Materials

Hand tools for digging

Reinforced concrete

Screens

Pipes

Proper development of a spring will increase the flow of ground water and lower the chances of contamination from surface water.

Springs are usually either:

1. Gravity Seepage, where the water-bearing soil reaches the surface over an impermeable layer, or
2. Pressure or artesian, where the water, under pressure and trapped by a hard layer of soil, finds an opening and rises to the surface. (In some parts of the world, all springs are called artesian.)

Dig a small hole near the spring to learn the depth to the hard layer of soil and to find out whether the spring is gravity-seepage or pressure. Check uphill and nearby for sources of contamination. Test the water to see if it must be purified before being used for drinking. A final point: Find out if the spring runs during long dry spells.

Usually the soil is dug to the hard, underlying part and a tank is made

with watertight concrete walls on all but the uphill side (see Figures 1 and 2). The opening on the uphill side should be lined with porous concrete or stone without mortar, so that it will admit the gravity seepage water. It can be backfilled with gravel and sand, which helps to keep fine materials in the water-bearing soil from entering the spring. If the hard soil cannot be reached easily, a concrete cistern is built which can be fed by a perforated pipe which is placed in the water-bearing layer of earth. With a pressure spring, all sides of the tank are made of watertight reinforced concrete, but the bottom is left open. The water enters through the bottom.

Read the section in this handbook on cisterns before developing your spring.

No matter how the water enters your tank, you must make sure the water is pure by:

building a complete cover to stop surface pollution and keep out sunlight, which causes algae to grow.

installing a locked manhole with at least a 5cm (2") overlap to prevent entrance of polluted ground water.

installing a screened overflow which discharges at least 15cm (6") above the ground. The water must land on a cement pad or rock surface to stop the water from making a hole in the ground and to insure proper drainage away from the spring.

arranging the spring so that sur-

face water must filter through at least 3 meters (10') of soil before reaching the ground water. Do this by making a diversion ditch for surface water about 15 meters (50') or more from the spring. Also, if necessary, cover the surface of the ground near the spring with a heavy layer of soil or clay to increase the distances that rainwater must travel, thus insuring that it has to filter through 3 meters (10') of soil.

- making a fence to keep people and animals away from the spring's immediate surroundings. The suggested radius is 7.6 meters (25').
- installing a pipeline from the overflow to the place where the water is to be used.

Before using the spring, disinfect it thoroughly by adding chlorine or chlorine compounds. Shut off the overflow to hold the chlorine solution in the well for 24 hours. If the spring overflows even though the water is shut off, arrange to add chlorine so that it remains strong for at least 30 minutes, although 12 hours would be much safer. After the chlorine is flushed from the system have the water tested. (See section on "Chlorination and Superchlorination.")

#### Source:

Manual of Individual Water Supply Systems, U.S. Department of Health, Education and Welfare, Public Health Service Publication No. 24.

Water Supply for Rural Areas and Small Communities, E. G. Wagner and J. N. Lanoix, World Health Organization, Geneva, 1959.

#### Acknowledgements

John M. Jenkins, III, VITA Volunteer, Marrero, Louisiana

Ramesh Patel, VITA Volunteer, Albany, New York

William P. White, VITA Volunteer, Brooklyn, Connecticut

## CISTERNS

Cisterns for family use are most practical in areas of adequate rainfall and where ground water is difficult to obtain or where it contains too many minerals. A sealed well usually requires no filtration, no chemical disinfection and little upkeep, while a cistern needs all of these. Cisterns cost more to build than wells. Cistern water has few minerals, however, and is ideal for washing clothes.

A cistern water supply has four basic parts: tank, catchment area, filter and a pump. (Pumps are discussed in the section on "Water Lifting.")

### Cistern Tank

The tank described here can be used for sanitary storage of rainwater for family use.

### Tools and Materials

Tools and materials for reinforced concrete

Asphalt sealing compound

Screening

Pipe

The cistern tank must be watertight to prevent surface contamination from polluting the supply. Reinforced concrete is the best material because it is strong, it has a long life and it can be made watertight.

A manhole and drain must be provided so the tank can be cleaned. (See Figure 1.) A vent and a place through which chlorine can be added easily for disinfection are also necessary.

The size of the cistern depends on the family's daily needs and the length of time between rainy periods. If a family needs 94.6 liters (25 U.S.

gallons) of water a day and there are 125 days between rainy periods, then the cistern must hold:

94.6 liters x 125 days = 11,835  
liters

or

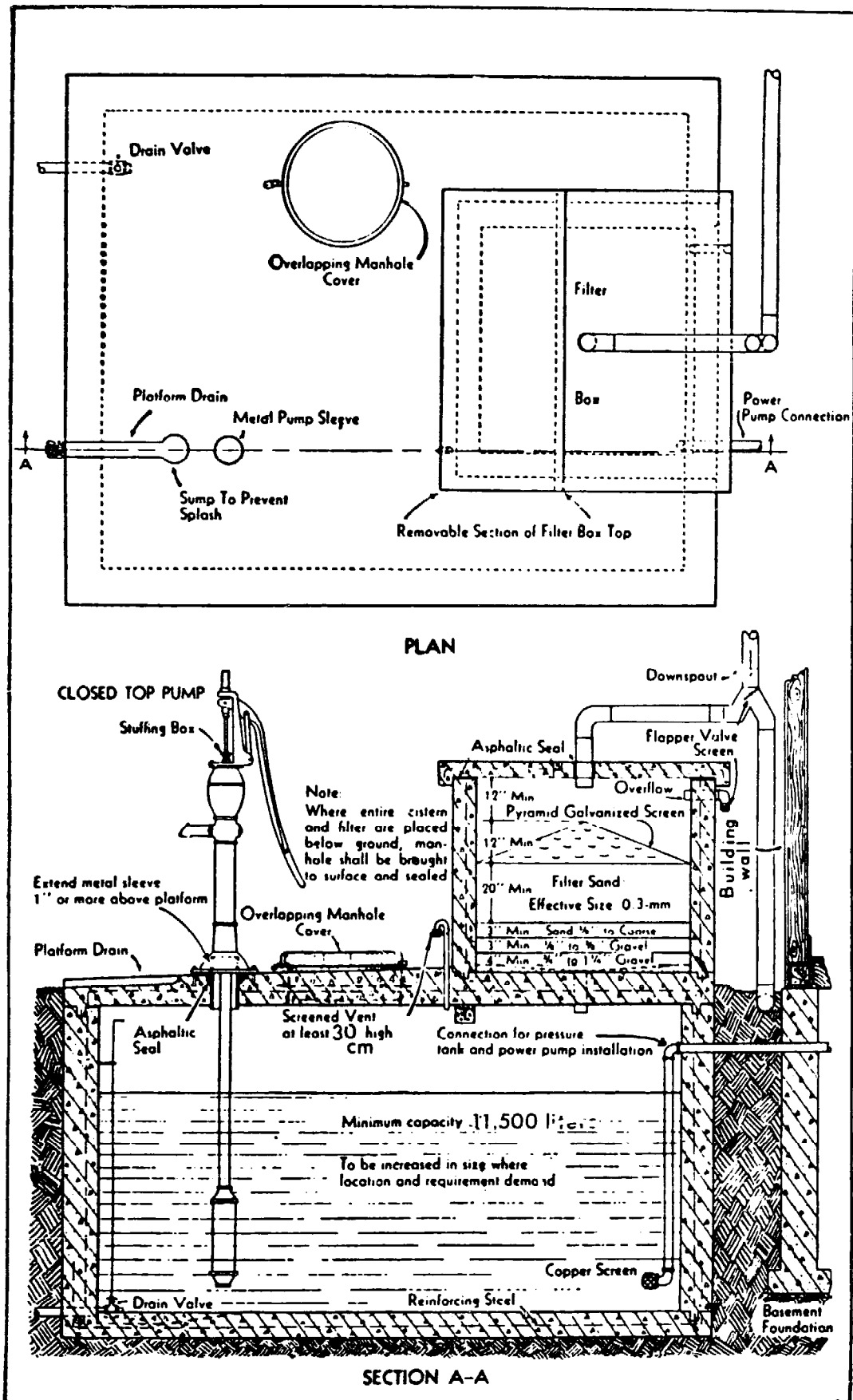
25 U.S. gallons x 125 days = 3,125  
U.S. gallons

A cistern with an inside size of 2 meters x 2 meters x 2 meters (7 1/2' x 7 1/2' x 7 1/2') holds 11,355 liters (3,000 U.S. gallons).

To be sure that the cistern is watertight, use about 28 liters of water per 50kg sack of cement (5 1/2 U.S. gallons per 94 pound or one cubic foot sack when mixing the concrete. (See section on "Concrete Construction.") Tamp the concrete thoroughly and keep the surface damp for at least 10 days. If possible, pour the walls and floor at the same time. The manhole entrance must be 10cm (4") above the cistern surface and the cover should overlap by 5cm (2"). Slope the bottom of the cistern, making one part lower than the rest, so that water can be more easily siphoned or bailed out when the cistern is being cleaned. You can do this by scraping the bottom to the proper contour. Do not use fill dirt under the cistern because this may cause the cistern to settle unevenly and crack. A screened drain pipe and valve will make cleaning easier.

An overflow pipe is not needed if a roof-cleaning butterfly valve is properly used. If the overflow is installed, be sure to cover the outlet carefully with copper window screen. A screened vent is necessary if there is no overflow, to allow displaced air to leave the cistern. The hand pump must be securely mounted to bolts cast into the concrete cistern cover. The flanged base of the pump should be

**FIG. 1 CISTERN WITH SAND FILTER (PUMP INSTALLATION OPTIONAL)**



solid, with no holes for contamination to enter, and sealed to the pump cover, or the drop pipe must be sealed in with concrete and asphalt sealing compound.

A small pipe with a screwed-on cap is needed through which to measure the water in the cistern and to add chlorine solution after each rainfall. The amount of water in the cistern is measured with a stick marked in thousands of liters (or thousands of gallons). To disinfect after each rainfall, add a 5 parts per million dosage of chlorine (see section on "Chlorination").

A newly built or repaired cistern should always be disinfected with a 50 parts per million chlorine solution. The cistern walls and the filter should be thoroughly washed with this strong solution and then rinsed. A small-pressure system can be disinfected readily by pumping this strong solution throughout the system and letting it stand overnight.

### Catchment Area

A catchment area of the proper size is a necessary part of a cistern water supply. Rainwater for a cistern can be collected from the roof of a house. The method given here for estimating catchment size should be checked against the actual size of nearby catchment installations.

### Tools and Materials

Galvanized iron roof or equivalent

Trough collectors

Downspout

The catchment or collecting area should be a smooth, watertight material, like a galvanized sheet-metal roof. Wood or thatch roofs may taint the water and retain dust, dirt and leaves; water from these roofs contains more organic matter and bacteria

than water from smooth surfaces. Stone, concrete and plastic film catchments are sometimes built on the ground. For family use, roofs are usually best because humans and animals cannot contaminate them.

To estimate your required catchment area, estimate the minimum yearly rainfall and the amount of water required by the family during one year. Sometimes, the government meteorological section can give you the minimum rainfall expected. If they cannot, estimate the minimum rainfall at two-thirds of the yearly average. Take the average amount of water needed by the family for one day and multiply it by 365 to learn how much is needed for one year. Then use the chart to find how much roofspace is needed (Figure 2). Add 10 percent to the area given by the chart to allow for water lost by evaporation and by discarding water at the beginning of each rainfall.  
Example:

Suppose you have an average rainfall of 75cm a year and a family needs 135 liters a day, then:

$2/3 \times 75 =$  minimum annual rainfall of 50cm

$365 \times 135$  liters/day = 49,275 liters a year.

Round this figure off to 50,000 liters a year. The example worked out on the chart shows that a catchment area of about 115 square meters is needed. Add 10 percent to this area to allow for water loss, giving a total required catchment area of about 126.5 square meters.

A collecting trough and downspout are needed. Be sure there is a good pitch to the trough so that the water flows freely and does not hold small puddles that can breed yellow-fever mosquitos and other insects. Troughs and downspouts need periodic inspection and cleaning. If you extend the trough, it increases the catchment area.

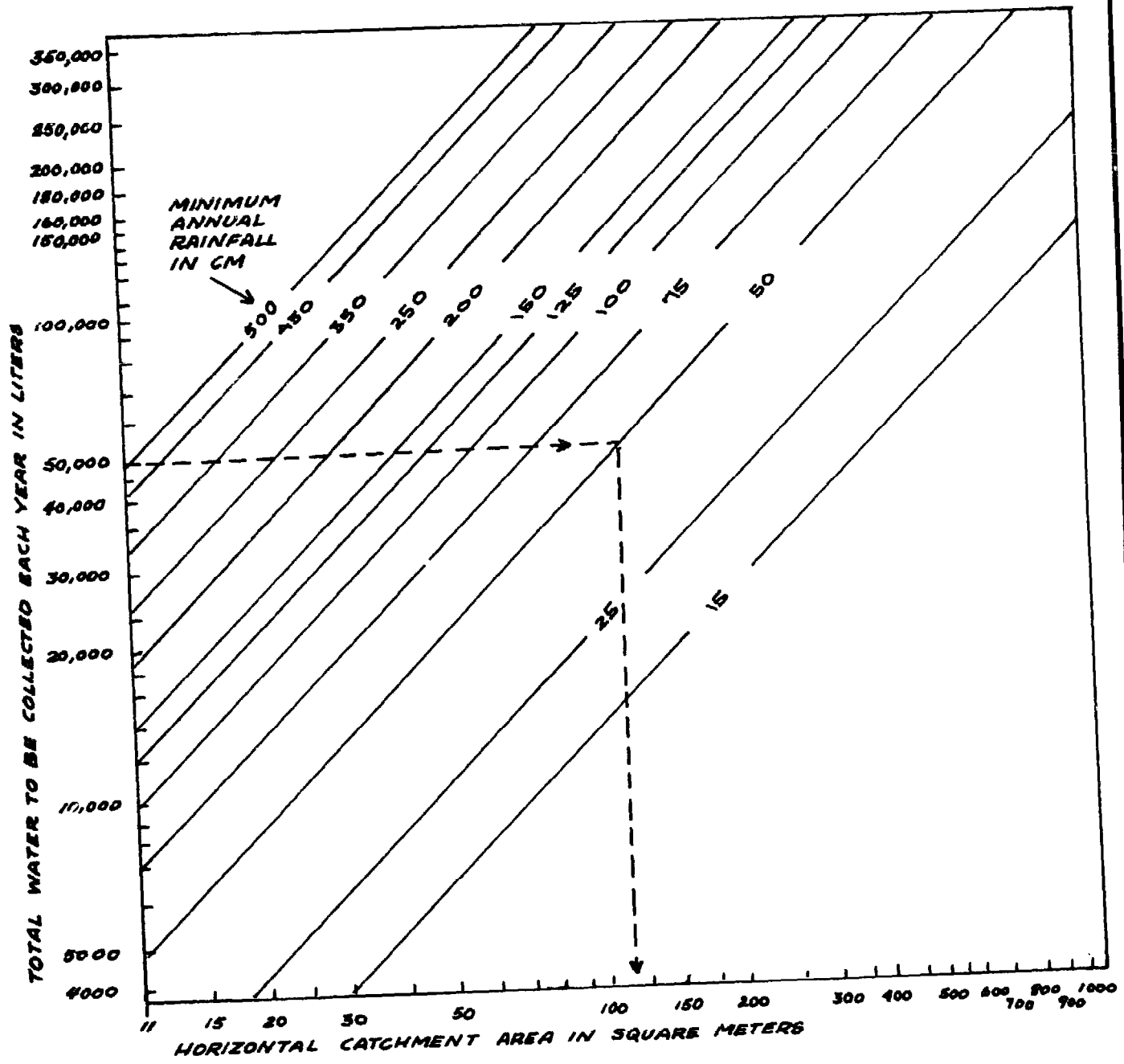


FIGURE 2

## Cistern Filter

The sand filter described here will remove most organic matter from water but it will not produce safe drinking water by removing all harmful bacteria. Water collected in the cistern tank should be chlorinated after each rainfall.

### Tools and Materials

Tools and materials for making reinforced concrete

Screen

Fine, clean sand

Graded gravel

Asphalt sealing compound

A catchment area always collects leaves, bird droppings, road dust and insects. A cistern filter removes as much of this material as possible before the water enters the cistern.

The sand filter is usually built at ground level and the filtered water runs into the cistern, which is mostly underground. The largest pieces, such as leaves, are caught in the splash plate. The splash plate also distributes the water over the surface of the filter, so that the water does not make holes in the sand. A piece of window screen forms the splash plate.

If a filter is made too small to handle the normal rush of water from rainstorms, the water will overflow the filter or dig a channel in the sand, ruining the filter. The filter area should not be less than one-tenth of the catchment area. A typical filter would be 122cm x 122cm (4' x 4') for a family-sized unit where rainfall intensity is average.

About every 6 months, remove the manhole cover and clean the filter. Remove all matter from the splash

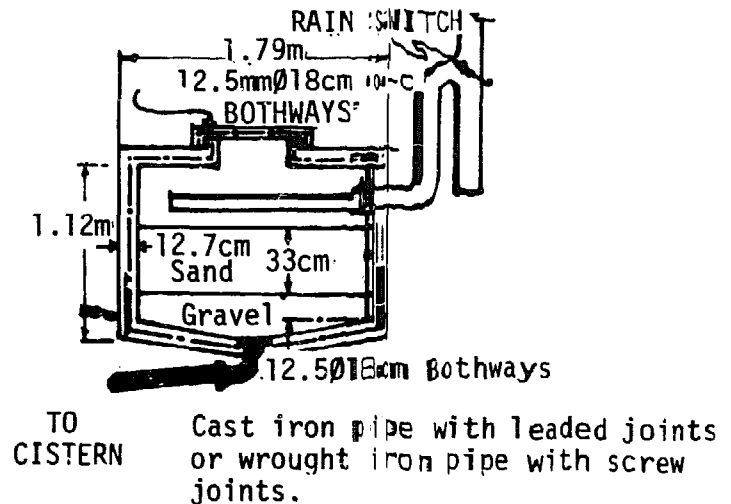


FIGURE 3

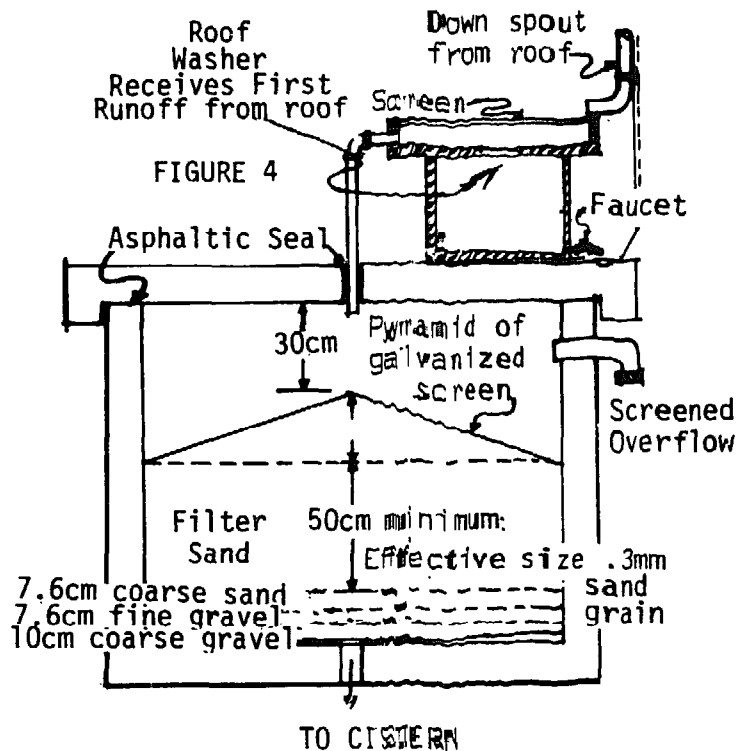




plate and scrape off and remove the top 1.25cm (1/2") of sand. When the sand is down to 30cm (12") in depth, rebuild it with clean sand to the original depth of 46cm (18").

The first runoff from the roof, which usually contains a great deal of leaves and dirt, should be discarded. The simplest way to do this is to have a butterfly valve (like a damper in a stovepipe) in the downspout (see Figure 3). After the rain has washed the roof, the valve is turned to let the runoff water enter the filter. A semi-automatic filter is shown in Figure 4.

In building the filter, it is important to use properly-sized sand and gravel and to make sure the filter can be cleaned easily. The filter must have a screened overflow.

#### Sources:

Cisterns, State of Illinois, Department of Public Health, Circular No. 833.

Manual of Individual Water Supply Systems, U.S. Department of Health, Education and Welfare, Public Health Service Publication No. 24.

Water Supply for Rural Areas and Small Communities, by Edmund G. Wagner and J. N. Lanoix, World Health Organization, Geneva, 1959.

## SELECTING A DAM SITE

A water reservoir can be formed by building a dam across a ravine. The preliminary evaluation described here will help to determine whether or not a particular site will be good for building a dam. If the information collected in this investigation shows that the site has good possibilities, consult an expert before starting to build.

### Materials

Maps

Rainfall data

Building a dam takes time, labor, materials and money. Furthermore, if a dam which holds more than a few acre-feet of water breaks, a great deal of damage could be caused. Therefore it is important to choose a dam site carefully, to guard against dam collapse, and to avoid excessive silting, porous soil, polluted water and lack of water because of a small catchment area.

One acre-foot of water equals 1 foot of water covering an acre of land (30cm of water covering 0.4 hectares). One acre-foot equals 1233.49 cubic meters.

Six factors are important in site selection:

1. Enough water to fill the reservoir.
2. Maximum water storage with the smallest dam.
3. A sound, leakproof foundation for the reservoir.
4. Reasonable freedom from pollution.
5. A storage site close to users.
6. Available materials for construction.

The annual rainfall and type of catchment (or natural drainage) area

will determine the amount of water which the reservoir will collect.

### Catchment Area

A catchment area with steep slopes and rocky surfaces is very good. If the catchment area has porous soil on a leak-proof rock base, springs will develop and will carry water to the reservoir, but more slowly than rocky slopes. Trees with small leaves, such as conifers, will act as windbreakers and reduce loss of water from evaporation.

Swamps, heavy vegetation, permeable ground and slight slopes will decrease the yield of water from a catchment area.

### Rainfall

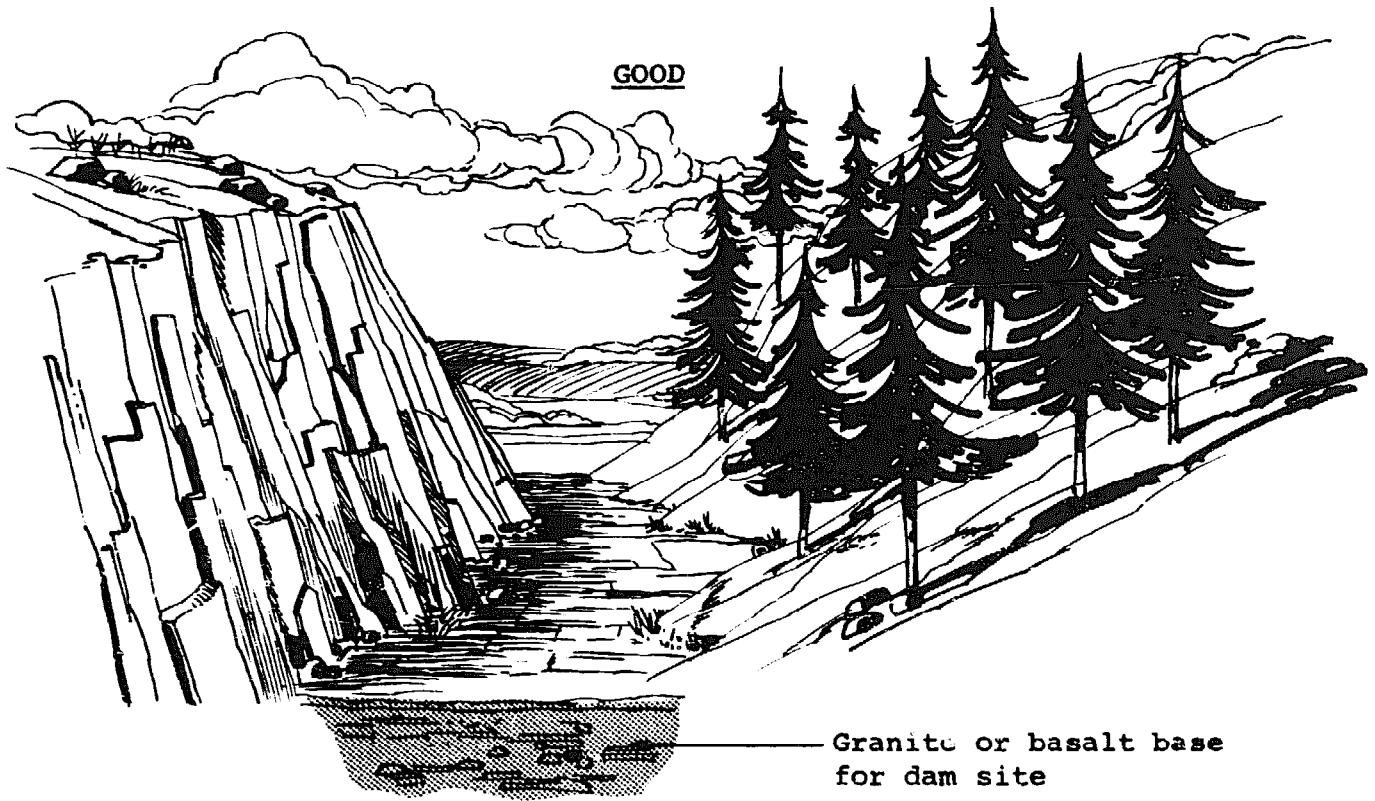
The average catchment area will, in a year, drain 5 acre-feet (6167.45 cubic meters) into a reservoir for every inch (2.5cm) of annual rainfall falling on a square mile (2.59 square kilometers); that is, about 10 percent of the rainfall.

### Location

The best location for building a dam is where a broad valley narrows with steep sides and a firm base on which to build the dam (see Figure 1). Ground which contains large boulders, weathered or fissured bedrock, alluvial sands or porous rock is not good. The best bases for building a dam are granite or basalt layers at or near the surface or a considerable depth of silty or sandy clay.

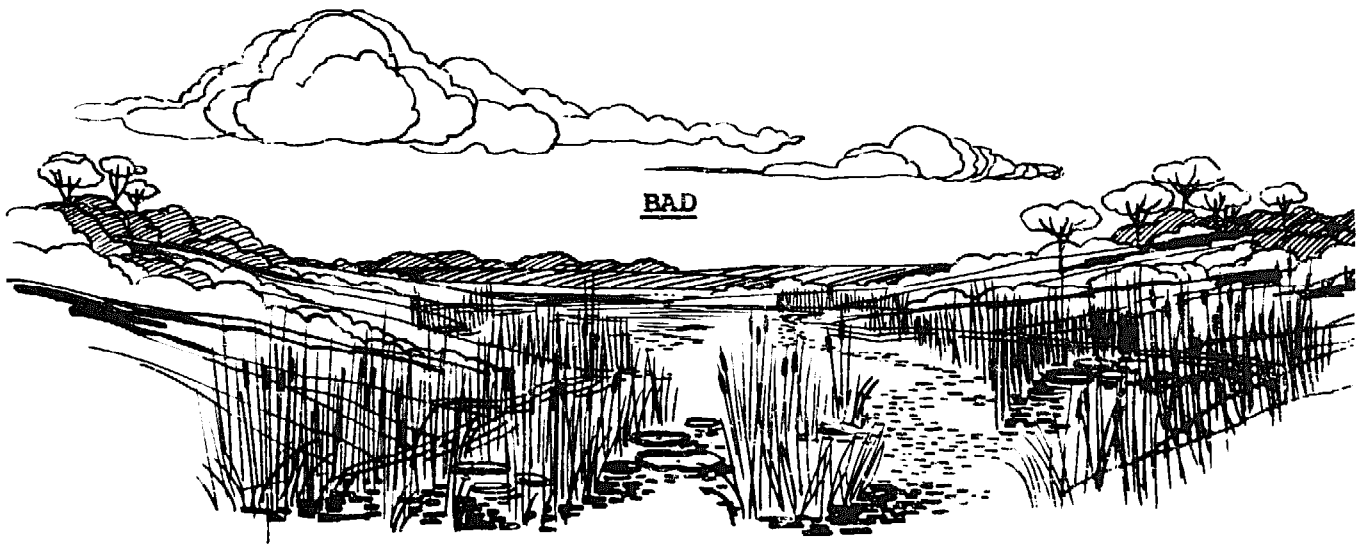
Location of a dam upstream from its point of use can lower pollution and may allow for gravity feed of the water to its point of use.

It is best if stone is nearby when building a masonry dam. When building



Granite or basalt base  
for dam site

*FIGURE 1*



BAD

an earthen dam, rock will still be required for the spillway. The best soils to use for earth dams contain clay with some silt or sand. There should be enough of this soil close to the dam site for building the entire dam of reasonably uniform material.

Careful selection of the dam site will save labor and material costs and help insure a strong dam.

Source:

Water Supply for Rural Areas and Small Communities, by E. G. Wagner and J. N. Lanoix, World Health Organization, Geneva, 1959.

## RECIPROCATING WIRE POWER TRANSMISSION FOR SMALL WATER WHEELS

A reciprocating wire can transmit power from a water wheel to a point up to 0.8km (1/2 mile) away where it is usually used to pump well water. These devices have been used for many years by the Amish people of Pennsylvania. If they are properly installed, they give long, trouble-free service.

The Amish people use this method to transmit mechanical power from small water wheels to the barnyard, where the reciprocating motion is used to pump well water for home and farm use. The water wheel is typically a small undershot wheel (with the water flowing under the wheel) one or two feet in diameter. The wheel shaft is fitted with a crank, which is attached to a triangular frame which pivots on a pole (see Figure 2). A wire is used to connect this frame to another identical unit located over the well. Counterweights keep the wire tight.

### Tools and Materials

Wire - galvanized smooth fence wire

Water wheel with eccentric crank to give a motion slightly less than largest stroke of farmyard pump

Galvanized pipe for triangle frames:  
2cm (3/4") by 10 meters long (32.8')

Welding or brazing equipment to make frames

Concrete for counterweight

2 Poles: 12 to 25cm (6" to 10") in diameter

As the water wheel turns, the crank tips the triangular frame back and forth. This action pulls the wire back and forth. One typical complete back and forth cycle, takes 3 to 5 seconds. Sometimes power for several transmission wires comes from one larger water wheel.

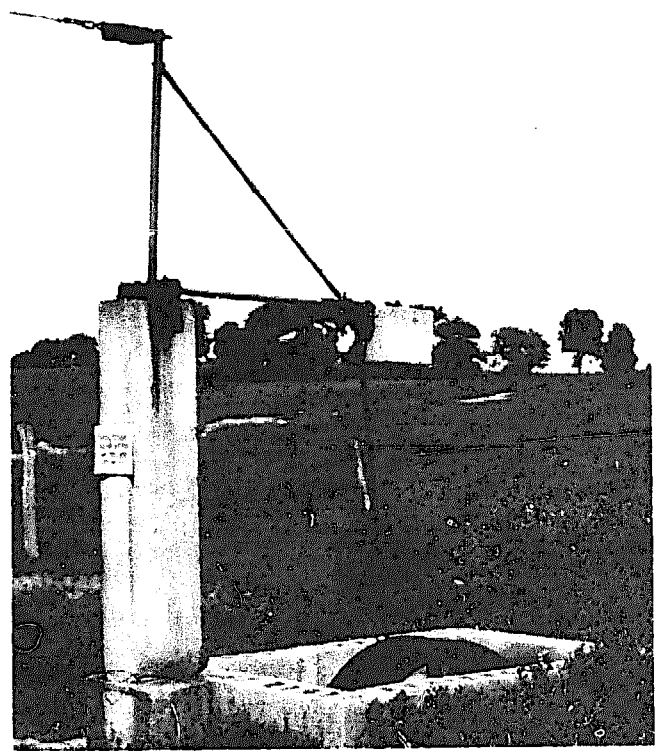
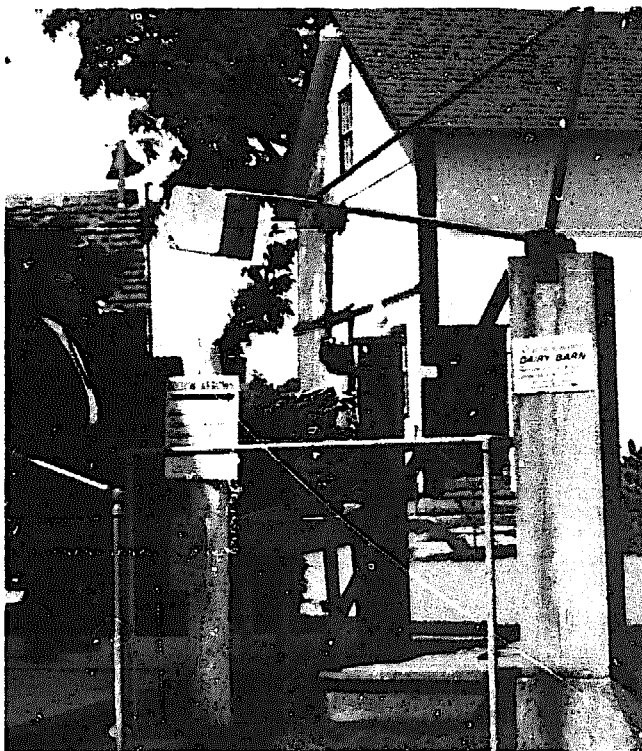
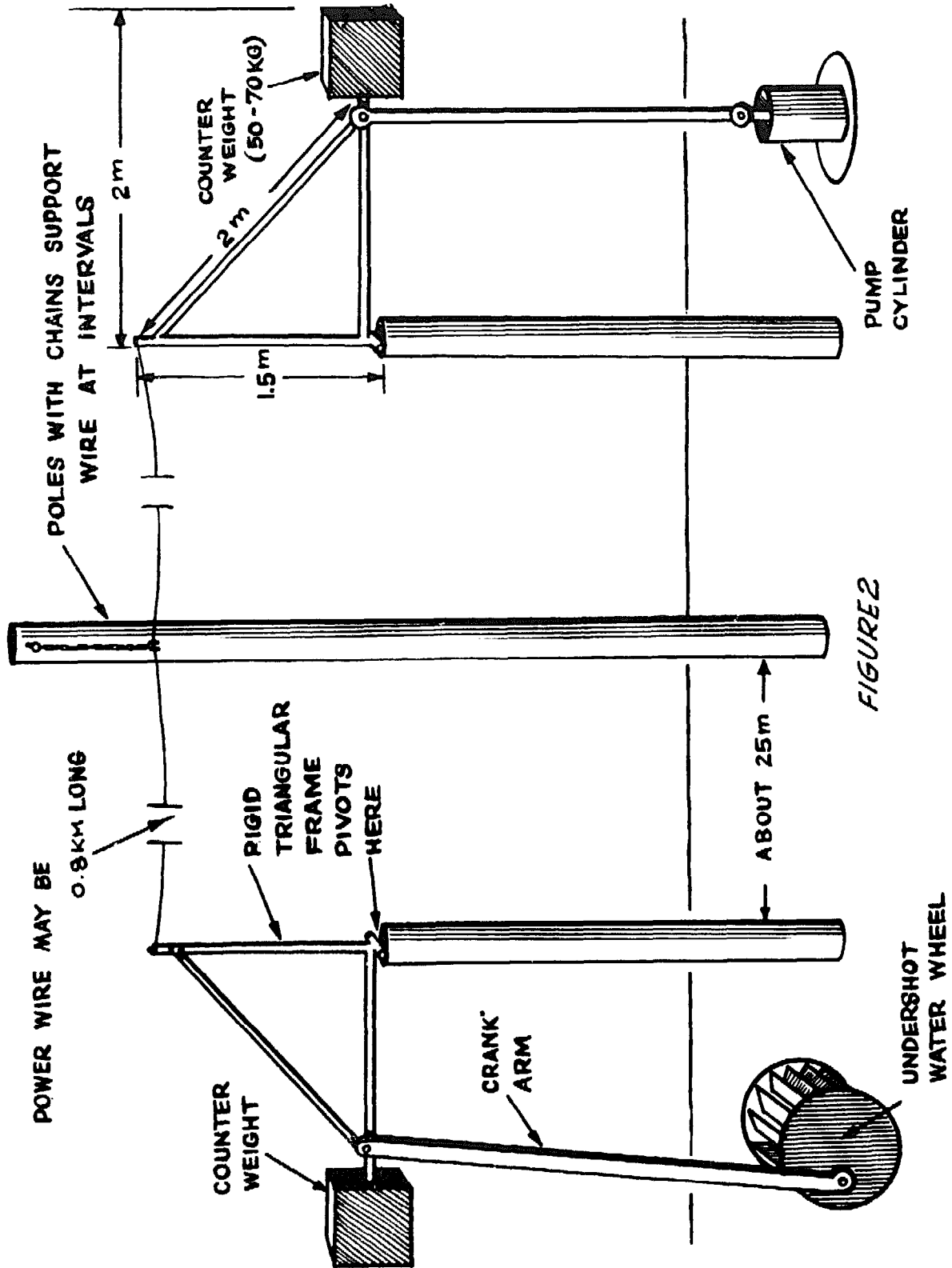


FIGURE 1.



Turns can be made in order to follow hedgerows by mounting a small triangular frame horizontally at the top of a pole as shown in Figure 4.

### Water Wheel

Figures 5, 6 and 7 show how to build and install a small water wheel made from wood and bamboo.

### Source:

New Holland, Pennsylvania VITA Chapter.

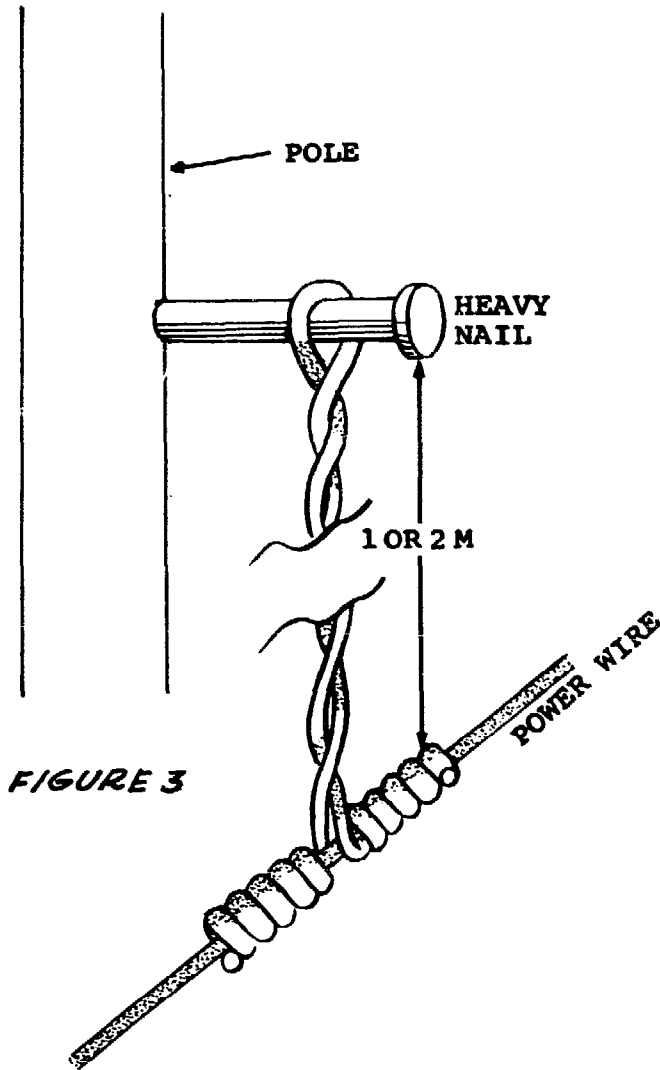


FIGURE 3

The wire is mounted up on poles to keep it overhead and out of the way. If the distance from stream to courtyard is far, extra poles will be needed to help support the wire. Amish folks use a loop of wire covered with a small piece of garden hose attached to the top of the pole. The reciprocating wire slides back and forth through this loop. If this is not possible, try making the pole 1-2 meters higher than the power wire. Drive a heavy nail near the pole top and attach a chain or wire from it to the power wire as shown in Figure 3.

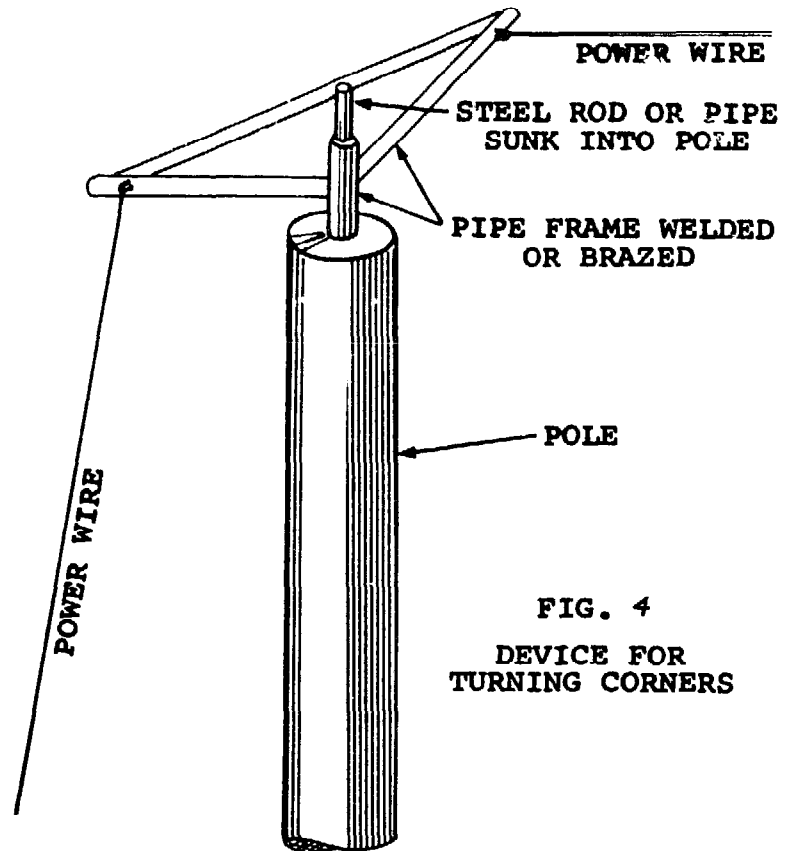


FIG. 4  
DEVICE FOR  
TURNING CORNERS

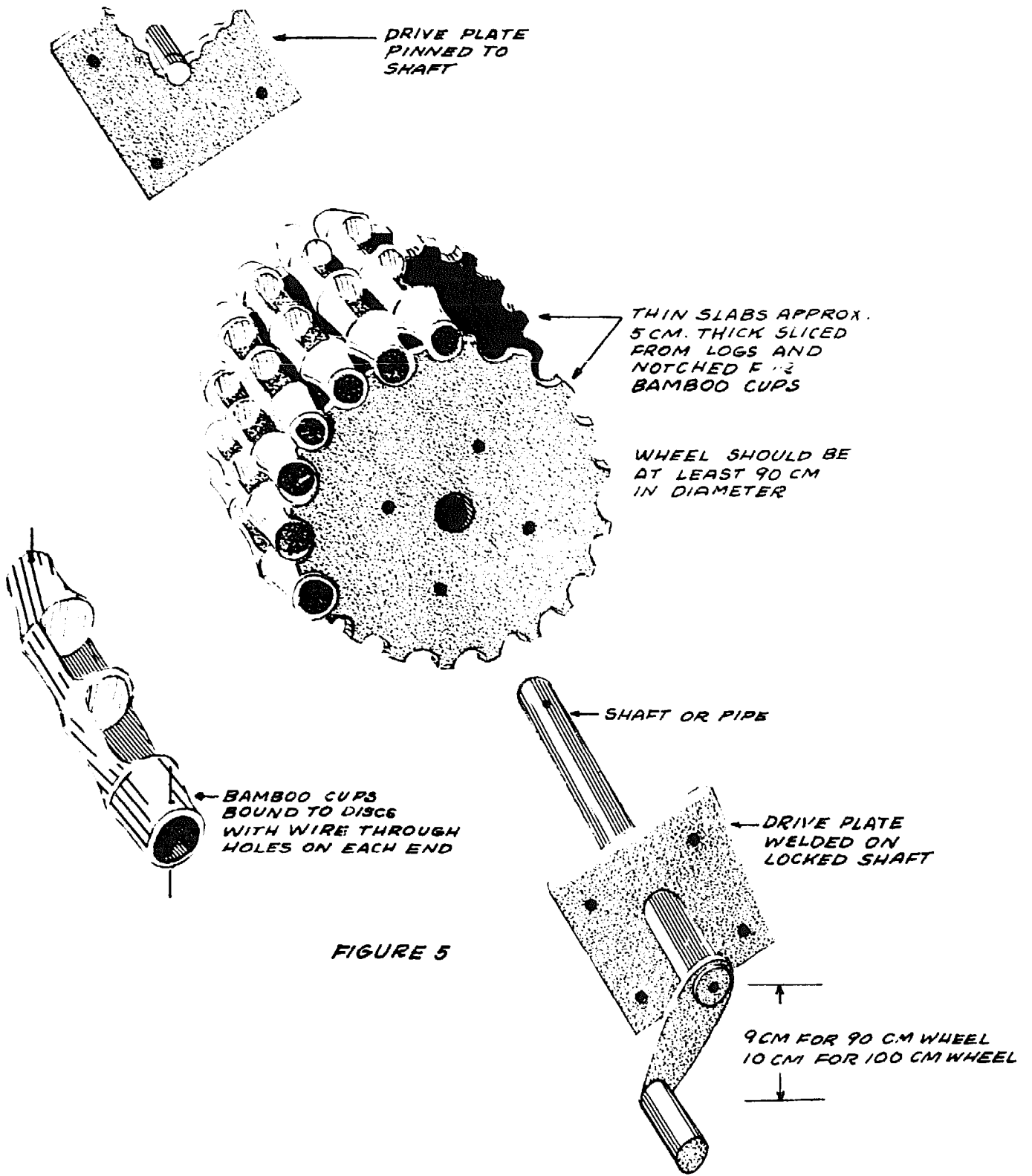


FIGURE 5

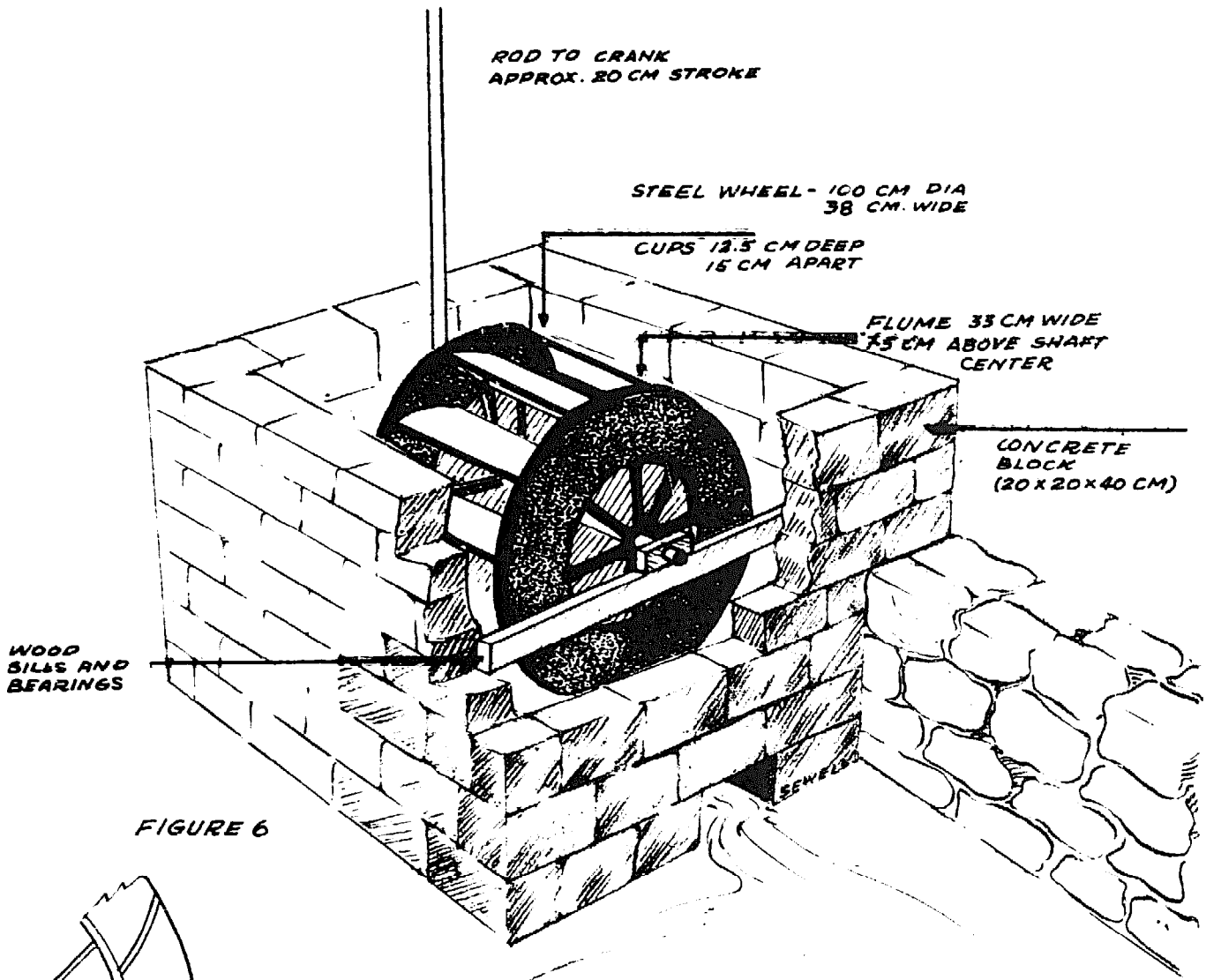
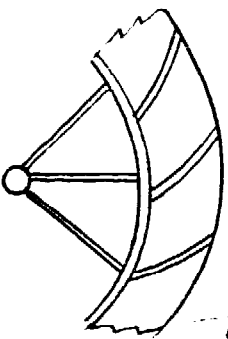


FIGURE 6



SHAPE  
OF  
CUPS  
SIDE  
SECTION  
VIEW



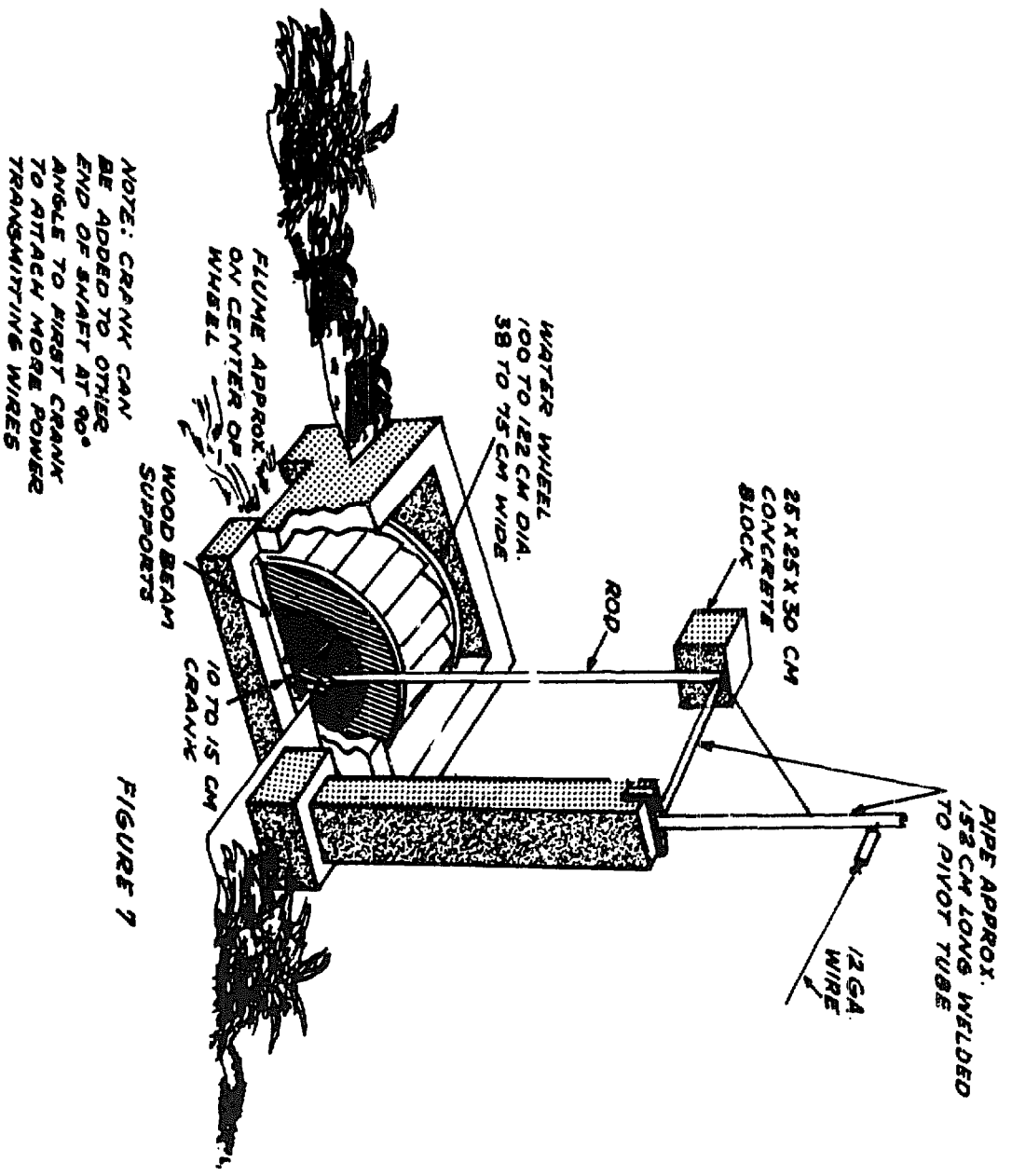


FIGURE 7

## Water Purification

The purification of unsafe water requires some trained supervision if it is to be done effectively. Such supervision is rarely available in the villages and the procedure tends to be neglected sooner or later. Under these circumstances every effort must be made to obtain a source that provides a naturally wholesome water and then to collect that water and protect it against pollution by the methods already described. Thus, the necessity for treatment of the water may be avoided, and the practical importance of managing this can hardly be over-emphasized.

Water treatment under rural conditions should be restricted by the responsible control agency to cases where such treatment is necessary and where proper plant operation and maintenance is assured.

If the water needs treatment, this should, if at all possible, be done for the whole community and certainly before, or on entry to the dwelling so that the water from all the taps in the house is safe. The practice, common in the Tropics, of sterilizing (by filtration and boiling) only the water to be used for drinking, teeth-cleaning, etc., though efficient in itself (when carefully done) is frequently nullified by carelessness. Furthermore, children are likely to use water from any tap. Contrary to an all too common opinion, ordinary freezing of water, though it may retard the multiplication of bacteria, does not kill them, and ice from a household refrigerator is no safer than the water from which it was made.

The principal methods of purifying water on a small scale are, boiling,

chemical disinfection and filtration. These methods may be used singly or in combination, but if more than filtration is needed the boiling or chemical disinfection should be done last.

The entries which follow this general introduction are:

Boiler for Drinking Water, Chlorination of Polluted Water, Water Purification Plant and Sand Filter.

Boiling is the most satisfactory way of destroying disease-producing organisms in water. It is equally effective whether the water is clear or cloudy, whether it is relatively pure or heavily contaminated with organic matter. Boiling destroys all forms of disease-producing organisms usually encountered in water, whether they be bacteria, viruses, spores, cysts or ova. To be safe the water must be brought to a good "rolling" boil (not just simmering) and kept there for some minutes. Boiling drives out the gases dissolved in the water and gives it a flat taste, but if the water is left for a few hours in a partly filled container, even though the mouth of the container is covered, it will absorb air and lose its flat, boiled taste. It is wise to store the water in the vessel in which it was boiled. Avoid pouring the water from one receptacle to another with the object of aerating or cooling it as that introduces a risk of re-contamination.

Chlorine is a good disinfectant for drinking water as it is effective against the bacteria associated with water-borne disease. In its usual doses, however, it is ineffective against the cysts of amoebic dysentery, ova of worms, cercariae which cause schistosomiasis and organisms embedded

in solid particles.

Chlorine is easiest to apply in the form of a solution and a useful solution is one which contains 1 percent available chlorine, for example, Milton Antiseptic. Dakin's solution contains 0.5 percent available chlorine, and bleaching powder holds 25 percent to 30 percent available chlorine. About 37cc (2 1/2 tablespoons) of bleaching powder dissolved in 0.95 liter (1 quart) of water will give a 1 percent chlorine solution. To chlorinate the water, add 3 drops of 1 percent solution to each 0.95 liter (1 quart) of water to be treated (2 tablespoonfuls to 32 Imperial gallons), mix thoroughly and allow it to stand for 20 minutes or longer before using the water.

Chlorine may be obtained in tablet form as "Sterotabs" (formerly known as "Halazone"), "Chlor-dechlor" and "Hydrochlorazone," which are obtainable on the market. Directions for use are on the packages.

Iodine is a good disinfecting agent. Two drops of the ordinary tincture of iodine are sufficient to treat 0.95 liter (1 quart) of water. Water that is cloudy or muddy, or water that has a noticeable color even when clear, is not suitable for disinfection by iodine. Filtering may render the water fit for treatment with iodine. If the water is heavily polluted, the dose should be doubled. Though the higher dosage is harmless it will give the water a medicinal taste. To remove any medicinal taste add 7 percent solution of sodium thiosulphate in a quantity equal to the amount of iodine added.

Iodine compounds for the disinfection of water have been put into tablet form, for example, "Potable Aqua Tablets," "Globaline" and "Individual Water Purification Tablets"; full directions for use are given on the packages. These tablets are among the most useful disinfection devices developed to date

and they are effective against amoeba cysts, cercariae, leptospira and some of the viruses.

Source:

Small Water Supplies, Bulletin No. 10, The Ross Institute, London, 1967.

Other Useful References:

Manual of Individual Water Supply Systems, Public Health Service Publication No. 24, U.S. Department of Health, Education and Welfare, Washington, D.C. Revised 1962.

Water Supply for Rural Areas and Small Communities, by Edmund G. Wagner and J. N. Lanoix, World Health Organizations, Geneva, 1959.

## BOILER FOR DRINKING WATER

The boiler described here will provide safe preparation and storage of drinking water in areas where pure water is not available and boiling is practical. When the unit has been used in work camps in Mexico, a 208-liter (55-gallon) drum has supplied 20 persons with water for a week.

### Tools and Materials

208-liter (55-gallon) drum

19mm (3/4") pipe nipple, 5cm (2") long

Bricks for two 30cm (1') layers to support drum

Sand and 1 sack of cement for mortar and base of fireplace

Large funnel and filter medium for filling drum

Metal plate to control draft in front of fireplace

19mm (3/4") valve, preferably all metal, such as a gate valve, which can withstand heat

The fireplace for this unit (see Figure 2) is simple. It should be oriented so that the prevailing wind or draft goes between the bricks from the front to the back of the drum. A chimney can be provided, but it is not necessary.

When filling the drum, do not fill it completely, but leave an air space at the top as shown in Figure 1. Replace the funnel with a filler plug, but leave the plug completely loose.

Water must boil at least 15 minutes with steam escaping around the loose filler plug. Make sure that the water in the pipe nipple and valve reach boiling temperature by letting about 2 liters (2 quarts) of water out through the valve while the drum is at full boil.

### Source:

Chris Ahrens, VITA Volunteer, Housing Specialist, Eastern Kentucky Housing Development Corporation, Inc.

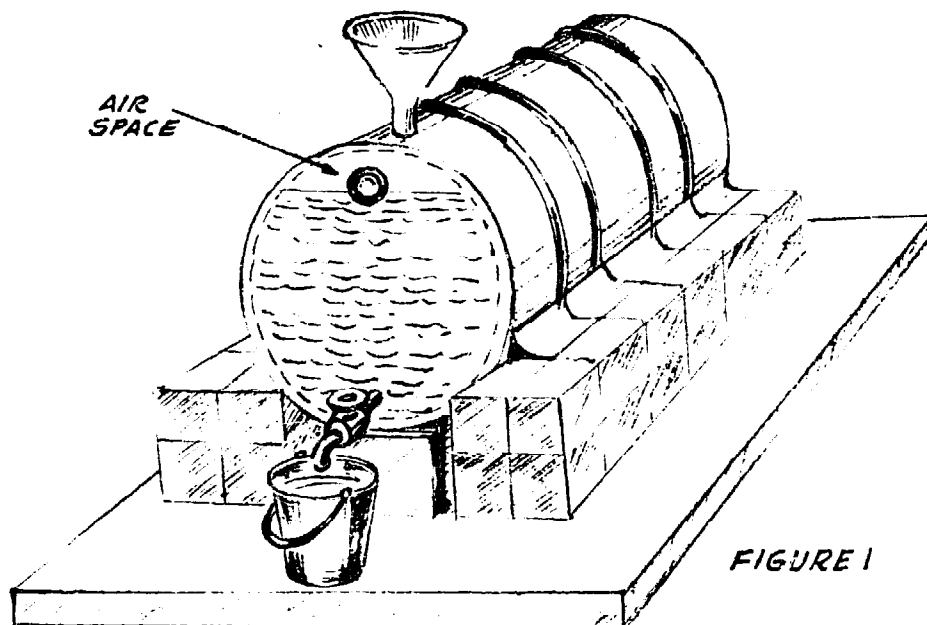
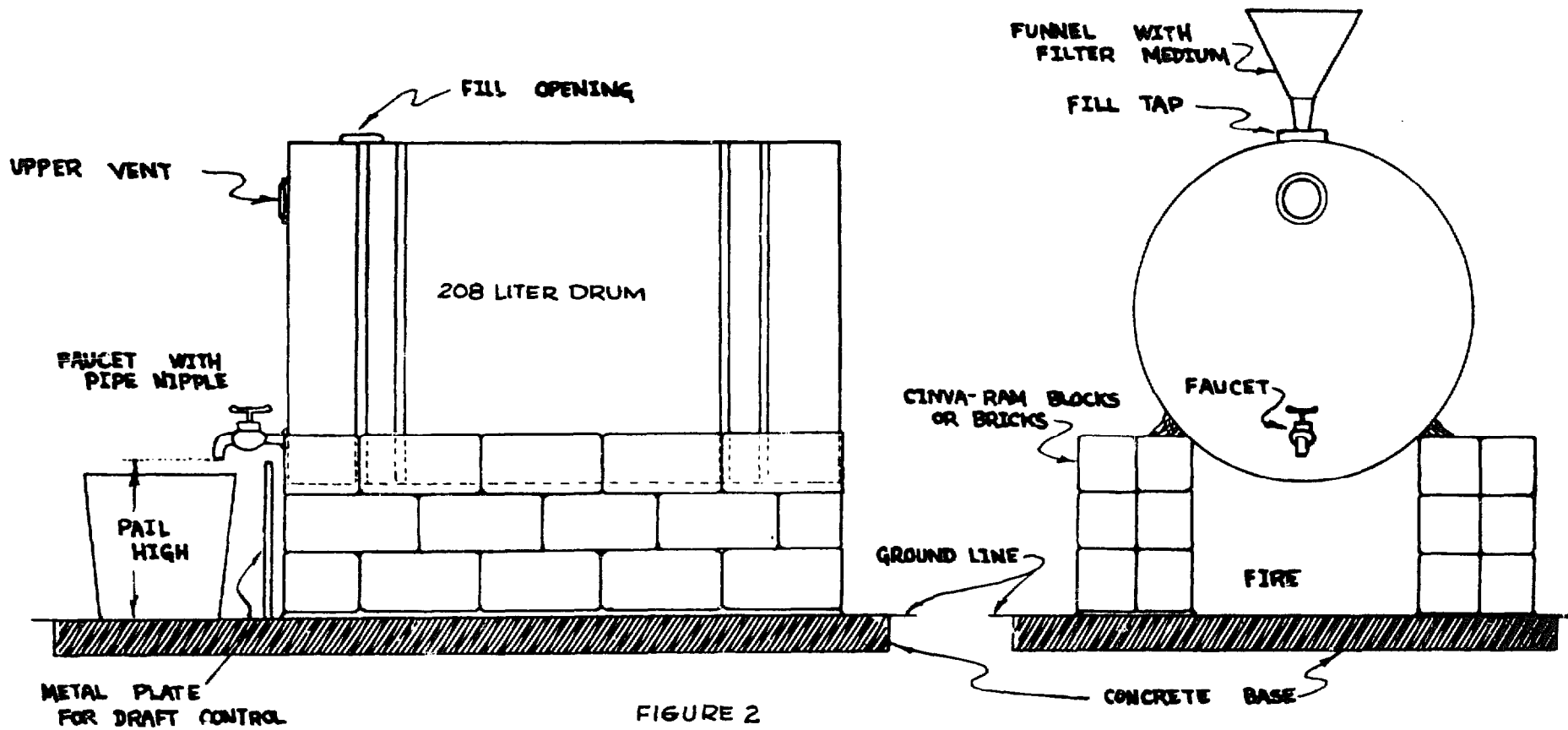


FIGURE 1



## CHLORINATION FOR POLLUTED WATER AND SUPER-CHLORINATION OF WELLS, SPRING ENCASEMENTS AND CISTERNS

Chlorination, when properly applied, is a simple way to insure and protect the purity of water. Guidelines given here include tables to give a rough indication of the amounts of chlorine-bearing chemical needed. Instructions are also given for super-chlorination for disinfecting newly built or repaired wells, spring encasements or cisterns. Chlorine-bearing compounds are used because pure chlorine is difficult and dangerous to use.

The amounts of chlorine suggested here will normally make water reasonably safe. A water-treatment system should be checked by an expert. In fact, the water should be tested periodically to make sure that it remains safe. Otherwise, the system itself could become a source of disease.

### Tools and Materials

Container to mix chlorine

Chlorine in some form

Scale to weigh additive

The safest way to treat water for drinking is to boil it (see "Boiler for Drinking Water"). However, under controlled conditions, chlorination is a safe method; it is often more convenient and practical than boiling. Proper treatment of water with chlorine requires some knowledge of the process and its effects.

When chlorine is added to water, it attacks and combines with any suspended organic matter as well as some minerals such as iron. There is always a certain amount of dead organic matter in water, as well as live bacteria, virus and perhaps other types of life. Enough chlorine must be added to oxidize all of the organic matter, dead or alive, and to leave some excess uncombined

or "free" chlorine. This residual free chlorine prevents recontamination. Residual chlorine in water is not harmful, because water which contains a harmful amount of chlorine is extremely distasteful.

Some organisms are more resistant to chlorine than others. Two particularly resistant varieties are amoebic cysts (which cause amoebic dysentery) and the cercariae of schistosomes (which cause bilharziasis or schistosomiasis). These, among others, require much higher levels of residual free chlorine and longer contact periods than usual to be safe. Often special techniques are used to combat these and other specific diseases.

It always takes time for chlorine to work. Be sure that water is thoroughly mixed with an adequate dose of the dissolved chemical, and that it stands for at least 30 minutes before consumption.

Polluted water which contains large quantities of organic matter, or cloudy water, is not suitable for chlorination. It is best, and safest, to choose the clearest water available. A settling tank, and simple filtration can help reduce the amount of suspended matter, especially particles large enough to see. Filtration that can be depended upon to remove all of the amoebic cysts, schistosomes, and other parthogens normally requires professionals to set up and operate.

NEVER depend on home-made filters alone to provide drinking water. However, a home-made slow sand filter is an excellent way to prepare water for chlorination.

Depending on the water to be treated, varying amounts of chlorine are needed for adequate protection. The best way to control the process is to measure

Water Condition	Initial Chlorine Dose in Parts Per Million(ppm)	
	No hard-to-kill organisms suspected.	Hard-to-kill organisms present or suspected.
Very Clear, few minerals.	5 ppm	Get expert advice; in an emergency boil and cool water first, then use 5 ppm to help prevent recontamination. If boiling is impossible, use 10 ppm.
A coin in the bottom of 1/4 - liter (8 ounce) glass of the water looks hazy.	10 ppm	Get expert advice; in an emergency boil and cool first. If boiling is impossible use 15 ppm.

Figure 3. Initial chlorine dose to safeguard drinking water supply. Parts per million (ppm) is the number of parts by weight of chlorine to a million parts by weight of water. It is equivalent to milligrams per liter.

\* \* \* \* \*

Figure 4 - Amounts of chlorine compound to add to drinking water

Chlorine Compound	Percent by Weight Active Chlorine	Quantity to add to 1000 U.S. gallons of water required strength			Quantity to add to 1000 liters to get required strength		
		5 PPM	10 PPM	15 PPM	5 PPM	10 PPM	15 PPM
High test Calcium Hypochlorite $\text{Ca}(\text{OCl})_2$	70%	1 oz	2 oz	3 oz	8 gms	15 gms	23 gms
Chlorinated Lime	25%	2 1/2 oz	5 oz	7 1/2 oz	20 gms	40 gms	60 gms
Sodium hypochlorite $\text{NaOCl}$	14%	5 oz	10 oz	15 oz	38 gms	75 gms	113 gms
Sodium hypochlorite	10%	7 oz	13 oz	20 oz	48 gms	95 gms	143 gms
Bleach - A Solution of Chlorine in water	usually 5.25%	13 oz	26 oz	39 oz	95 gms	190 gms	285 gms

<u>Application</u>	<u>Recommended Dose</u>	<u>Procedure</u>
New or repaired well	50 ppm	<ol style="list-style-type: none"> <li>1. Wash casing, pump exterior and drip pipe with solution.</li> <li>2. Add dosage to water in well.</li> <li>3. Pump until water coming from pump has strong chlorine odor (for deep wells, repeat this a few times at 1 hour intervals).</li> <li>4. Leave solution in well at least 24 hours.</li> <li>5. Flush all chlorine from well.</li> </ol>
Spring encasements	50 ppm	Same as above.
Cisterns	100 ppm	<ol style="list-style-type: none"> <li>1. Flush with water to remove any sediment.</li> <li>2. Fill with dosage.</li> <li>3. Let stand for 24 hours.</li> <li>4. Test for residual chlorine. If there is none, repeat dosage.</li> <li>5. Flush system with treated water.</li> </ol>

Figure 5. Recommended doses for super-chlorination. To find the correct amounts of chlorine compound needed for the required dosage, multiply the amounts given under 10ppm in Figure 4 or 5 to get 50ppm and by 10 to get 100ppm.

the amount of free chlorine in the water after the 30 minute holding period. A simple chemical test which uses a special organic indicator called orthotolidine can be used. Orthotolidine testing kits available on the market come with instructions of their use.

When these kits are not available, the chart in Figure 3 can be used as a rough guide to how strong a chlorine solution is necessary. The strength of the solution is measured in parts by weight of active chlorine per million parts by weight of water, or "parts per million" (ppm).



The chart in Figure 4 gives the amount of chlorine-compound to add to 1000 liters or to 1000 gallons of water to get the solutions recommended in Figure 3.

Usually it is convenient to make up a solution of 500 ppm strength which can then be further diluted to give the chlorine concentration needed. The 500 ppm solution must be stored in a sealed container in a cool dark place, and should be used as quickly as possible since it does lose strength. Modern chlorination plants used bottled chlorine gas, but this can only be used with expensive machinery by trained experts.

### Super-chlorination

Super-chlorination means applying a dose of chlorine which is much stronger than the dosage needed to disinfect water. It is used to disinfect new or repaired wells, spring encasements and cisterns. The chart in Figure 5 gives recommended doses.

#### Example 1:

A water-holding tank contains 8000 U.S. gallons. The water comes from a rapidly moving mountain stream and is passed through a sand filter before storage. How much bleach should be added to make this water drinkable? How long should the water be mixed after adding?

#### Solution:

In this case 5 ppm are probably sufficient to safeguard the water (from Figure 3.) To do this with bleach requires 13 ounces per 1000 gallons. Therefore the weight of bleach to be added is 13 x 8 or 104 ounces.

Always mix thoroughly, for at least a half hour. A good rule of thumb is to mix until you are certain that the chemical is completely dissolved and distributed and then ten minutes long-

er. In this case, with an 8000-gallon tank, try to add the bleach to several different locations in the tank to make the mixing easier. After mixing, test the water by sampling different locations, if possible. Check the corners of tank especially.

#### Example 2:

A new cistern has been built to hold water between rainstorms. On its initial filling it is to be super-chlorinated. How much chlorinated lime should be added? The cistern is 2 meters in diameter and 3 meters high.

#### Solution:

First calculate the volume of water. For a cylinder, Volume is  $\frac{\pi D^2}{4} H$  (D is diameter, H is height and  $\pi$  is 3.14.) Here D = 2 meters H = 3 meters.

$$V = \frac{3.14}{4} \times (2 \text{ meters}) \times (2 \text{ meters}) \times (3 \text{ meters})$$

V = 9.42 cubic meters = 9,420 liters. (Each cubic meter contains 1000 liters.) From Figure 5 we learn that a cistern should be super-chlorinated with 100 ppm of chlorine. From Figure 4, we learn that it takes 40 grams of chlorinated lime to bring 1000 liters of water to 10 ppm Cl. To bring it to 100 ppm, then, will require ten times this amount, or 400 grams.

$$\frac{400 \text{ grams}}{\text{thousand liters}} \times 9.42 \text{ thousand liters} = 3768 \text{ grams.}$$

#### Source:

Environmental Sanitation, by J. S. Salvato, John Wiley & Sons, Inc., New York, 1958.  
Field Water Supply, TM 5-700.

## WATER PURIFICATION PLANT

The water purification plant described here uses laundry bleach as a source of chlorine. Although this manually-operated plant is not as reliable as a modern water system, it will provide safe drinking water if it is operated according to instructions.

Many factors in this system require operating experience. When starting to use the system, it is safest to have the assistance of an engineer experienced in water supplies.

### Tools and Materials

3 Barrels, concrete tanks or 208 liter (55-gallon drums)

20cm (8") funnel, or sheet metal to make a funnel

2 Tanks, about 20 liters (5 gallons) in size

4 Shut-off valves

Throttle or needle valve (clamps can be used instead of valves if hose is used)

Pipe or hose with fittings

Hypochlorite of lime or sodium hypochlorite (laundry bleach)

The water purification plant is made as in Figure 6. The two at the top of the structure are for diluting the bleach. (The system can be simplified by eliminating the concentrate tank; the bleach is then added directly to the mixing tank.)

The two smaller tanks on the shelf below are for holding equal amounts of diluted bleach solution and water at a constant pressure; this makes the solution and the water flow at the same speed into the hoses which lead to the mixing point. The mix, which

can be seen through the open funnel, is further controlled by the valves. If a needle or throttle valve is not available a throttle action can be obtained by installing another shut-off valve in series with Valve #4.

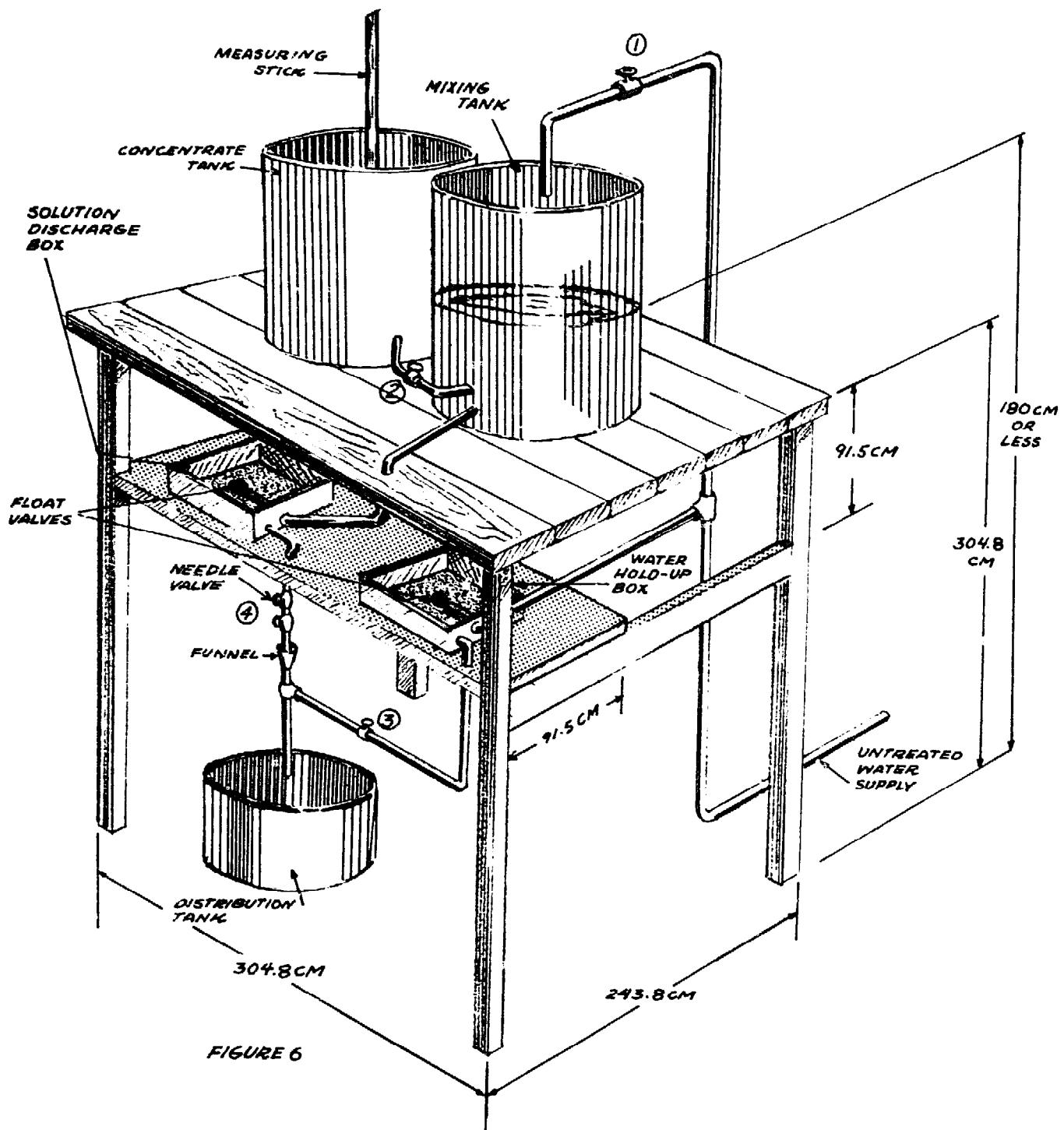
Placing the two barrels at a height of less than 1.8 meters (6') above the float valve causes a pressure of less than 0.35kg per square centimeter (5 pounds per square inch). Thus, the plumbing does not have to be of high quality except for Valve #1 and the float valve of the water hold-up tank, if the water supply is under higher pressure.

### Operation

A trial and error process is necessary to learn how much concentrate should be put in the concentrate tank, how much concentrate should flow into the mixing tank and how much solution should be allowed past the funnel. A suggested starting mixture is 1/4 liter (1/2 pint) of concentrated bleach for a mix tank capacity of 190 liters (50 gallons) to treat 1900 liters (500 gallons) of water.

The water in the distribution tank should have a noticeable chlorine taste. The amount of bleach solution required depends on how dirty the water is.

1. Mix concentrated bleach with water in the concentrate tank with all valves closed. The mixing tank should be empty.
2. Fill the pipe from the mixing tank to the solution tank with water after having propped the float valve in a closed position.
3. Let a trial amount of concentrate flow into the mixing tank by opening Valve #2.
4. Use a measuring stick to see how



much concentrate was used.

5. Close Valve #2 and open Valve #1 so that untreated water enters the mixing tank.
6. Close Valve #1 and mix solution in the mixing tank with a stick.
7. Remove the prop from the float valve of the solution tank so that it will operate properly.
8. Open wide the needle valve and Valve #4 to clean the system. Let 4 liters (1 gallon) drain through the system. (Steps 2, 7 and 8 can be omitted after the first charging of the system, if the pipe mentioned

in the second step is not permitted to empty before recharging the mixing tank.)

9. Close down the needle valve until only a stream of drops enters the funnel.
10. Open Valve #3.

The flow into the funnel and the taste of the water in the distribution tank should be checked regularly to insure proper treatment.

Source:

Chris Ahrens, VITA Volunteer, Eastern Kentucky Housing Development Corporation, Inc.

## SAND FILTER

Surface water from streams, ponds or open wells is very likely to be contaminated with leaves and other organic matter. A gravity sand filter can remove most of this suspended organic material, but it will always let virus and some bacteria pass through. For this reason, it is necessary to boil or chlorinate water after it has been filtered.

Although sand filtration does not make polluted water safe for drinking, a sand filter which is properly built and maintained will prepare water for boiling or chlorination. Sand filters must be cleaned periodically.

The household sand filter described here should deliver 1 liter (1 quart) per minute of clear water, ready for boiling or chlorinating.

### Tools and Materials

Steel drum: at least 60cm wide by 75cm (2' x 29 1/2")

Sheet metal, for cover: 75cm (29 1/2") square

Wood: 5cm x 10cm (2" x 4"), 3 meters (9.8') long

Sand: 0.2 cubic meter (7 cubic feet)

Gravel

Blocks and nails

Pipe, to attach to water supply

Optional: valve and asphalt roofing compound to treat drum

The gravity sand filter is the easiest type of sand filter to understand and set up. The gravity filter uses sand to strain suspended matter from the water, although this does not always stop small particles or bacteria.

Over a period of time, a biological growth forms in the top 7.5cm (3") of sand. This film increases the filtering action. It slows the flow of water through the sand, but it traps more particles and up to 95 percent of the bacteria. The water level must always be kept above the sand to protect this film.

Sand filters can get partially clogged with organic matter; under some conditions this can cause bacterial growth in the filter. If the sand filter is not operated and maintained correctly, it can actually add bacteria to the water.

By removing most of the organic matter, the filter:

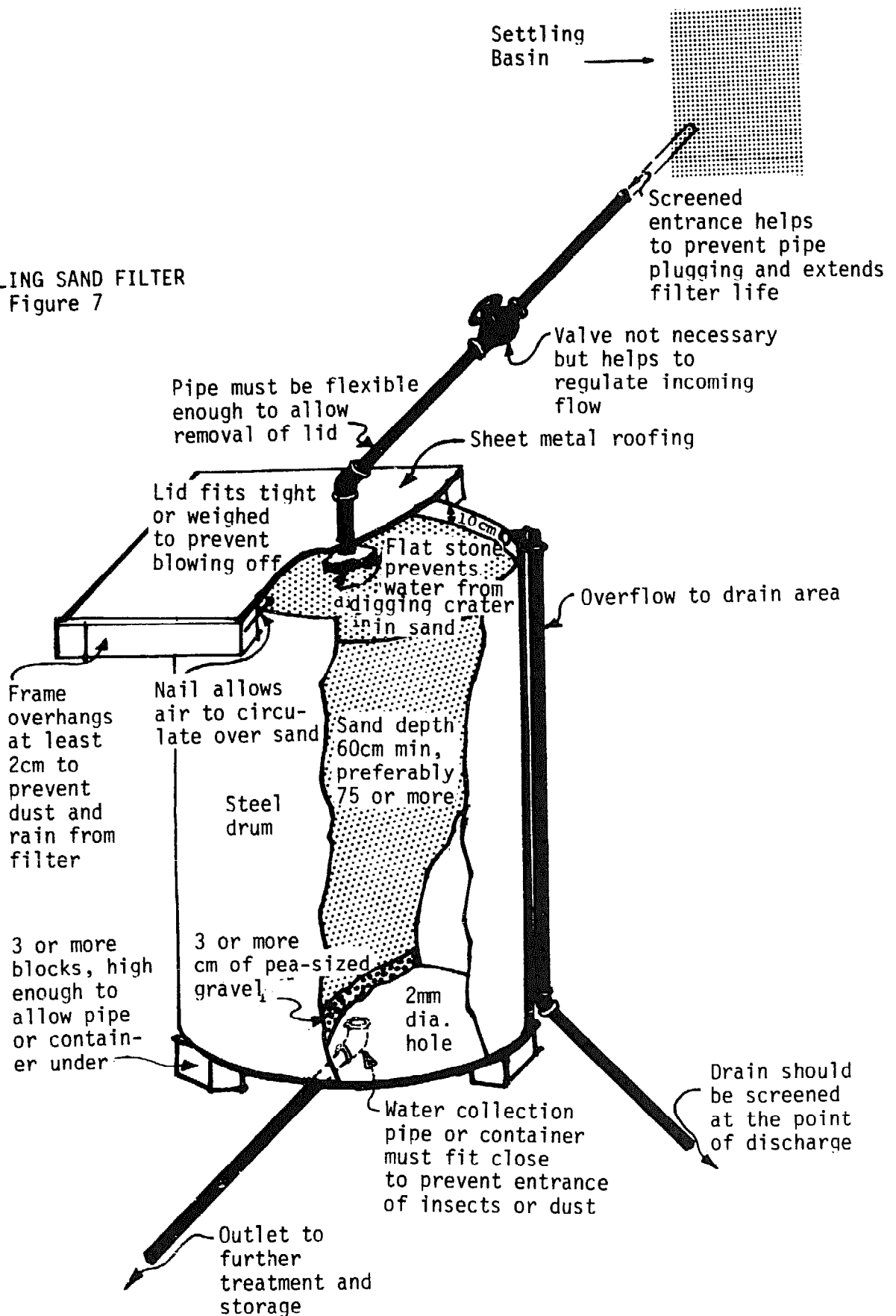
1. Removes larger worm eggs, cysts, and cercariae, which are difficult to kill with chlorine.
2. Allows the use of smaller and fixed doses of chlorine for disinfection, which results in drinkable water with less taste of chlorine.
3. Makes the water look cleaner.
4. Reduces the amount of organic matter, including living organisms and their food, and the possibility of recontamination of the water.

The drum for the sand filter shown in Figure 7 should be of heavy steel. It can be coated with asphalt material to make it last longer. The 2mm (3/32") hole at the bottom regulates the flow: it must not be made larger.

The sand used should be fine enough to pass through a window screen. It should also be clean; it is best to wash it.

The following points are very important in making sure that a sand filter operates properly:

TRICKLING SAND FILTER  
Figure 7



1. Keep a continuous flow of water passing through the filter. Do not let the sand dry out, because this will destroy the microorganisms which form a film on the surface layer of sand. The best way to insure a continuing flow is to set the intake so that there is always a small overflow.
2. Screen the intake and provide a settling basin to remove as many particles as possible before the water goes into the filter. This will keep the pipes from becoming plugged and stopping the flow of water. It will also help the filter to operate for longer periods between cleanings.
3. Never let the filter run faster than 3.6 liters per square meter per minute (4 gallons per square foot per hour) because a faster flow will make the filter less efficient by keeping the biological film from building up at the top of the sand.
4. Keep the filter covered so that it is perfectly dark to prevent the growth of green algae on the surface of the sand. But let air circulate above the sand to help the growth of the biological film.
5. When the flow becomes too slow to fill daily needs, clean the filter: Scrape off and discard the top 1/2cm (1/4") of sand and rake or scratch the surface lightly.

After several cleanings, the sand should be raised to its original height by adding clean sand. Before doing this, scrape the sand in the filter down to a clean level. The filter should not be cleaned more often than once every several weeks or even months, because the biological growth at the top of the sand makes the filter more efficient.

Source:

Water Supply for Rural Areas and Small Communities, by Edmund G. Wagner and J. N. Lanoix, World Health Organization, Geneva, 1959.

## CONSTRUCTION OF A PLANE TABLE FOR MAP MAKING

The plane table described here can be used for mapping villages, roads, trenches and fields. This type of plane table has been widely used by professional surveyors.

### Tools and Materials

Some boards of soft wood, about 1858 square centimeters (2 square feet) approximately 2.5cm (1") thick

Some boards of a fairly strong wood, 19mm (3/4") to 2.5cm (1") thick, and at least 1m (3') long

7 bolts, 6mm (1/4") in diameter and 5cm (2") long

Nuts for each of the bolts, preferably wing nuts, and washers

Saw

Drill and 6mm (1/4") bit

### Drawing Surface

From the soft wood, make a flat drawing surface. The one shown in Figure 1 is 40.5cm x 53.5cm (16" x 21") but any dimension of this general size-range is satisfactory. The surface should be sanded smooth and should be soft enough to permit easy use of thumb tacks and pins.

### Pivot

To allow the table to be rotated on the tripod, a pivot is required. In the illustration, two 15cm (6") circles of 2.5cm (1") wood were cut. A 6mm (1/4") hole was drilled in the center of each circular block and one of the 6mm (1/4") bolts used as an axis. The head of the bolt was counter sunk so that a flush surface was available for nailing or screwing the upper block to the under side of the drawing board. This block should be centered.

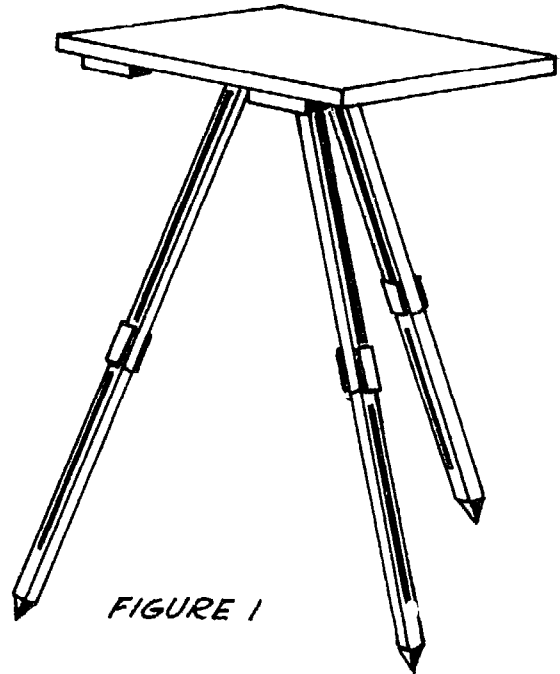


FIGURE 1

### Tripod Legs

The tripod legs are extendable. As Figures 2 and 3 show, each leg has two side rails, 10mm x 19mm x 81.3cm (3/8" x 3/4" x 32"), and a slotted center piece, 2.5cm x 16mm x 71.1cm (1" x 5/8" x 28"), which has been pointed at one end.

The legs are now assembled as follows: One end of two side rails is rounded in the 19mm (3/4") direction and a 6mm (1/4") hole is drilled 13mm (1/2") in from that end. A 6mm (1/4") hole is also drilled 15cm (6") from the other end.

Two wooden plates, 10mm x 4.5cm x 12.7cm (3/8" x 1 3/4" x 5") are nailed one on each side of the pair of side rails at the unrounded end. See Figure 3. This plate should space the side rails, such that the center piece may move reasonably freely but not be loose. The 6mm (1/4") wide slot in



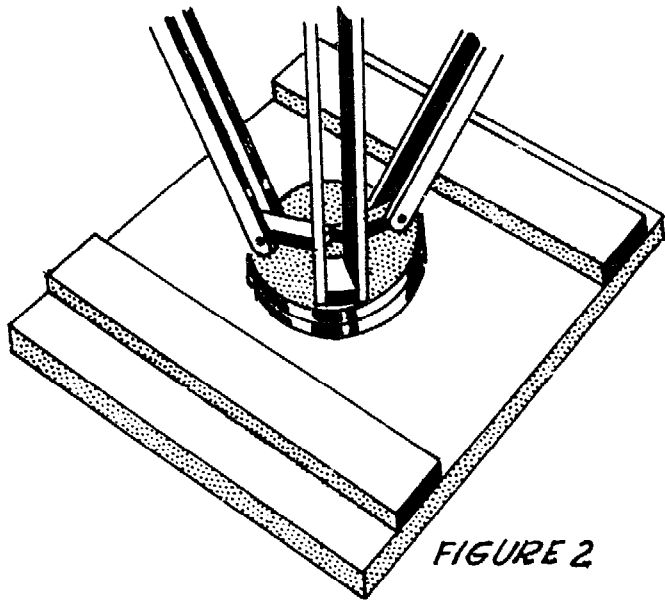


FIGURE 2

the 16mm (5/8") dimension (which extends most of the length of the center piece) will permit a 6mm (1/4") bolt to pass through. The blunt end of the center piece has been inserted up through the opening formed by the two plates and the two side rails: a 6mm (1/4") bolt may be passed through the hole in one side rail, through the slot in the center piece and then through the 6mm (1/4") hole in the other side rail; the wing nut is then put on. See Figure 4.

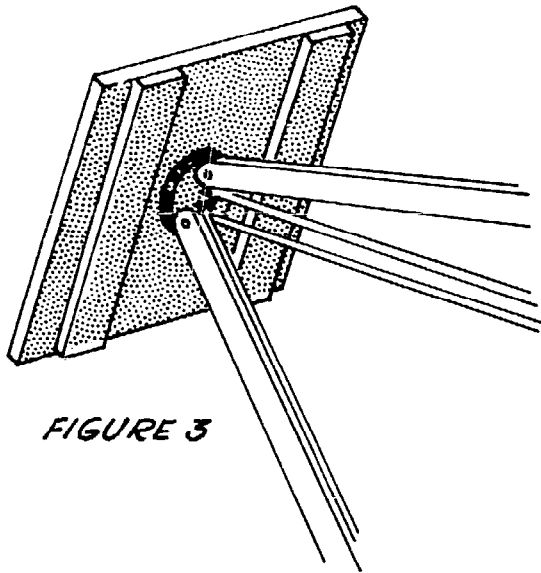


FIGURE 3

THESE MIGHT BE MADE OF METAL ABOUT THE THICKNESS OF THAT FROM OLD BARRELS, PUT ON WITH WOOD SCREWS

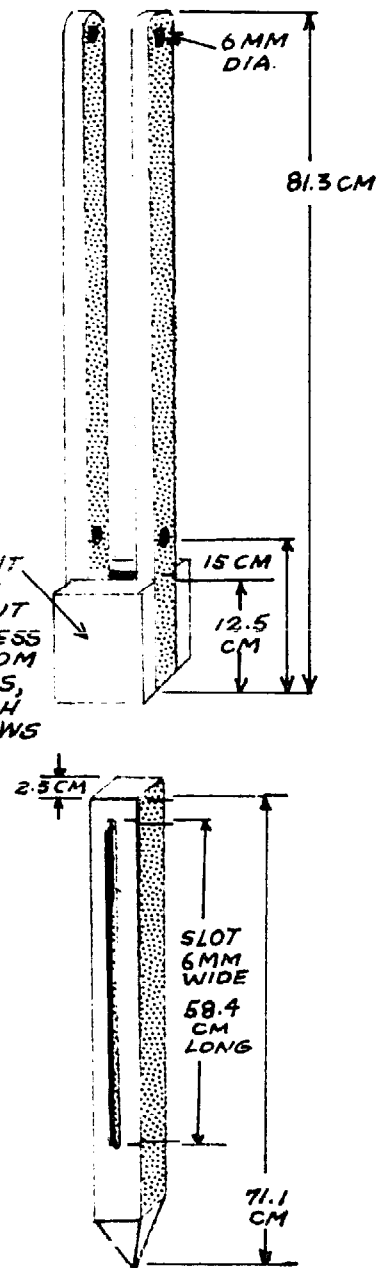


FIGURE 4  
TRIPOD LEG

In order to affix the two side rails to the lower block, the latter must be cut away in a fashion to space the side rails 2.5cm (1") apart. It must be cut back somewhat more than the width, 22mm (7/8"), of the side rail. This lower block is cut away in this manner in three equally spaced locations, so that the legs will be equally spaced. A 6mm (1/4") hole is then drilled in line with the previously drilled holes in the rounded ends of the side rails. A 6mm (1/4") bolt may then be inserted through the three holes and a nut placed on the other end. See Figure 5.

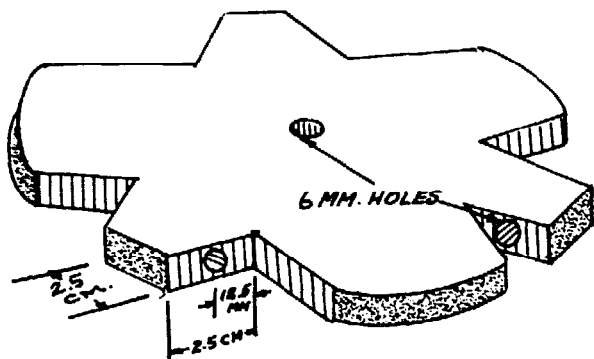


FIGURE 5  
LOWER BLOCK

An alternate method of making the lower block, which will make the block stronger and should be used when it is made from soft wood, is shown in Figure 6. Three blocks of wood, 2.5cm x 3.8cm x 7.6cm (1" x 1 1/2" x 3"), are screwed to the 15cm (6") diameter lower block. A 6mm (1/4") diameter hole is drilled 13mm (1/2") from the end of each block, in the direction of the 2.5cm (1") thickness, to allow for attaching the leg.

The advantage of this method is the strength obtained by having the grain

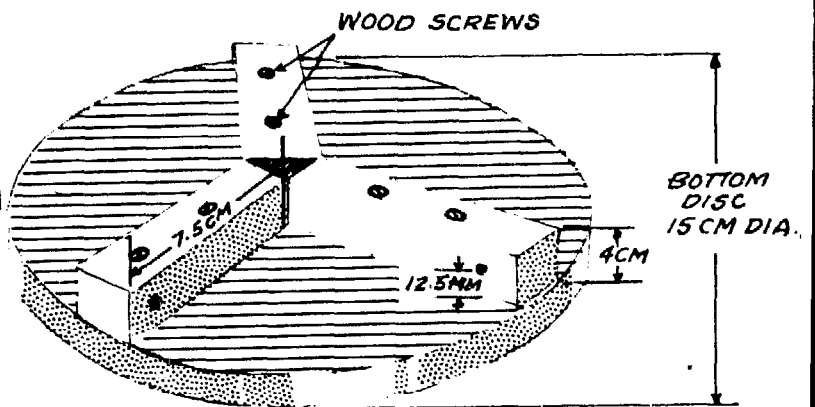


FIGURE 6

of the wood always at right angles to the bolt holding the leg in place. In the first method the grain will be parallel to one of the bolts and it will break if it is handled roughly, as it probably will be.

It is now possible to (1) change the length of the legs so that the table can be accommodated to sloping ground; (2) to change the spread of the legs to better accommodate setting up the table on rough grounds and; (3) rotate the drawing board in relation to the tripod.

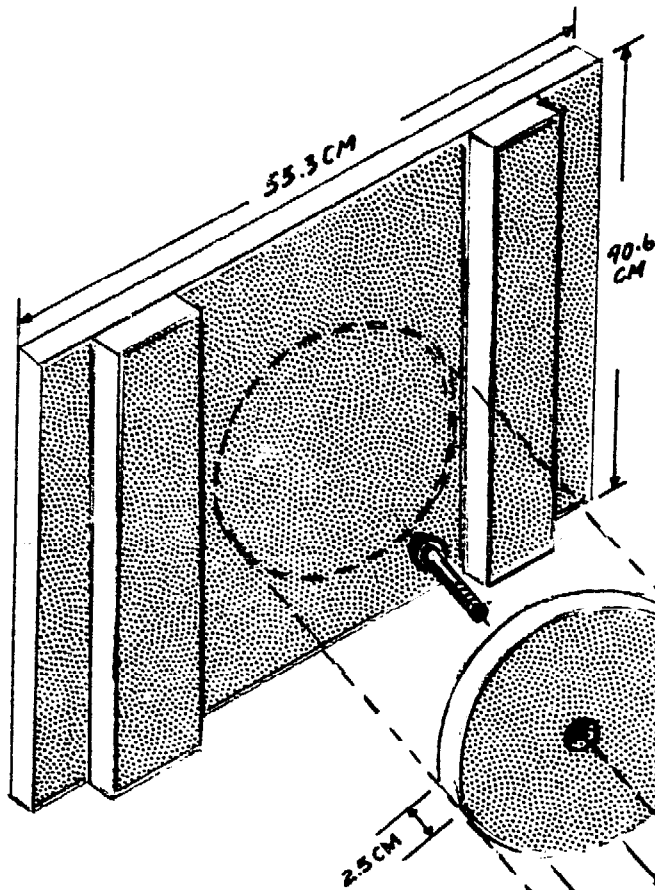
The blown-up drawing in Figure 7 will be helpful in assembling the plane table. A table whose legs cannot be extended would still be useful. In this case, use single pieces, 22mm x 45mm x 142cm (7/8" x 1 3/4" x 56"), which are pointed on one end and cut away at the other end to allow for the same sort of connection to the lower end.

#### Source:

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CONSTRUCT DRAWING SURFACE FROM 19 MM PLYWOOD IF AVAILABLE, OR USE BATTENS TO MAKE UP A DRAWING SURFACE OF APPROX. 40 BY 53 CM.

15 CM DIA. DISC WITH 6 MM HOLE IN CENTER. NAIL OR SCREW TO DRAWING SURFACE AFTER INSTALLING 6 MM BOLT THRU HOLE

LOWER BLOCK 15 CM. (SEE FIG. 6)

USE WASHERS IF AVAILABLE 7 REQ'D.

WING NUT 7 REQ'D

6 MM X 5 CM LONG BOLTS (7 REQ'D)

FIGURE 7

10 MM X 19 MM X 81.3 CM UPPER TRIPOD LEGS 6 REQ'D (SEE FIG. 4)

WOOD PLATES 10 MM X 45 MM X 12.6 CM 6 REQ'D.

58.4 CM

LOWER TRIPOD LEG 25 MM X 16 MM X 71.1 CM 3 REQ'D (SEE FIG. 4)

## MAP-MAKING USING A PLANE TABLE

Instructions are given here for making serviceable maps using a plane table. Such maps are valuable for irrigation, drainage and village layout plans.

Before aerial photography, most topographical maps were made by the use of plane tables.

### Tools and Materials

Plane table (see preceding entry)  
Paper  
Pencil  
Ruler  
Pins  
Tape measure (optional)  
Spirit level (optional)

### Measuring Pace

If no long tape measure is available, the first step for a map maker is to measure his pace: A 30-meter (100-foot) distance should be measured out on level ground. If only a 30cm (12") ruler is available, this can be used to mark out a meter (3' or 4') on a stick; this stick in turn can be used to measure the 30m (100').

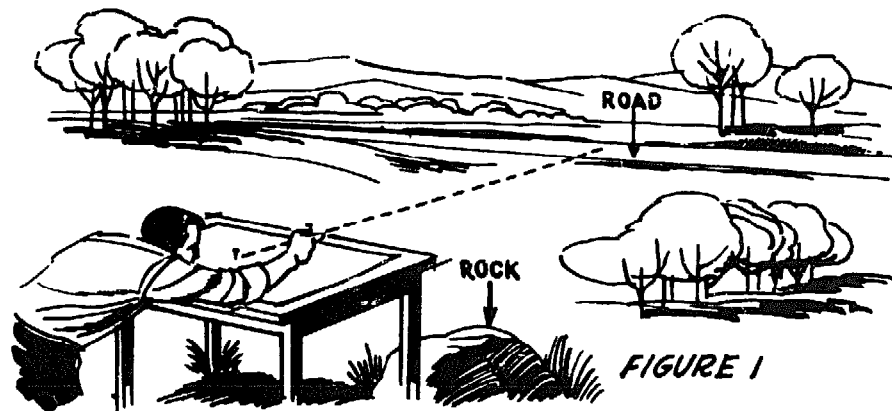
Being careful to walk normally, the map maker then counts the number of paces he takes in walking the 30m (100') interval. Simple division will then give the average length of a pace.

### Map Scale

The next step is to decide on a scale for the map. This is determined by judging the longest distance to be mapped and the size of the map desired. The map does not have to be made on a single sheet of paper; it can be pieced together from several sheets when it is completed. For example: if you want a map 80cm (2 1/2') long of an area whose longest dimension is 800 meters (1/2 mile or 2540 feet), then a scale of 1 meter to 1cm (100 feet to the inch) would be convenient.

### Map Making

1. Place paper on the plane table and orient the plane table on or near some principal feature of the area; for example, a path, road, creek or tree.



2. Place a pin vertically in the spot on the map to locate this feature.

3. Make the plane table level; for example, by using a spirit level. If a spirit level is not available, you can level the table by using anything which rolls easily.

4. Rotate the table to a proper orientation, so that the map will be made in the desired direction.

5. Sight along the first pin to another principal feature which is visible from the table location (a bend in a road, a hill or any feature which will tie the map together, moving the second pin into the line of sight (see Figure 1). A ruler can be used for this purpose if it has a sighting edge; a sighting edge can be made by sticking a couple of pins into the ruler.

6. Draw a line in the direction defined by the two pins.

7. Measure the distance to the feature observed either by pacing or with a tape measure.

8. Scale this distance along the line drawn on the map, starting at the first pin.

9. Repeat this process for other principal features which can be seen from this location (see Figure 2).

10. When this has been done, move the table to one of the points just plotted, selecting one which will enable you to move over the area conveniently. For example, follow a lane or creek or some feature which ties things together.

11. Set the plane table over this point and re-orient the table by putting pins in the map at the present and previous locations. This procedure locates the line joining the two locations on the map in the same direction as the line exists in nature, making it possible to go on to the next step with the map oriented properly.

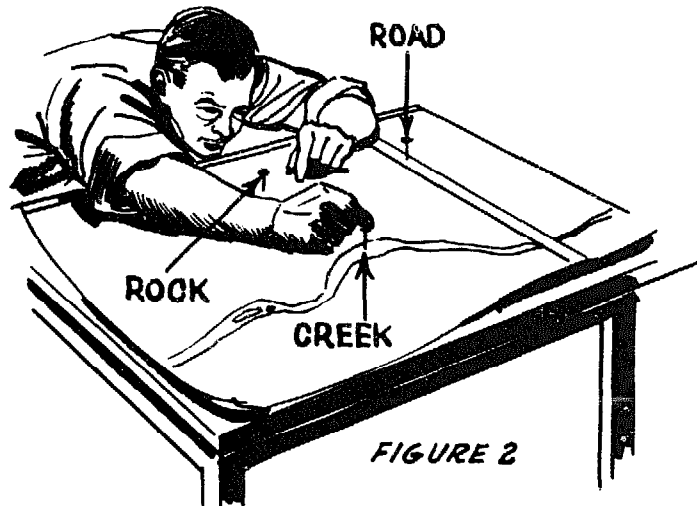


FIGURE 2

12. From this new location, map in the principal features which can be conveniently sighted.

In this way the entire region to be mapped may be covered in a systematic way. If gaps appear or if more detail is needed, go back and set up over some mapped feature, reorient the map by sighting on a second feature, and proceed to map in the detail.

To map features which are not going to be used as plane table locations in the mapping process, draw a line in the direction of each feature from two plane-table locations. The intersection of these two lines corresponding to a single feature locates the feature on the map. This avoids the need for measuring distances. Note, however, that the distances between plane-table locations must be measured.

#### Relative Elevations

If a spirit level is available, it is possible to level the plane table accurately and, using a ruler or other sighting device, plot relative elevations on the map.

A stick about 2 or 3 meters (6' or 8') long should be marked off in centimeters (inches). A person holding the stick vertically can, by moving his

finger up or down, identify to the person sighting the distance up from the ground through which the line of sight passes.

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