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INTERREGIONAL PROJECT FOR THE IMPLEMENTATION AND EVALUATION OF SPECIAL PUBLIC WORKS PROGRAMMES

TECHNICAL INSTRUCTIONS
No. VII

CONSTRUCTION OF HAND DUG WELLS AND PROTECTION AGAINST POLLUTION

by
Ivo Boschi
Senior Adviser in Sanitary Engineering

Geneva, 1982

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PREFACE

The purpose of these instructions is to put together in simple and logical form various methods of hand digging wells and different aspects which must be considered during their construction. This manual is intended to be a guide for technical personnel and village leaders involved in well construction, especially of village wells in tropical and sub-tropical areas, which are often built using very simple methods that can be carried out by relatively unskilled villagers.

The methods described combine traditional and modern techniques. Well construction is an ancient craft going back thousands of years. As in the past, many unprotected wells are furnishing polluted water today, which presents a constant danger for consumers' health.

Hand-dug wells are used for a variety of purposes but, in the majority of villages, they are primarily used for personal purposes. Good quality water is essential for the promotion of public health. At present, over half the world's population (excluding China) does not have safe water. In many parts of the Third World and, especially in tropical areas, health hazards resulting from a polluted water supply system are very frequent. In the execution of hand-dug wells, the public health aspects should be given high consideration, since a new construction that does not respect good public health practices may do more harm than good.

This manual has been prepared within the framework of the International Drinking Water Supply and Sanitation Decade(1981-1990), launched by the General Assembly of the United Nations on 10 November 1980. The instructions present a range of technology suitable for the construction of hand-dug wells, which could also be used in labour-intensive special public works programmes.

1. INTRODUCTION

The water found on the earth's surface originates in meteorologic precipitations: rain, snow, hail, etc.. Ground waters usually have the same origin. Movements of water in its various forms is called the hydrological cycle(Fig. 1.). The sun's rays evaporate water from the sea, from inland bodies of water and from the leaves of vegetation. Evaporation increases with the temperature and creates large masses of water vapour. The water vapour thus formed rises and collects into clouds which are blown by the wind to the point where meteorological conditions cause them to precipitate as rain, snow or hail. Rain precipitation is the most common.

Some precipitation falls directly into the sea. The remainder which falls on the mainland is divided into three types: one part immediately evaporates and is returned to the hydrological cycle, the second part runs off into streams, rivers and then into the sea; the third part soaks into the ground, sinks through the permeable ground and collects into an aquifer. Very often an aquifer under the force of gravity gradually runs its way downhill: it either emerges as a spring or returns below ground to the sea to be re-evaporated and recommence a new hydrological cycle. At this stage, the aquifer is called ground water.

Aquifers may be of several types: the open aquifer appears when the lower part of porous soil that reaches up to the surface is saturated with water; artesian water is formed when the aquifer is under pressure between two impermeable layers of soil or rock(Fig. 2).

Hand-dug wells extract water from open aquifers. The amount of water stored in an open aquifer depends on the quantity of rainfall soaked into the ground. The part of rainfall that soaks far underground depends largely on the composition and form of the land surface. For example, sandy and vegetated areas will permit a greater proportion of rain to penetrate than steep or hard ones.

However, it is possible in hard areas to increase the amount of water that sinks into the soil by slowing down the speed of surface run-off. This may be achieved by a combination of different measures such as contour ploughing, bunding flood plains, terracing steep slopes and erecting small dams across the head waters of streams; these measures will also help control soil erosion.

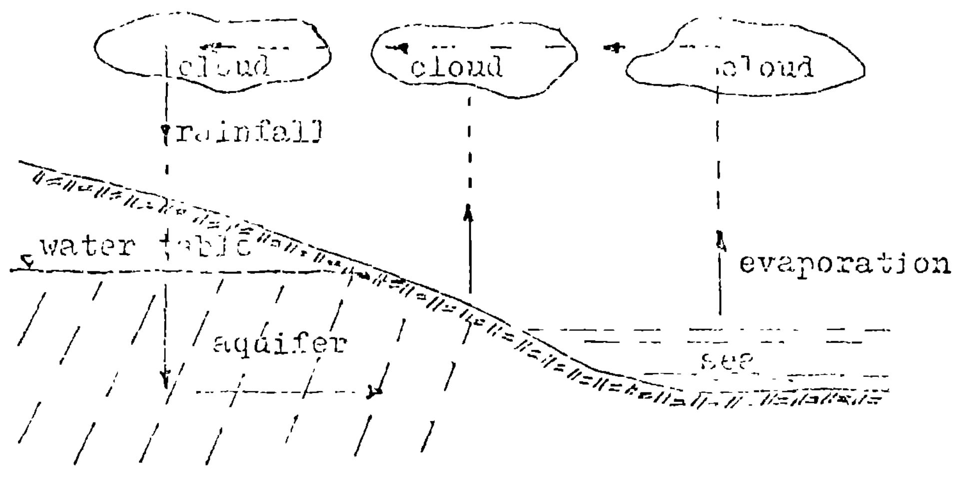


Fig.1 Hydrological cycle

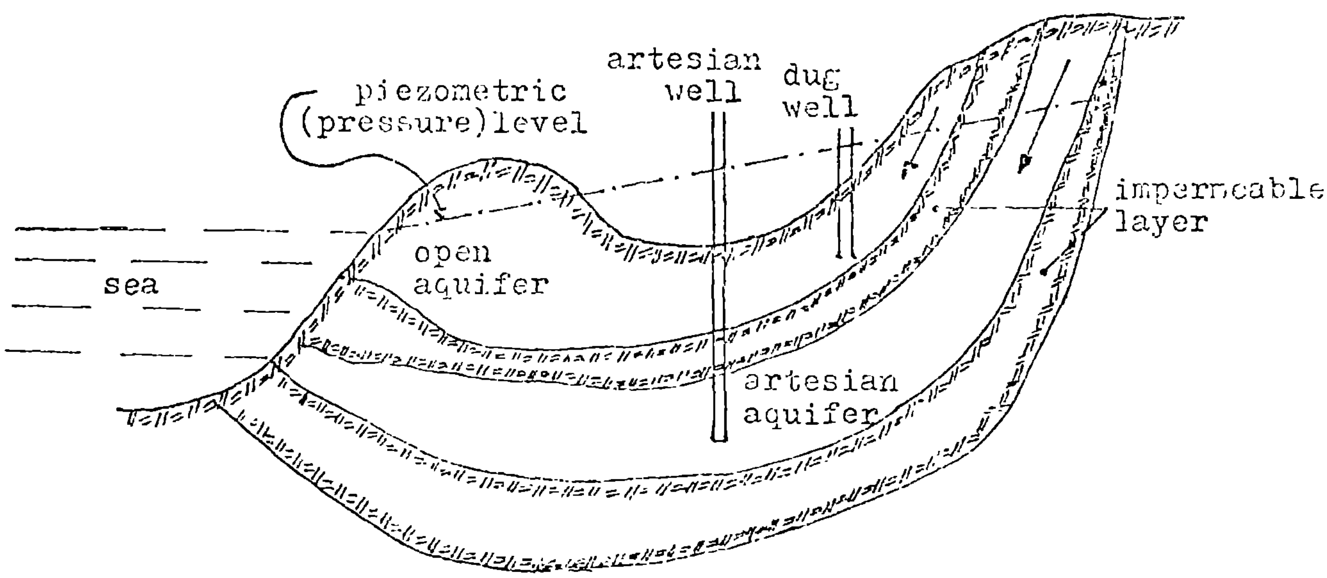


Fig.2.Types of aquifer

2. TYPE OF WELLS

There are five main methods of drawing water from an aquifer. These are:

driven tube well,
bored tube well,
jetted tube well,
hand dug well,
borehole.

a) The driven tube well is the easiest type of well to build. A special tube is forced into the soil 5 to 6 meters using a hammer. The tube diameter is 50-60mm. and it has a special filter on top. Its advantage is that it can be pulled out and re-used when only a temporary water supply is required.

b) The bored tube well is also a type of tube well but the hole is bored by auger and then the tube is driven in. This method has been used for more than a thousand years. It is not expensive and both construction and maintenance can be done by unskilled workers. However, the depth is limited to 20 meters and, in general, the output is very low.

c) Jetted tube well: This method may be used for a well having a tube diameter of 25-40mm., driven into sandy soil. The well hole is made by a strong water jet. This system can be used down to a depth of 80 meters. Jetting requires plenty of water, some steel pipes and usually a pump and various special fittings.

d) The hand-dug well is the most widely used type of well in the world. There are many Biblical references to well digging, and there are wells in existence today which are believed to have been sunk in ancient times. The hand-dug well is still one of the cheapest methods of providing a small supply of water for villages, but it is relatively expensive for individual families. Digging a well by hand is a "labour-intensive" activity --in other words, the manual effort put in represents a large proportion of the total cost of the well. Consequently, hand digging is a particularly appropriate method of well construction in low-income villages. There are additional advantages: villagers take a more receptive attitude towards a well that they have helped to build and they also learn some skills such as mixing and pouring concrete.

There are two principal types of hand-dug wells:

- Step wells: this type is common in Asia. Consumers can step into the water so surface washings may pass into the wells and the water is subject to constant pollution. The spread of dracontiasis through such sources has been well established.
- Wells without step are currently very popular. They are not expensive because construction and maintenance can be managed by unskilled workers. Their depth is restricted to 20-30 m. and, in general, their output is very weak.

e) Boreholes are usually the most expensive type of well. When the aquifer is very deep, it is attainable only by utilising a borehole. Boreholes differ from other types of wells in their dimensions. Generally, their diameter is smaller and they can range from a few meters to more than 100 meters in depth.

3. WATER AND HEALTH

Pure water does not exist in nature. Water is a universal solvent and tends to dissolve almost all that it comes in contact with. For this reason water always contains numerous impurities, which may be divided into physical, chemical and bacteriological. The physical and chemical characteristics deal with colour, turbidity, odour, water temperature, resistivity, radioactivity, acidity, hardness, organic substances in water and composites of azote. However, the principal factors which can impair the potability of water or its taste are turbidity, odour and the presence of a certain number of substances recognised as toxic or undesirable. When their concentration exceeds a certain level, diverse chemical pollutants such as nitrates, arsenic and lead present a direct health threat if consumed in the water. Fluoride in small concentrations is beneficial to health, but in concentrations greater than 1.5 p.p.m., it will cause children's teeth and, to a lesser degree, those of adults to turn brown-stained and pitted.

The pollution of water may be accidental and it sometimes provokes serious consequences, but, in most cases, it is imputable to uncontrolled discharges from diverse origins: human excreta, other solid and liquid domestic and industrial waste, application of fertilizers to cultivated land, leachings from cesspools and livestock yards. Municipal and domestic liquid wastes contain different micro-organisms some of which may be pathogenic.

Normally, natural ground water is better for human consumption than any other untreated surface water because it is filtered as it flows through the ground. However, ground water is sometimes polluted by domestic or industrial liquid waste.

Certain means of control should be established for water supply systems in rural areas. Bacteriological analysis is the only way to determine if the water is dangerous for consumption.. However, a routine bacteriological control which is obligatory in urban areas is not realistic in rural conditions and periodic examination of the physical, chemical and bacteriological quality of water must be done in order to discover the major health risks.

The diseases related to water supplies are numerous and especially great and diverse in the tropics. Human health in most developing countries there is poor due to polluted water and its related infections. Human health could be affected by:

- water ingestion either directly or through food;

- water use in personal hygiene;
- agricultural and industrial practices; or
- recreation activities, or simply the fact of living close to polluted water.

Five types of disease can be distinguished which are linked to water or its shortage and to sanitary conditions:

3.1 Water-borne diseases

Table 1 presents the principal diseases likely to be transmitted by ingestion of polluted water or food prepared with that water, or by washing food, hands or face with polluted water. The main biological agents transmitted in that way can be classified in the following categories: pathogenic bacteria, viruses, parasites, and other micro-organisms. They are responsible for the major epidemic diseases which permanently rage throughout rural and urban populations particularly in developing countries.

The two predominant diseases which cause high mortality if untreated are typhoid and cholera. These diseases occur as an "outbreak" when a community water supply is contaminated by faeces from a person suffering from, or carrying, one of the infections.

Typhoid is the classic example of a water-borne infection which is widespread the world over. The only known host is Salmonella typhi. Bacteria are ingested and very few are needed to incite infection. Prevention by immunisation is possible. Typhoid bacteria survive persistently in water but do not multiply there. They are removed by slow sand filtration and killed by chlorination.

Cholera acts similarly to typhoid. Over the last ten years, the most typical type of cholera, caused by Vibrio cholera, has been in regression.

Several other infections are waterborne but are less important than typhoid and cholera.

A large group of enterobacteria related to typhoid may cause diarrhoea or dysentery.

Table 1

Disease	Biological agent	Means of transmission of contamination
Cholera	Bacteria	From man to man by water
Amoebic dysentery	Parasites	From man to man by food flies contact water
Bacillary dysentery	Bacteria	From man to man by dirty hands water food milk flies
Paratyphoid fevers	Bacteria	From man to man by contact food milk shells water dirty hands
Typhoid fever	Bacteria	From man to man by water food milk shells contact dirty hands
Infectious hepatitis	Viruses	From man to man by water contact food milk shells
Leptospirosis	Bacteria	From animals to man by water food contact
Diarrhoeal disease	Bacteria Viruses Parasites [illegible]	From man to man or direct infection by water food contact
Tularaemia	Bacteria	From animals to man by ticks flies infected domestic animals food water

3.2 Skin and eye infections due to lack of water

It is impossible to maintain reasonable personal hygiene with little water. The diseases in this group are trachoma, scabies, leprosy, conjuctivitis and skin ulcers infected by bacteria. Sometimes, when the water supply is very low, reusing water to wash people and utensils is, in general, worse than not cleaning at all.

3.3 Diseases of which the vector is an aquatic invertebrate organism

The primary disease from this group is schistosomiasis. There are three main schistosome species: Schistosoma haematobium, Schistosoma mansoni and Schistosoma japonicum, appearing respectively in Africa and the Middle East, Africa and South and Central America, including the Caribbean, and in East Asia and the Philippines. The schistosome worms bore their way directly through human skin and therefore present a hazard to all in contact with contaminated water. Water development in the tropics in cases where an irrigation scheme or a man-made lake has been constructed in an area where schistosomiasis occurs, increases endemicity. The four main approaches for limiting transmission are: deploying preventive measures in the transmission cycle, reducing the snail population, limiting consumers' water contact and killing worms.

Guinea worm infection or Dracunculiasis is spread through cyclops, a minute crustacean.The adult worm lies beneath the skin, often in the leg. When water is splashed on the leg, the blister bursts and many guinea worm larvae are released. If these are washed into a well or pond containing cyclops, the life cycle can repeat itself - people have to drink water containing infective cyclops.

3.4 Diseases having insects living(swarming) near water as vector

Some insects need water to pursue their life cycles during which they can become dangerous for man.

Mosquitoes are well known all over the world. They transport various pathogens to man which are responsible for such diseases as malaria, dengue, haemorrhagic fever, yellow fever, filariasis.

Mosquitoes are divided into two groups and only the anophelines can spread malaria. The other group is culicines. Human filariasis is spread mainly by anophelines in Africa and by culicines in Asia.

Onchocerciasis or river blindness when can be found in tropical Africa and in parts of South and Central America is transmitted by Simulium flies. These flies breed in rapidly running water.

Among other diseases, trypanosomiasis, or sleeping sickness, caused by tsetse flies in Africa may be mentioned.

3.5 Diseases due to inadequate sanitation

Only ankylostomiasis will be mentioned under this paragraph as the most important one. The larvae of ankylostomiasis penetrate the human body through the soles of feet. Nearly 800 million people are afflicted with this infection.

3.6 Health factors in well construction

Incidence of the first two groups of the above-mentioned diseases can be reduced by providing adequate amounts of safe water. The third and fourth group will not be directly affected by well construction, but there may be an indirect effect. Villagers will reduce contact with the infected spots for fetching water and washing clothes. Incidence of diseases belonging to the last group will be drastically reduced if sufficient water is provided for personal washing and domestic use.

It must be understood that the above remarks are valid only if the well supplies safe water. If this condition is not met, contrary to being a factor in health improvement, the well will become a means of further spreading diseases.

Therefore, education on the subject of hygiene is indispensable in any water supply improvement scheme so that people will understand the dangers of polluted water, the need for safe waste disposal and the importance of personal hygiene.

It should also be noted that most water-related diseases are spread through the waste of an ill or infected person which is transmitted in the water.

3.7 Improvement of existing wells

Improvement of an existing well can be requested for needs relative to sanitation or yield.

3.7.1 Water quality improvement

One of the problems that must be faced in rural sanitation work is the existence of wells with unsafe water. It is often more feasible to improve an existing polluted well than to dig a new one.

A scheme for improving existing wells should be part of any sanitation programme. When a polluted well is spotted, the first task is to carry out a survey of the well and its surroundings and to investigate the means for improvement.

There are three ways in which a well may become contaminated: through the wellhead, through the lining and through the water entering the intake. In view of these facts, particular attention should be paid to:

- the location of the well in relation to nearby buildings and particularly to latrines, refuse heaps and soakaways;
- the slope of the ground surface around the well;
- the condition of the headwall and well cover and of the platform around the well;
- the condition of the lining;
- the method of drawing water out of the well;
- any other factor of contamination affecting the ground water flowing into the well.

However, it should be noted that experience has demonstrated that it is often expensive to build properly protected wells from a sanitary point of view, and that the permanent improvement of wells is a long process also involving education.

In order to eliminate the above-mentioned channels of contamination, the following steps should be followed.

i) Location of well

In rural areas, shallow ground water is commonly used as a supply source and this water may often be easily polluted from privies, cesspools and seepage pits, septic tanks and barnyard manure which will result in contaminated water that soaks down into the soil. Usually, on its downward path, the polluted drainage will be filtered and purified within a short distance, but if the well is too close to the source of pollution, the purification will not be complete before the water enters the well(Fig. 3). This is why a well should be located as far away from the potential source of pollution as possible (30 to 50 meters).

However, it should be pointed out that there is no rule setting the required distance between a privy and a source of water supply, because many factors influence the removal of bacteria from ground water. Moreover, if the well is situated too far from consumers, it will go unused and will not fulfill its purpose - the provision of an adequate quantity of safe water.

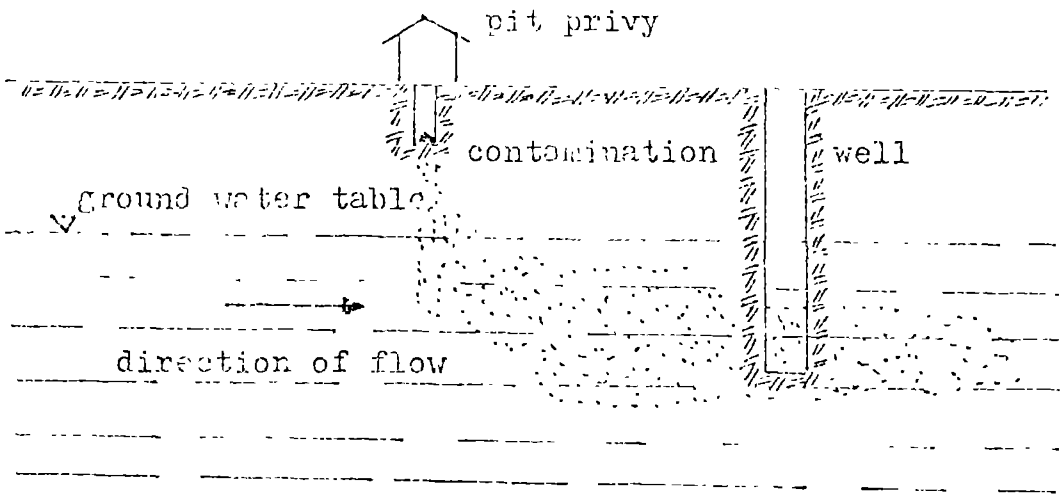


Fig.3 Process of contamination

ii) <u>Platform around the well, headwall and well cover</u>

Very often the ground around the well becomes worn and sloped so the rain will run and wash into the well if it has no headwall. In areas where Guinea worm is endemic, the parasite's eggs are carried into the water spreading the disease to water users. Hookworm and other infections will also flourish in such soil surrounding the well and consumers will be infected through their bare feet.

A properly-designed and suitably-constructed wellhead can eliminate most of these hazards. Two features are essential: (a) a drainage apron 2 meters wide sloping down away from the well so that spilt water will drain away to a soakway; (b) a headwall set high enough above the ground surface to prevent anything from washing or blowing into the well yet narrow enough to discourage users from standing on it (Fig. 4).

These simple measures can completely prevent guinea worm transmission and considerably reduce other health risks. Increased protection can be ensured either by covering the well with a concrete slab and fitting on a hand pump or by using a movable cover when a rope and bucket are used to draw water.

Any open well should be cleaned once a year during the dry season when the ground water table is at its lowest level. An open well without headwall and apron is generally contaminated by dust, dead animals, rubbish and spilt water which has been polluted by human and animal defecation and washing.

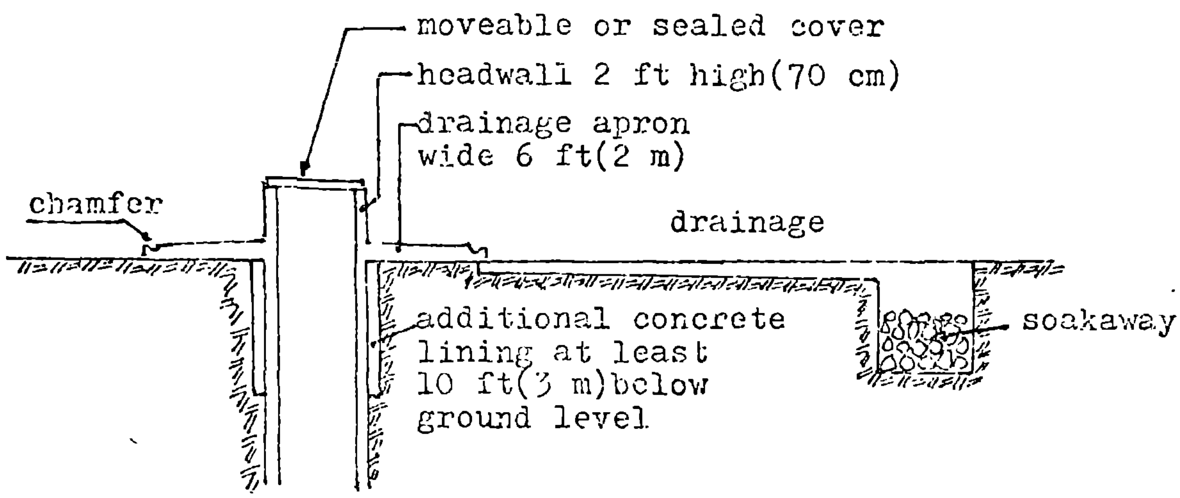


Fig.4 Prevention of well pollution

The movable cover can be wooden or metal and it should be locked.

The concrete cover slab should be cast on the ground near the well and after drying (one week later) be fitted onto the headwall. If the diameter of the headwall is not more than 1,5 meters, the following instruction could be followed:

- the slab should be at least 15 cm. thick;
- the slab should be reinforced with steel rods 8 mm. in diameter, set on the bottom, running both ways at right angles at 15 cm. intervals.

Extra reinforcing rods should be placed diagonally around the access hole(Fig. 5). If the diameter of the headwall is more than 1.5 m, then the thickness and number of steel rods should be calculated.

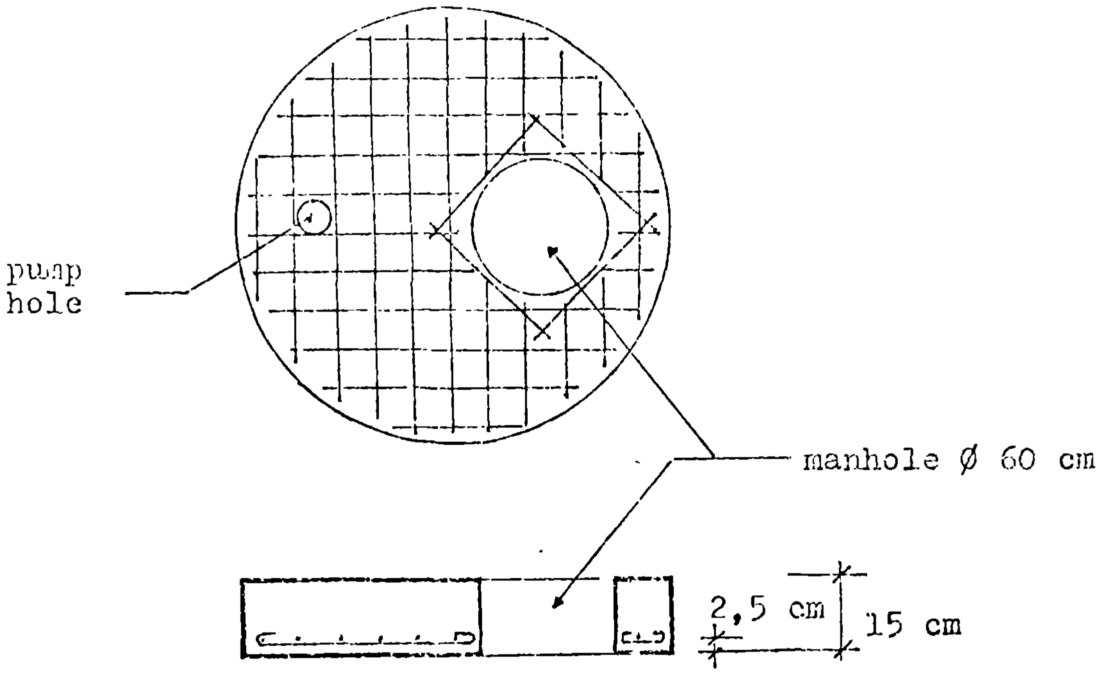


Fig. 5 Reinforced concrete well cover

The manhole cover is steel or reinforced concrete slab and sealed on the hole.

iii) Lining

If the lining is in poor condition or is missing, the surface water which may be polluted will probably seep into the well. In order to stop seepage, a new lining must be built or the existing one improved. The best material for a new or repaired lining is brick or reinforced concrete. The cheapest and simplest method is to make the upper section of the soil around the well watertight. The soil around the well will be dug and packed with puddled clay(Fig. 6). If possible, a 10-15cm. thick ring of concrete reinforced with chicken wire can be placed between the old lining and the clay. The well's inner concrete lining is not always impermeable against surface water infiltration and outer protection is recommended.

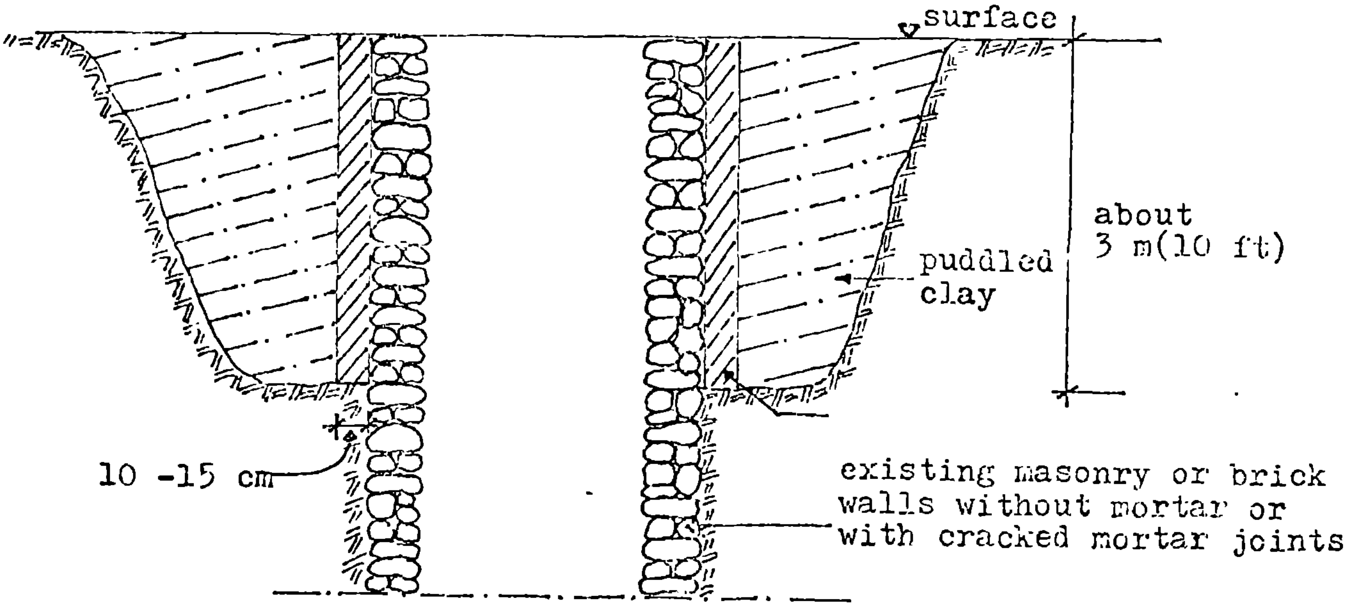


Fig.6 Improving an existing lining

iv) Drawing water

The buckets used to draw water are usually unsanitary. The individual bucket system should be replaced by the installation of a hand pump or a water-lifting device which can be a pulley and bucket arrangement or a bucket permanently hung from a pole and rope. In the latter cases, the well must be protected against pollution with a sliding or movable cover.

3.7.2 Water yield improvement

The yield of a well and sometimes its quality may be improved by applying three principal methods: deepening, increasing the size of the intake in contact with the aquifer, or making the intake lining more porous.

a) Due to drought or over pumping, the aquifer could be depleted and consequently, the well runs dry. In the first instance, deepening the well is recommended while, in the second case, one should reduce the quantity of raised water until an equilibrium is reached with the amount of water which the aquifer can provide. A well can be deepened in two ways: digging and casing a hole on the well bottom (Fig.7) or digging the well deeper over its entire diameter. For the former method, a drilling rig is used. The ring type can be percussion or rotary. The hole is drilled deeper in the aquifer. Plastic or metal casing should be installed to prevent the soil from caving into the hole in case it is not compact enough.

By deepening a well, a greater difference in water level exists between the inside and outside of the well and this will increase the yield. However, factors limiting the difference between the two levels are: a) the difficulty of keeping the water level inside the shaft low enough to permit sinkers to work continuously and b) the nature of the soil around the well intake.

Sometimes the ground water table is only 3 to 6 meters deep. The well yield is low and the conditions for pollution are favorable. If the aquifer is "thicker", the well could be deepened. The standard casing will be set in with the screen at its bottom. The well will be filled with washed round gravel as far as the ground water table. A concrete seal will be cast on the gravel and the remaining length of the well will be packed with puddled clay. The well will be sealed with a reinforced concrete slab. The type of hand pump chosen depends on the depth of the ground water level (Fig. 8).

b) To increase the filtration area of the intake, the most obvious method is to make its diameter larger by driving tunnels or pipes into the well side below the water table. Perforated galvanized steel pipes

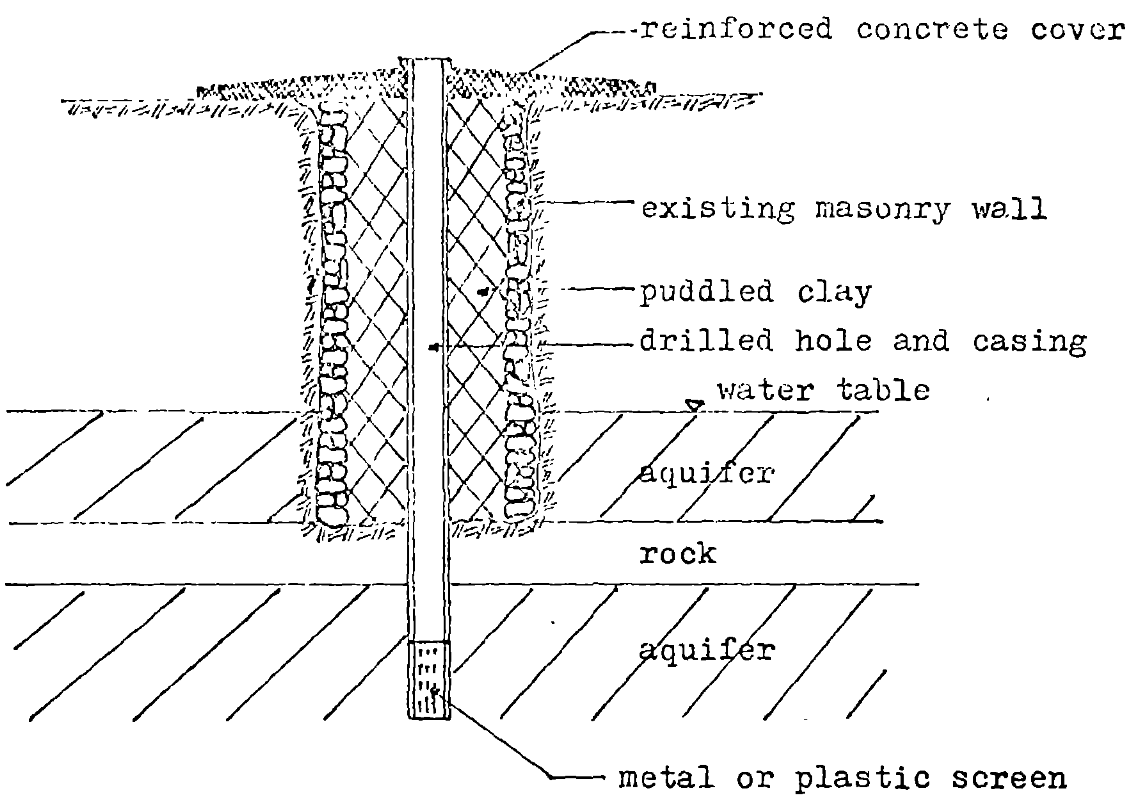


Fig.7 Improving dug well yield by drilling

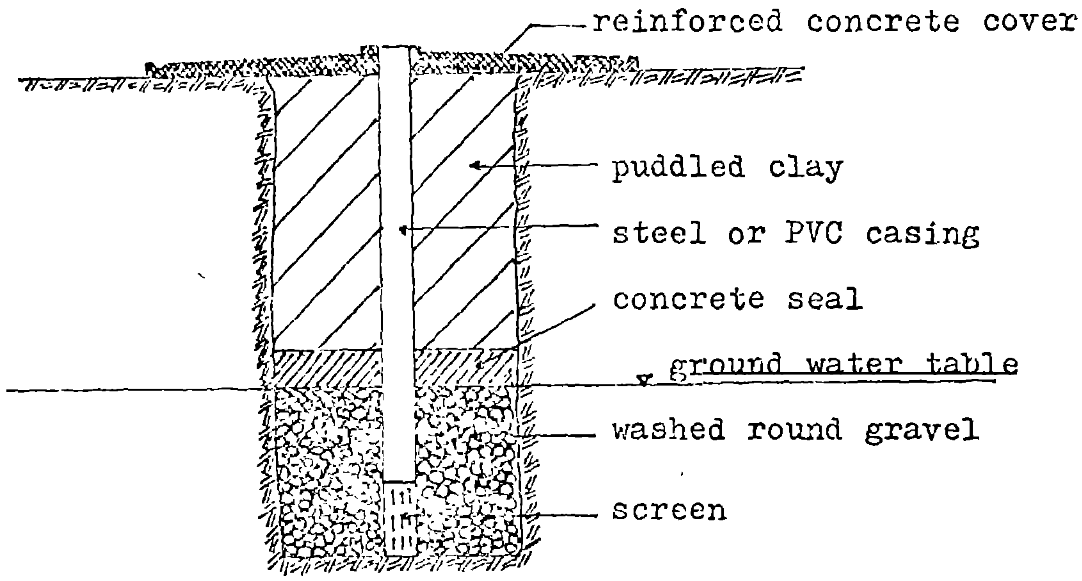


Fig.8 Improving dug well capacity and water quality

with fitted points can be thrust horizontally through the well sides using a car jack. This method is simpler and less costly than driven adits.

c) The method of making the intake lining more porous is rarely used since sand and other aquifer material is likely to seep in and clog the well.

4. LOCATION OF A WELL

Before embarking upon a regular well construction programme, it is advisable to collect and study data which could give information on ground water availability. It is useless to start a well digging project unless there are at least reasonable prospects of obtaining adequate amounts of water. It is also very important that subsoil conditions be such that the method used is capable of penetrating to the aquifer.

In prospecting for groundwater it is important to get some information on:

- the general geology of the area,
- replenishment area,
- the presence of shallow aquifers,
- the yielding capacity of the aquifers,
- the hardness of the soil layers,
- the chemical and bacteriological quality of the groundwater,
- rainfall and evaporation data.

In most countries there are government geological survey departments furnishing knowledge of local conditions. Furthermore, the information may be obtained from:

- aerial photographs,
- drilling/digging logs,
- existing water supply installations.

The advice of traditional well sinkers should not be overlooked.

Another likely indication of an aquifer is the presence of springs. When one or more springs are situated on a hillside or at its base, a well sunk further up the slope will usually tap the saturated strata that feed the spring water.

Similarly wells dug in the flood plain of a river or close to a stream, lake or swamp may provide a satisfactory quantity of water.

Groundwater is present in the form of water filling the pores between the grains of a waterbearing layer or aquifer. Layers of sand and gravel are the best aquifers. In limestone areas holes may frequently exist which are as big as large caverns. It should be noted that limestone does not possess any filtering properties and the danger of polluting groundwater from the surface is relatively high. In granite areas, weathered rock may contain good aquifers. Weathering breaks granite down into sand which is often very coarse and lies in thick layers up to dozens of meters.

Climate and topography determine whether a potential aquifer is indeed waterbearing. In mountainous areas, the beat aquifers are found along valley edges. In wide river valleys sandy deposits under the river bed and in the banks of existing and buried rivers offer good prospects for groundwater. In arid regions, grounwater may be the only permanent water source. The coarser river sediments especailly may be likely terrains for aquifers.

One means of obtaining information about grounwater might be the use of an electric-resistance system. By measurement of the earth's resistance at desirable well locations and by application of formulas developed by the equipment manufacturers, reasonable accurate ground data can be obtained. When properly employed, this method can be very valuable, and the equipment is relatively simple to operate.

Deciding on where to locate a shallow well is generally based on two kinds of considerations. The first one is technical: the site should be suitable for making a well:

- it should be accessible by truck during its construction and accessible to villagers throughout the year. However, non-accessibility by truck may be resolved by building a road or by accepting that construction equipment be transported by human labour;

- the soil type should warrant the construction of a well;
- there should be a sufficient quantity of high quality water;
- the site should be safeguarded against flooding if it is located near a river. Furthermore, the danger of floods in low-lying areas should be taken into account.

The second kind of consideration is socio-economic and political and cannot be neglected. There will sometimes be pressure to dig a well close to the village headman's house or near other influential citizen's homes. It is very important that the well not be located too far from villagers. One to two kilometers walking distance should not be surpassed.

5. WELL CONSTRUCTION

In the past, wells have been constructed of circular or square sections, but all wells constructed now are circular.

The present manual deals with one particular method of well sinking -- the hand-dug well in which the shaft is large enough to enable sinkers to descend and work below ground. Except for large-diameter wells built for special purposes, the minimum diameter is limited to the room available for a man or men to work. Experience shows that a diameter of about 1 meter is necessary for one man and about 1.3 m. for two. For security reasons and higher efficiency, two sinkers should work together.

A hand-dug well can have equal diameter in its total depth or be narrower in its upper section. For an aquifer found at the level of less than 5 m. depth, the well's diameter may be reduced, but should be constant if the aquifer lies deeper.

The well lining must be able to withstand the compressed weight from all directions exerted by sifting sand or swelling shales as well as the concentrated pressures from shifting rocks or strata. The role of the lining is to distribute the load around the shaft and stay intact. Of all the materials commonly used for well lining a thin wall of reinforced concrete cast in-situ in the well meets this condition most satisfactorily. However, various methods of lining may be used such as:

a) construction lining in situ, which consists of

- concrete poured in situ(shuttering/molds erected in pit),
- prefabricated concrete rings,
- brickwork cemented in situ(burnt clay bricks, stone, cement blocks);

b) sinking prefabricated concrete rings by digging the soil material away from underneath(caissoning).

In general, the caissoning method is faster and less expensive than the construction lining in situ method.

Well depth is governed by storage capacity required to provide water for 200 to 300 people. Water is drawn at certain times in the morning and evening. For the depth needed in those circumstances, the two following general guidelines can be given:

i) The depth is sufficient when the empty hole is refilled to a water depth of about 3 m. after one night;

ii) In principle digging must go on right through the aquifer down to the next solid layer. For example, when going through an aquifer which consists of sand, digging should be continued to at least about 30 cm. into the underlying clay or other solid layer.

There are practical reasons for accepting less depth, as exceptions to the rules given above:

- the capacity of the aquifer is not sufficient to replenish the well with at least 3 m^3 in one night. In such a case, storage capacity equal to the overnight discharge capacity of the aquifer is sufficient. However, a well with storage capacity of less than 3 m^3 is considered an inadequate well;

- the capacity of the aquifer is larger than the capacity of the pumps which are used to empty the hole during digging. When the available pumps are unable to reduce the water level in the hole low enough with the result that digging becomes impossible, the well can be finished.

5.1 Preparatory work

After the location of the well has been chosen the preparatory work must be done before construction of the hand dug well may start.

The site should be cleared and a working space of about 20 m. radius is cleared of all vegetation and roughly levelled. The shelter to house tools, cement, etc., should then be constructed. The nature of this shelter will vary according to the season, location, available local materials and whether dangers exist from thieves, fire or animals.

Setting up the work area is more important than it first appears, the objectives being to ensure that there is adequate working space for each operation, that no stage of the work hampers another and that the distance over which heavy loads have to be moved is kept to the minimum.

The center of the well is determined using a 25mm. diameter iron peg and four additional pegs which orient the central one. All pegs including the offset pegs used to plumb the well should be secured so that they will not be knocked off by kibbles or by caisson rings when these are being lowered into the well.

A typical worksite layout is shown in Fig. 9, but the proposed arrangement is subject to site conditions, direction of access, location of the disposal area for excavated material and similar factors.

Corner pegs projecting one meter out of the ground are driven as guides, the space between them is cleared of grass and roughly levelled. Sand and gravel need to be hauled to the site; preferable they should both have been dug in readiness before the work starts, but at least some must already be at the site. Water will probably be hauled to the site in drums(which must be thoroughly cleaned of all traces of oil or other contaminants) and these will be placed close to the mixing slab.

Cement will be taken in bags.

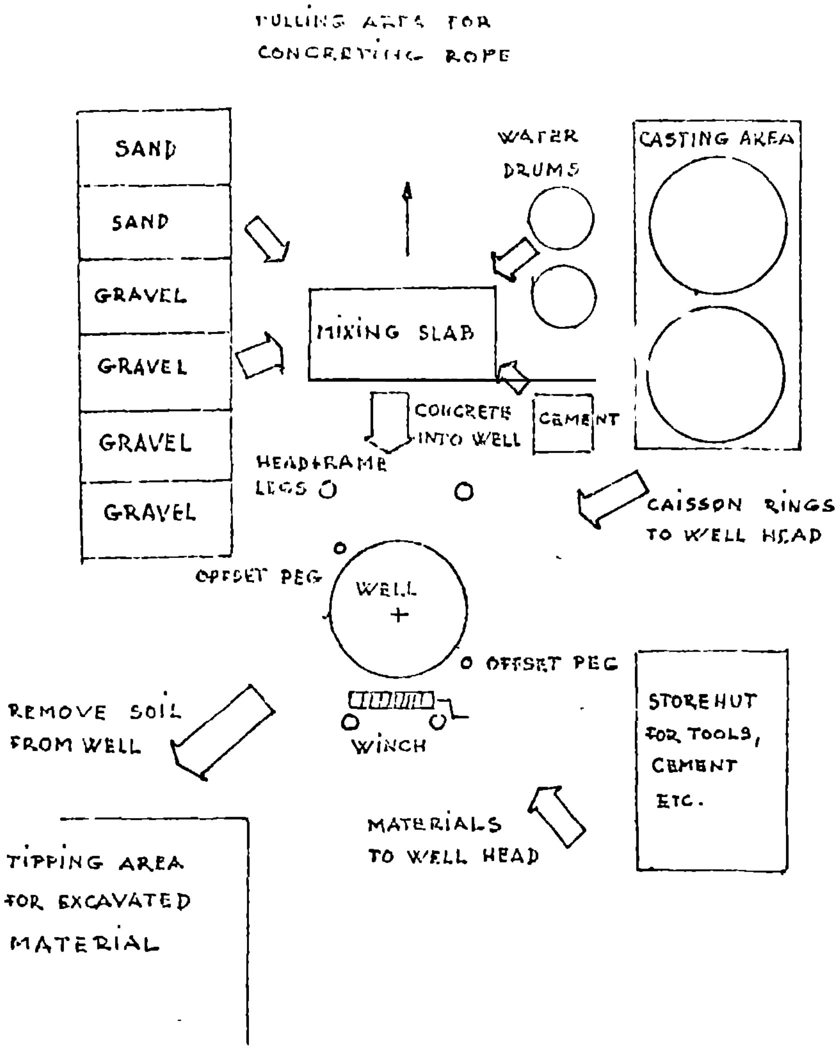


Fig.9 Layout of well work site

The most essential tools and equipment used for well construction should be brought on the construction site, and these are: 2-3 miner's picks and bars, 2 heavy hammers, 2 light hammers, 2-3 spades, 2-3 short-handled shovels for filling the loosened materials into the kibble(hoisting bucket), 2-3 mattocks for accurately trimming the shaft wall, 2 buckets with at least 15 meters of rope for each, 1 tripod with pulley, 1 hand pump, 1 plumb, 1 measuring tape. To this list, two sets of trimming rods(Fig. 10) should be added. The "short" set having a total length a fraction less than 1.3 m and the"long" set just under 1.45 m. These measurements correspond to a well of 1.3 m. diameter. The rods can be made of timber, 15 mm. thick and riveted together in the center and opening out into a cross during use or folding together for storage at other times.

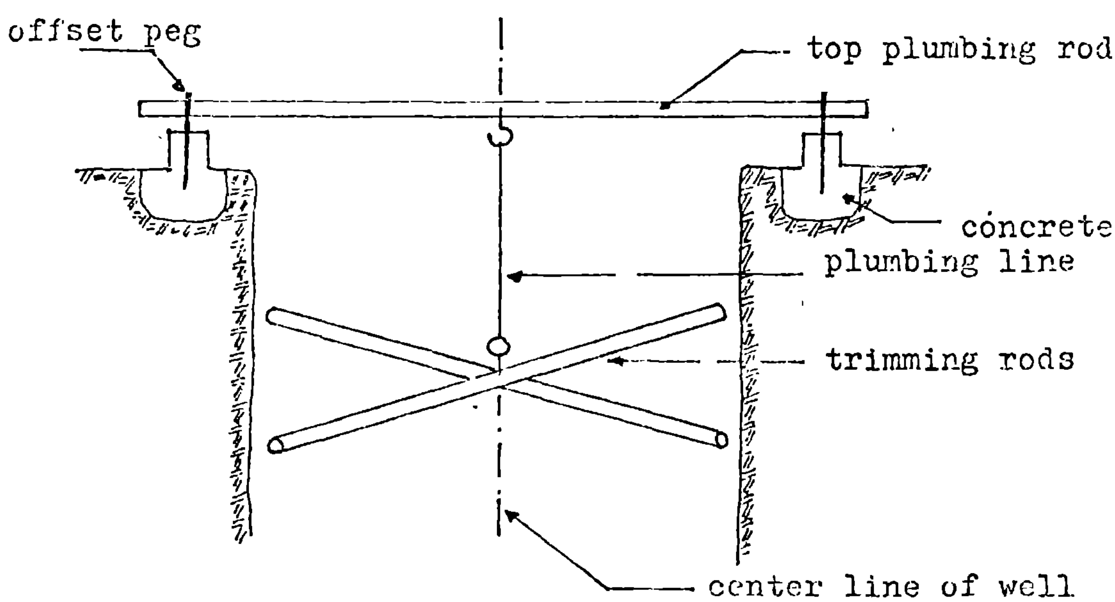


Fig.10 Trimming rods

5.2 Construction lining in situ

The excavating method with shaft lining in situ is known as "dig-down-build-up" method. The shaft is excavated to a larger diameter than the finished dimension, after which a lining is built up from the bottom by pouring concrete behind removable shutters, lowering prefabricated concrete rings or lining with brickwork cemented in situ. This method is used from ground level up to the water table. As soon as the water table is reached the method is changed to caissoning. The caissoning method will be described in a separate paragraph.

5.2.1 Concrete poured in situ

a) Excavating and lining of top section

Most accidents that occur in well construction are caused by the cave-in of loose surface soil into the well or by tools and materials being accidentally knocked into the well. In order to avoid this risk, the first meter of excavation should be temporarily lined regardless of soil quality with a set of meter-high assembled concrete shutters with 10-15 cm. of their length projecting above ground level.

It is very important that the temporary lining be accurately centered and that its sides be vertical. Next, the top plumbing rod is fit over the offset pegs. One must check the lining position and the straightness of the sides with a plumb bob and adjust them if necessary.

A circle with the suitable diameter is then marked and digging can begin. The diameter of the circle varies but should not be under 1.45 m. to enable two workers to work in the shaft.

Excavation is normally carried out in layers of about 10 cm. at a time. At the beginning, it is recommended until the workers become experienced to excavate somewhat less than the total diameter until at least 1 meter has been sunk and then to trim it back precisely to the proper dimensions. This is one of the most important operations in well digging; the degree of accuracy in trimming will affect the lining thickness and consequently, the cost of the well.

After 1 meter of the well has been roughly excavated, one should fit the short set first and roughly trim the shaft so that the short trimming rods may slide up and down. Then, at the half point center, four notches must be cut into the soil of the wall 7.5 cm. deep and the long set should be fit so that their ends hang freely in these notches. One then trims a band a few centimeters wide all around within which the long rods will revolve freely. Cuts up and down from this band are made until the entire shaft wall is trimmed to a suitable diameter.

Provided that the soil is reasonably hard and not too wet, it should be possible to dig to a depth of 4.5 to 5 meters without any danger of collapse. Only if the soil is particularly strong and firm should excavation be continued. It is risky to go any deeper before lining with concrete. The excavated material is brought to the surface in a bucket attached to a rope using a tripod with a pulley and occasionally a winch.

After the first 4.5 to 5 meters(first lift) have been excavated and carefully trimmed to an appropriate diameter, a set of 1.3 diameter shutters, .5 meter deep and oiled on the surface is lowered down the well for assembly. (The diameter of the shutters depends upon the selected diameter of the well). The first set of shutters will be placed exactly to carry the lining shutters on top and to support the re-rods. The assembled shutters are blocked up level, using a spirit level and centered using 1.3 m. diameter trimming rods.

The next step is to assemble the iron rods around the side of the well. The 8mm. diameter vertical rods will be inserted behind the bottom shutter, which will then be backfilled with soil to hold both the rods and the shutter steady.

The number of vertical rods depends on the nature of the ground.

Sometimes, the rods are unnecessary, when sinking is done through sandstone or similarly firm ground. The vertical rods are cut about 4 meters long and attached behind the first shutter. The rings of the horizontal rod are prepared outside and then lowered down the shaft and fitted around the outside of the vertical rods. The external concrete cover over the horizontal rods should be about 3 cm.. At this point the time is ripe to pour concrete behind the shutter.

A second set of shutters, 1 meter deep and oiled on the surface, is lowered down the well, assembled and set into place on the first shutters. The horizontal rings will be fitted and the concrete poured.

By the same method, the third and fourth meters will be lined with concrete. The temporary shutter lining is then removed and the sides cut back. Once the shutters have been placed on top of the fourth shutter, the space behind them is filled to the surface with concrete and the bars bent down onto the ground. The extra layer of concrete lining on the top 1.5 meters will provide a solid base for the wellhead structure(Fig. 11).

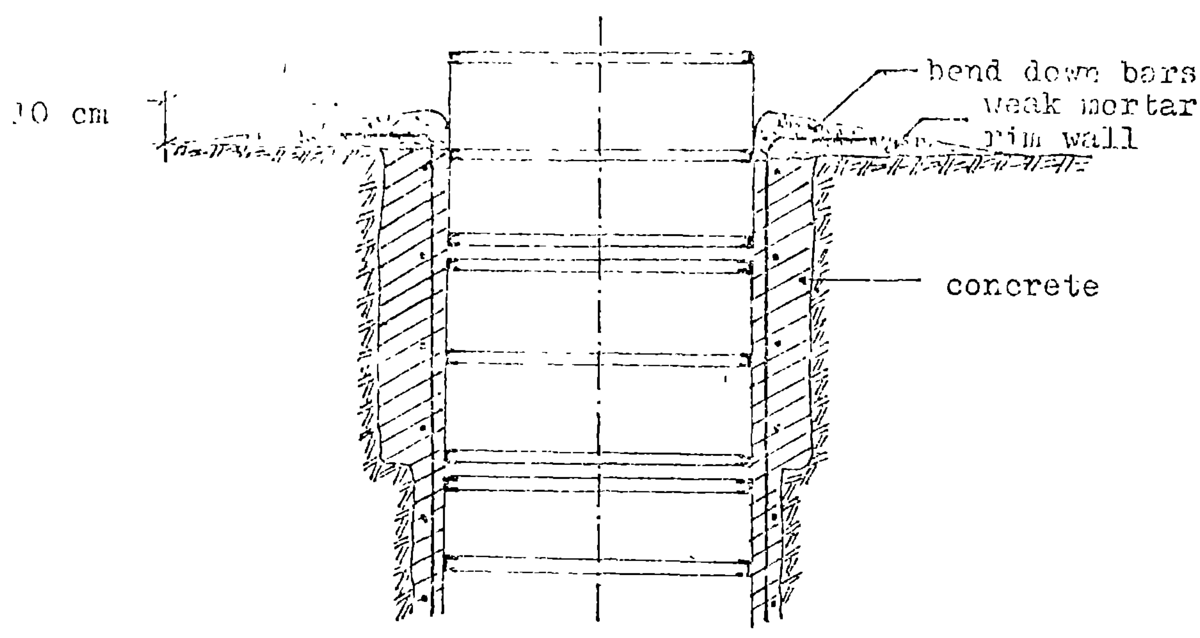


Fig. 11 Temporary rim wall

The concrete is usually mixed on the mixing slab in the proportions of 1:2 1/2:5(cement:sand:gravel). The water used to make the concrete must be clean and rid of organic matter, oil or floating clay. Too much water will make the concrete weak and liable to leak out between the joints of the shutters. Good concrete can only be produced by proper mixing of the right materials.

When the concrete is prepared on the mixing slab, it is lowered down in the bucket. The concrete is poured between the shutter and the wall carefully and evenly all around to prevent weight building up on one side and shifting the shutter, and the concrete is tamped using a piece of re-rod to remove air pockets. The top of the concrete should be left rough so that a good bond is made with the above layer.

When the second shutter has been filled with concrete(the first shutter is filled with earth), the first curb is made. A curb is made for a maximum of every 5 meters lining to provide support against the downward slip of the lining during digging. It is made by cutting a triangular-sectioned groove in the side of the excavation immediately above the top of the second shutter. The groove is 20 cm. deep all round and 20 cm. high at the well face. Re-rod pins are driven into the groove.(Fig. 12).

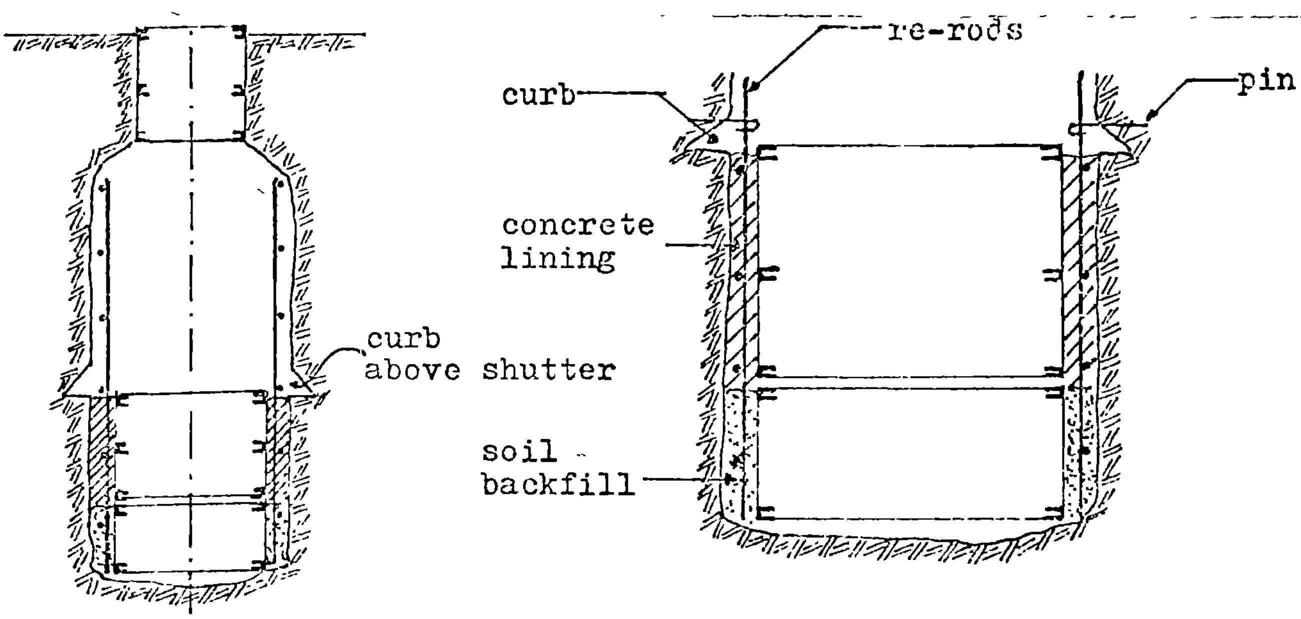


Fig.12 Curb for the lining lift

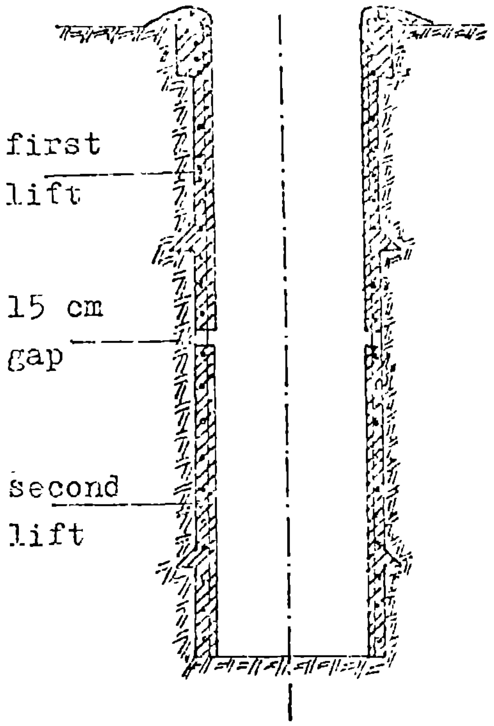
b) Digging and lining to aquifer

The second lift is now excavated while the shutters for the first lift remain in position. The earth-filled shutter is removed and the re-rods should be cleaned with a wire brush. The second lift will be excavated in exactly the same way as already described to a depth of 4.65 m. below the concrete lining of the first lift.

The procedure for the construction of the lining and curb of the second lift is exactly the same as that of the first lift, except that there will be a gap of 15 cm. between the concrete lining of the second and first lift(Fig. 13). This gap is needed to pour concrete behind the shutters of this second and subsequent lifts. The re-rods of the second lift should overlap by at least 20 cm. those from the first lift. The specially-shaped concrete blocks will be fitted into the 15 cm. gap.

The digging and lining routine of each lift is then continued until the water is reached or until unstable ground conditions threaten the excavated shaft. However, experience has shown that, in most wells, the greatest risk of collapse results from loose soil in the first few meters of the well. If this is made safe with the temporary lining or even the first lift, then it sometimes possible, in firm soil, to excavate down until water is reached. The concrete lining, if it is needed to support the well walls will then be poured up in one continuous lift with curbs built in every 5 meters. Only the builder can judge if the ground is likely to be stable.

Finally, when the water has been reached, a strong curb is constructed in the lining at the well bottom to strengthen the end of the lining tube.



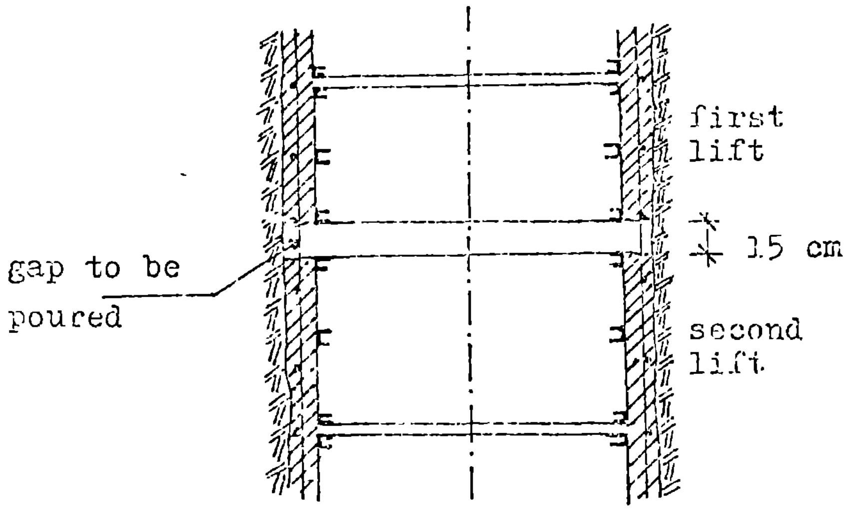


Fig.13 Pouring top of second lift

5.2.2 Other methods for well digging and lining to aquifer

The lining in situ method with reinforced concrete is described in paragraphs 5.2.1(a) and (b). There are circumstances which sometimes call for a different approach to the work and in this chapter some other methods will be described.

a) Dig-a-meter, line-a-meter method

By using this method, construction progress is necessarily slow because each meter which has been lined must be allowed to reach its set strength before the work commences on the following section. This method is appropriate at times when just one well is needed in good soil and in places where shutters are not available.

The well excavation work is achieved in exactly the same way as described in paragraphs 5.2.1(a) and (b); the well is dug and trimmed using the trimming rods, plumb line and mattocks for a depth of 1 or 2 meters. The walls are splashed with cement slurry to prevent them from crumbling and when dry, a 1:4 (cement:sand) mixture of mortar is plastered onto the walls about 3 cm. thick. Work starts at the bottom. After the mortar hardens a few hours, horizontal and vertical reinforcement of the same size and numbers as recommended in the standard method is installed and secured. Then, a second 3 cm. thick layer of mortar is trowelled on identical to the first layer.

b) Lining of prefabricated concrete rings

This method of lining is used in soil which is particularly hard and firm and consequently, will not cave in. The shaft is excavated by the same method as already described in the paragraph 5.2.1. This method could be used from ground level up to the water table or for a depth of 30m. maximum. The shaft must be vertical and accurately trimmed in order to be the same diameter all the way down. When the water level has been reached and the well bottom is installed horizontally, lining it with prefabricated rings can start.

The type of the bottom-most ring depends on the nature of the aquifer reached:

- if the aquifer is "perched", the well will pass through it in order to reach the main water-bearing stratum deeper down. The bottom ring will be a "normal" concrete ring and further well excavation will be implemented by the caissoning method;
- if the well has reached the main water-bearing stratum and the water inflow is high, excavation of the shaft could be stopped. The bottom ring will be a "filter ring", with highly permeable walls to enable water to flow into the well. The well bottom is finished off with a sand and gravel layer or with a porous concrete slab, to filter water which flows into the well from underneath the ring. More details are given in paragraph 5.3.3. The caissoning method always increases the well's construction cost, and it should be avoided if possible. In order to increase the yield of the well, its construction should be planned for the dry season when the ground water level is at its lowest.

The rings are manufactured either centrally, far from the work site, or are cast on the spot. Ring casting should be carried out as far in advance of need as possible. The longer these rings have to cure and mature the stronger and more resistant they will be to accidental damage during handling. Ring casting can be started while the upper part of the well shaft is being excavated. All rings are provided with rebates on top and bottom. To keep the rebates in filter rings strong, 15 cm. of the top and bottom of the rings are poured of solid concrete. The full size rings are .5 m. or 1 m. high. Sometimes the concrete is reinforced with steel bars. The outer diameter of the ring should be smaller than the diameter of the shaft. Usually the mould is composed of two metallic cylinders. While casting the ring, it is very important that enough concrete be mixed and the whole mould filled in a continuous operation. The rings which have a diameter of 1.3m. weigh about 700 kg. for 1m. of height. Whether the ring is to be made porous or solid will depend upon the nature of the expected soil. To have a solid ring wall, the mould will be filled with a 1:2:4 concrete (cement:sand:gravel) mixture and for porous concrete, with a mixture of 1:1:4. The concrete should not be too wet but well banged with blocks of wood. Whatever the type of ring cast, it is important that sufficient concrete be mixed and the whole mould filled in a continuous operation. The moulds can be removed after 24 hours and are then available for re-use. The ring castings as well as the rings from which the mould is removed should be made in the shade.

One should not forget to make the top part of the shaft secure against accidents that occur in well construction and are caused by the collapse of loose surface soil into the well or by tools and materials being accidentally knocked into the well. The method of protection is described under paragraph 5.2.1.

It is very essential for the lowest ring to be set in a horizontal position and properly centered. This will permit all sections of the lining to be in straight vertical position. Once the shaft has been excavated and carefully trimmed to a desired diameter, the rings will be lowered down one by one.

Since the weight of each ring is about 350 kg. or 700 kg., special equipment is necessary to handle them. As they are easily damaged, this handling should be done carefully. If the ring has to be moved over short distances, it can be rolled over without damage. Loading and unloading from a truck and the sinking in the well hole cannot be done by hand. For lifting the rings, a tripod is usually used. When the first ring is lowered and put in the correct position on the bottom of the shaft, the same operation may be repeated for the second and subsequent rings.

The top rim of the lower ring is coated with about a 10mm. coat of mortar (1:4 cement and sand) and the upper one is lowered into place.

c) Brick or masonry lining

This is a very old method but still used in some places where brick or stone are plentiful and where there are local skills in laying these materials. These materials can be used in caissoning, but not for great depths or in unstable ground. It should be pointed out that brickwork and masonry are very weak under pressure, and the stress resulting from sliding earth sides can often fracture the linings. The difficulty with this method comes in supporting the completed lining of one lift while the one below is being excavated and lined.

The well is dug in the usual way as deep as possible.

A ring of timber segments is set at the bottom of the well and the lining built up to the surfact (Fig. 14).

For the construction of the second lift, a narrow pit is excavated 1-2 meters into the center of the well and the timber ring is wedged in with the help of strong timber props. The excavation is trimmed to the correct diameter; a second timber ring is fitted into place and the lining is built up under the first one. (Fig. 15). Digging and lining continues in this way until the water level, where caisson sinking becomes necessary. Sometimes the timber ring may be replaced by reinforced concrete curb. This also eliminates the need for timber props. Brick and masonry are very difficult to make watertight for the purpose of preventing polluted surface water from soaking into the well. The measures against pollution are described in chapter 3.7.

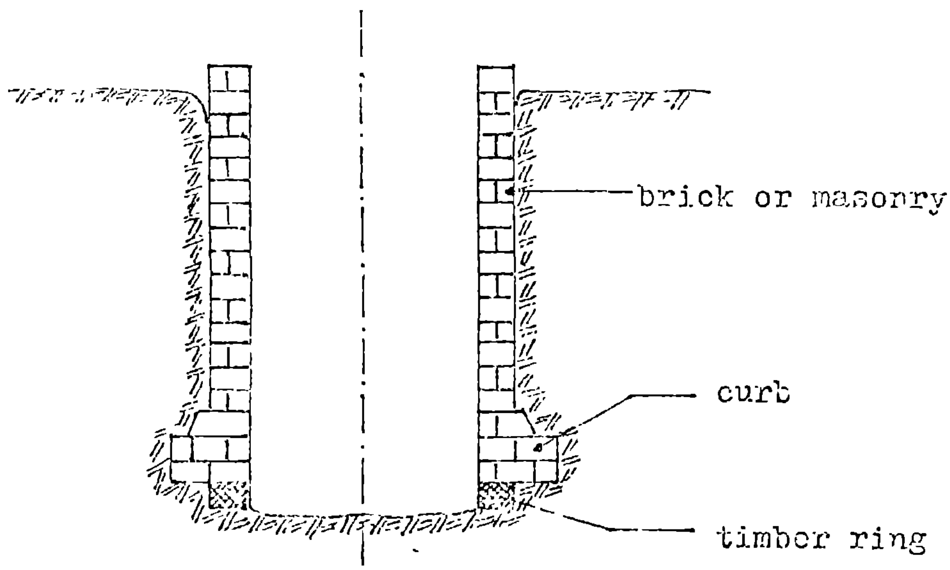


Fig.14 Build up lining of brick or masonry on timber ring

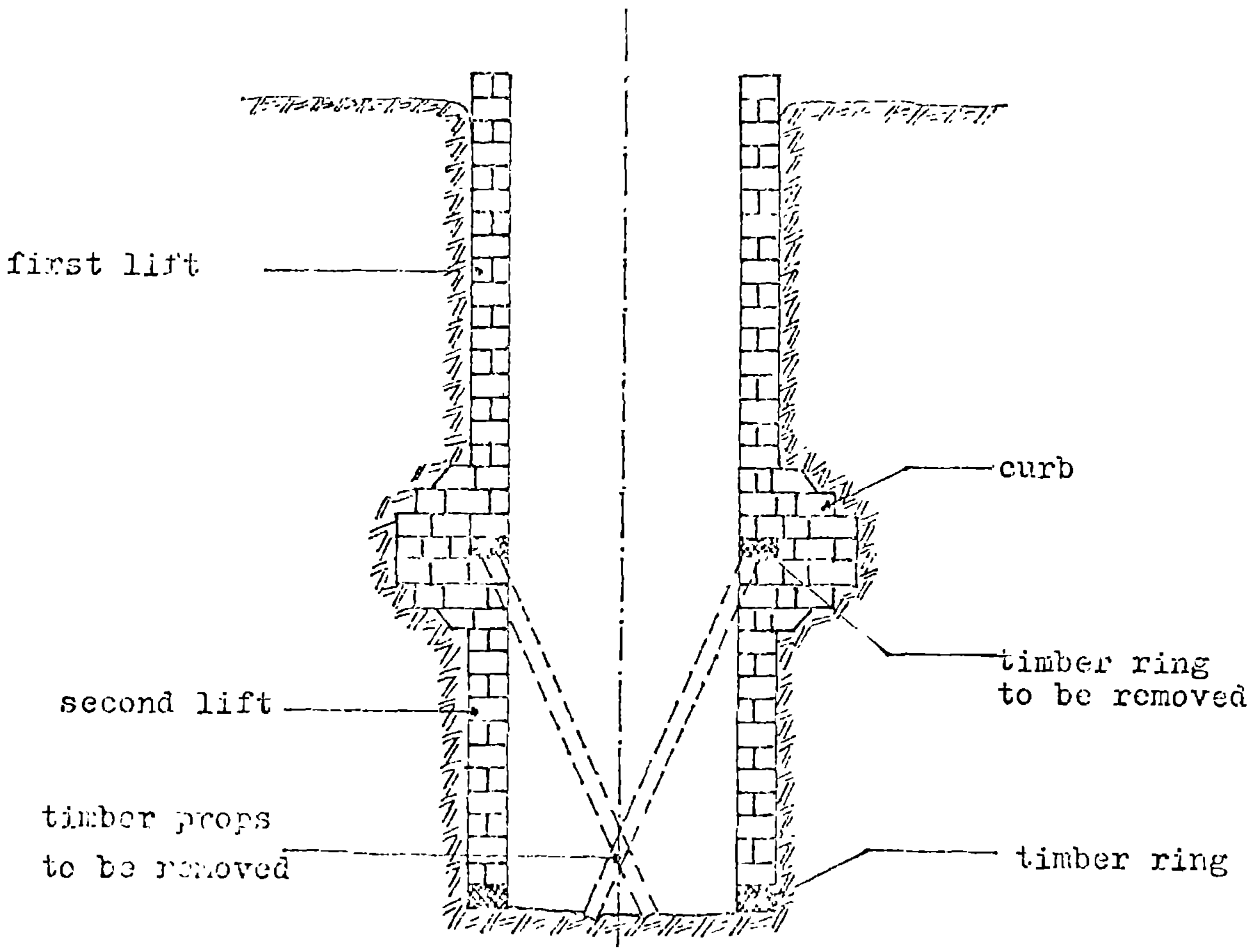


Fig.15 Building the second lift

5.3 <u>Caissoning</u>

Constructing wells by caissoning is generally done in the cases when:

- specific difficulties are encountered due to geological features of the site; i.e.when a hole is dug in areas with sandy soil and in old river beds;
- a smaller size lining is telescoped through the regular lining in order to rehabilitate existing wells which happen to go dry in the arid season;
- constructing a well intake.

The three commonly used methods of caissoning are:

a) using reinforced concrete rings, precast on the surface;

b) using reinforced concrete rings, poured at the well bottom;

c) using precast concrete blocks, built on a cutting ring.

5.3.1 Construction in sandy soils

One of the disadvantages of the methods described in paragraph 5.2 is the obligation of leaving a length of the shaft wall unsupported for a while during construction.

Very often good aquifers are overlaid with sandy soil or are under river beds. When a hole is dug in this soil, it is not possible to maintain vertical walls due to the inconsistency of the sand, which will slide under its own weight and which may be wet or dry.

Dry sand will frequently contain some moisture and will appear quite firm when first encountered. Only after it has been exposed to air for some hours does it begin to slide out of the well. In order to avoid collapse of the well, it is necessary to always keep it wet while excavating through it and line it in half-meter lifts if the caissoning method is not used.

Wet sand is water-bearing and is part of the aquifer. Sometimes, a well will pass through one or more aquifers which lie above the main water-bearing strata. The digging method described in chapter 5.2 could be used up to the first "perched" aquifer, and then the procedure described below will be applied.

A filter ring with a cutting edge is put down in the shaft. Digging is started inside the ring which lowers itself as the sand is dug away underneath the cutting edge. Before the ring is completely lowered into the ground, another ring is stacked on top of the first. Digging inside proceeds with rings stacked one upon the next until the required well depth is reached. Usually, while digging in sand, a serious problem occurs when the well has reached a depth of about one meter below the natural water level. By then, the difference in water level in and outside the well causes a rush of water into the well and underneath the cutting edge, and considerable amounts of sand enter the rings with this water. If this sand is very fine, the lower ring could be filled up in a few seconds. The greater the difference between the outer and inner water level, the more serious the problem will be, and consequently, digging and sinking become more difficult. Experience has taught that one should not try to construct a well in a layer of fine or medium-grain sand thicker than 3 meters and water-bearing. (Fig. 16).

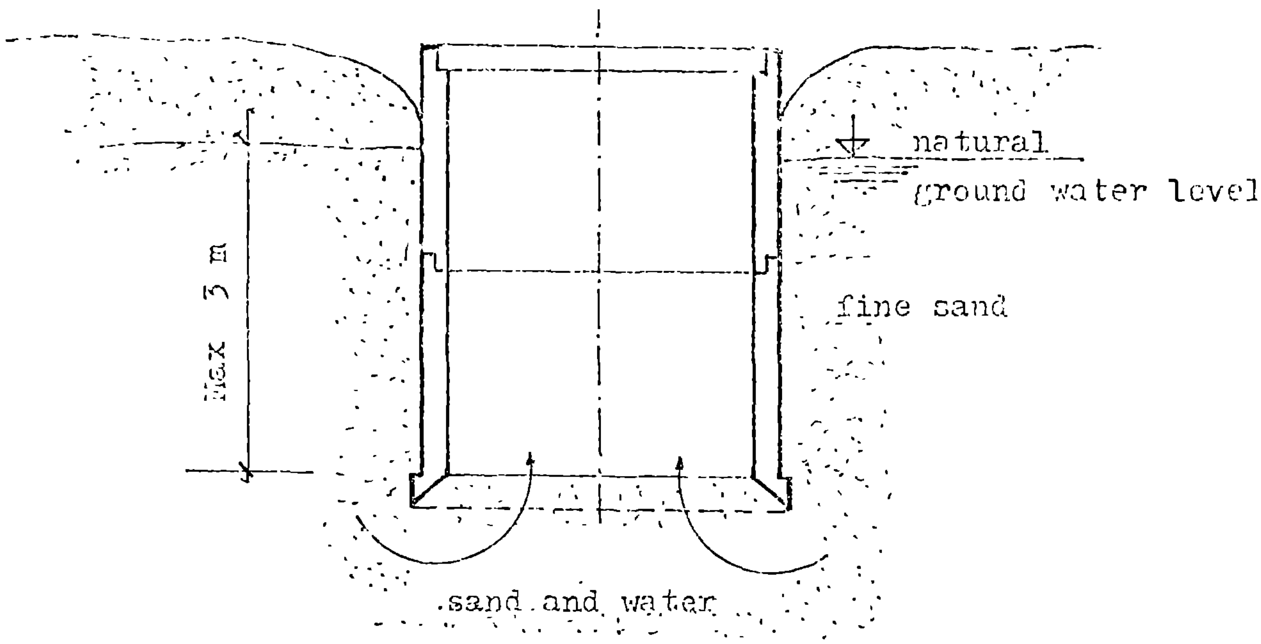


Fig.16 Entering of sand and water underneath the cutting edge

A general problem when sinking concrete rings in loose soil is the risk of sinking them askew. There are various reasons for this. If the hole caves in more on one side than on the other of the rings, the result will be unequal ground pressure on both sides, which may cause sinking askew. One may attempt to correct this if the rings have not been sunk farther than about 2 meters.

The correction should be attempted by digging on the opposite side of the deviation from the vertical axis.

5.3.2 Rehabilitating existing wells

Telescoping a smaller size lining through the existing lining is used in the rehabilitation of existing wells which dry up in the arid season. This kind of construction can also be used for completely different reasons. Two of these are the most important:

- a well may dry up during the arid season if the seasonal ground water level fluctuates widely. Additional excavation by the telescoping method could be realised during the dry season.(Fig. 17);
- very often, due to an arranged construction programme, it is not possible to dig deeper during the dry season, and the telescoping method will be used in the wet season to ensure water during the period of low ground water level.

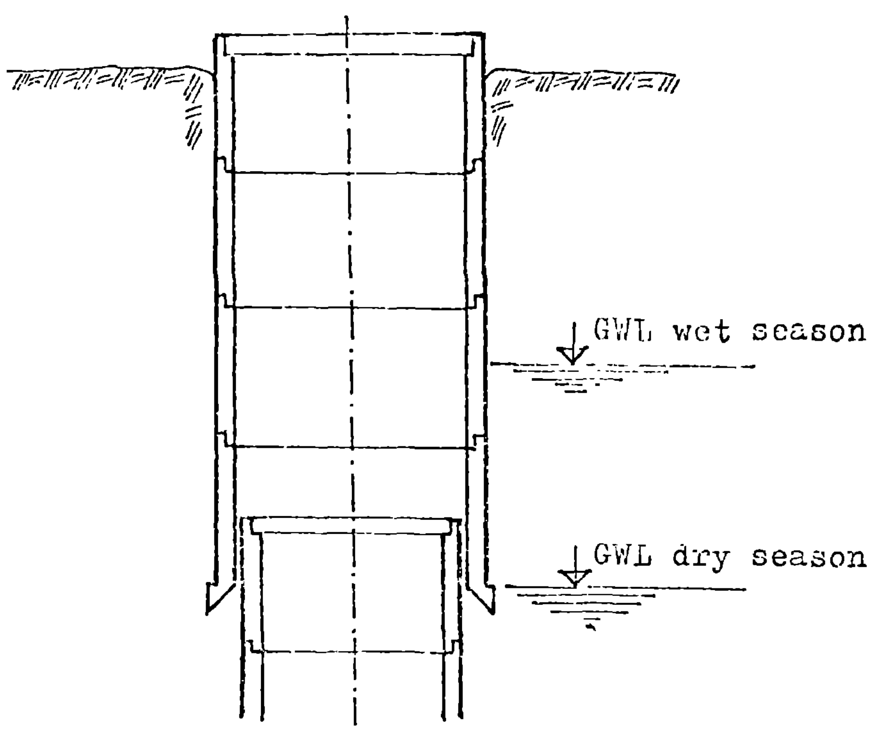


Fig.17 Telescoping an existing well

5.3.3 Construction of a well intake

The well digging will be terminated with the construction of the well intake. The depth required to ensure storage capacity for providing needed water to 200 to 300 people was described in paragraph 5. The depth of the well intake below the lowest water table depends on the inflow of ground water. If the water inflow is satisfactory, the well bottom will be at the lowest level of the main water-bearing stratum. The smaller the inflow, the deeper the well will be dug under the ground water level.

Depending on the soil quality, two basic construc - tion methods for the well intake may be applies:

i) In very hard soil, it will be possible to dig the well intake without using the caissoning method. Once the required depth has been reached and the shaft trimmed to the needed diameter, the lining can be executed. To avoid troubles which might be raised by incoming water, the method of lining with prefabricated rings may be applied. In the meantime, it is supposed that the section of the shaft above ground water level has already been lined by one of the methods described in this manual. The prefabricated rings will be lowered from the surface into the intake.

ii) In soil prone to caving in, the caissoning method will be applied for the section of the well which is below ground water table. The caisson-lining method has already been described in chapter 5.3.1. The outer diameter of the caisson lining is smaller than the inner diameter of the main existing lining. The sinking of prefabricated concrete rings lowered one by one from the surface soil is a slow process since only one sinker at a time can work in the tube, and the operation has to be interrupted constantly in order to pump or bail out the water inside enough to permit continued excavation.

The deeper the tube penetrates below the water table, the faster water will enter, and the limit for sinking will be reached as soon as it becomes impossible to keep the water level within the caisson low enough for the sinker to continue working.

The first ring will be carefully lowered and placed on the bottom in the right position. The second and subsequent rings are lowered and fitted in the same manner – up to four or five rings.

Excavation takes place inside the caisson. First, a hole is dug in the center of the well and cut back in layers all around the sides toward the ring (Fig. 18). When the soil has been trimmed back far enough, the caisson should begin to slowly sink under its own weight. When the caisson has been sunk to the required depth, a base plug is installed at the base of the well. The plug can be made of porous concrete pre-cast or from layers of sand and gravel (Fig. 19). The plug is important as it prevents the aquifer material from flowing up into the well if the well is over-pumped. After the plug or filter has been installed, the space between the caisson and lining should be filled in with light gravel; the caisson should not to tightly attached to the shaft lining.

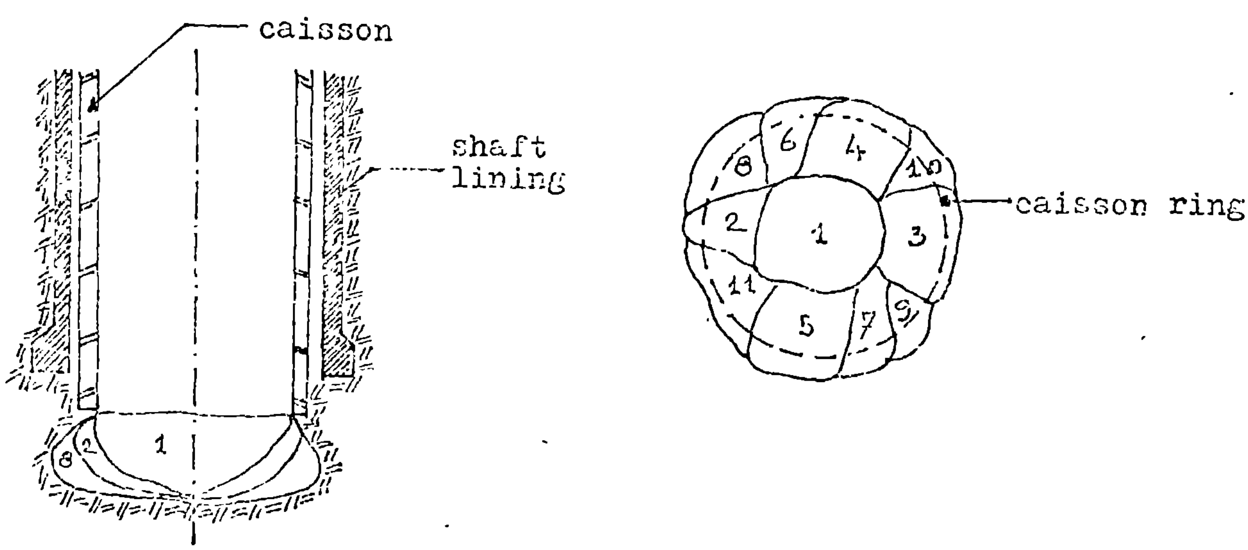


Fig.18 Stages of cutting under caisson

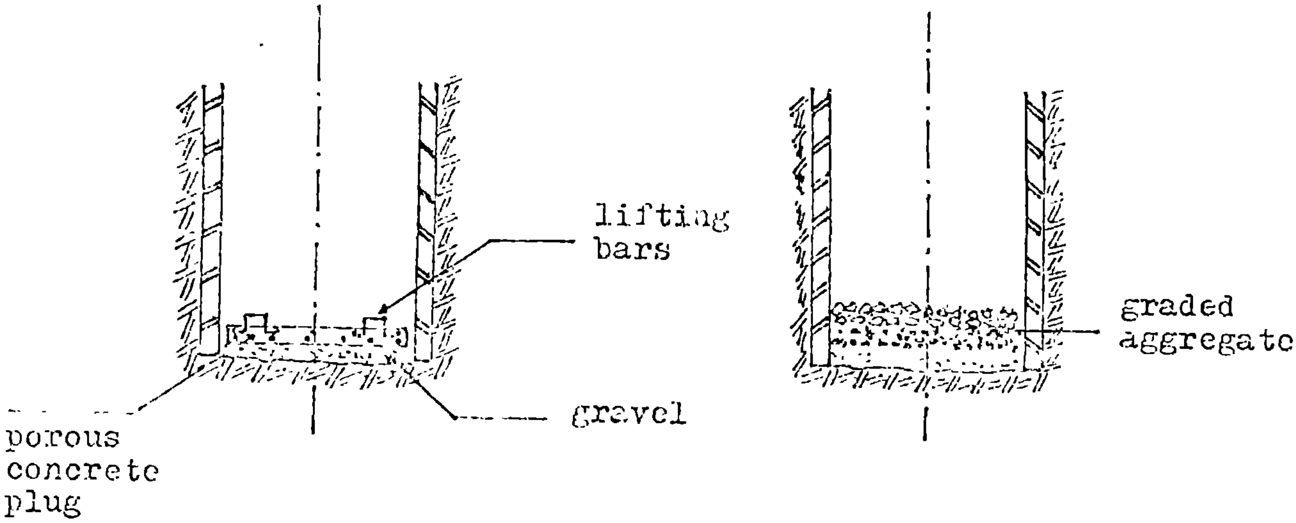


Fig.19 Base plug

5.4 Construction of the well head

The well head consists of a reinforced concrete headwall about 1 meter high, 15 cm. thick, with a gently sloped concrete apron at least 2 meters wide to evacuate spilt water. The wall prevents animals and people from falling down the well and also partly protects water from pollution, i.e.,surface water washed into the well, rubbish thrown down it. The best protection will be had when the well head is provided with a cover and fitted with a hand pump.

The construction procedure to build a well head is as follows:

- break up the weak mortar layer around the stub wall of the main lining and bend the re-rods up into a vertical position;
- attach and tie four horizontal circles of 8mm. re-rod to the vertical re-rods and then tie to each one a re-rod bent into an elbow shape. These right-angle bars will provide reinforcement for the concrete apron(Fig. 20);
- a drainage apron will be constructed before the shutters for well head construction are set in place(The protective role of the drainage apron was described in paragraph 3.7.)

- bend and secure eight circles of re-rod around the apron bars and attach the main lining shutters in place over the well. One should already know what sort of equipment will be used to draw the water.

At this point, it should already have been determined what sort of pumping equipment people in the area will be able to maintain. This indicates the type of mountings that will be needed on the headwall. The headwall can be fitted with rollers, a pulley or a windlass to help people pull up the bucket without leaning over the well. Even greater protection from pollution can be attained by covering the well with a concrete slab and fitting it with a hand pump.

The outside shutter for the wall may either be made specially for the purpose or may be built up out of scrap wood. Using the regular 1:2 1/2:5 concrete mix, the apron slab should be first poured, and after it has set, the collar wall shutters should be put. At least 7 days after the concrete has been poured, the shutters should be removed and the site around the well cleaned.

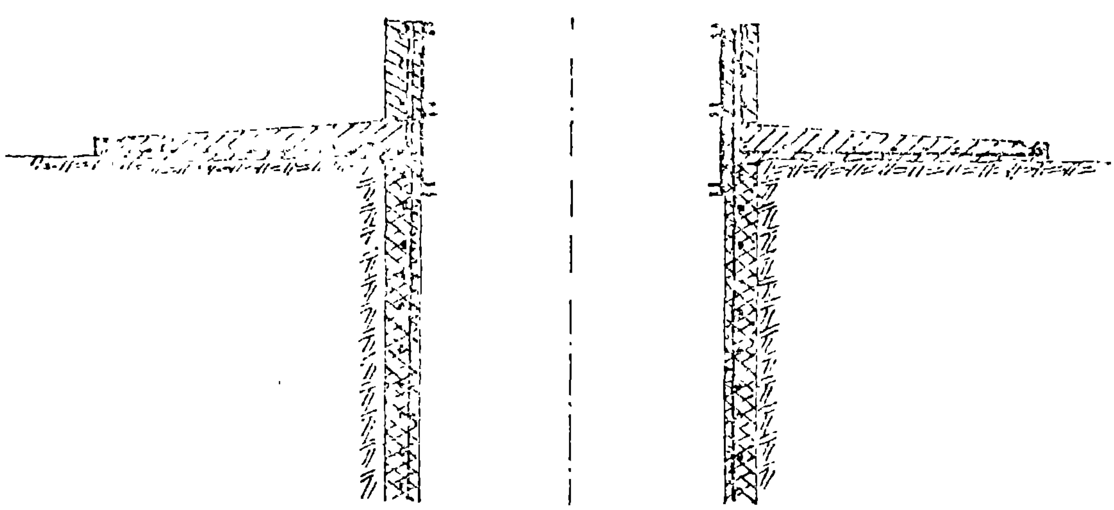


Fig.20 Building up wellhead

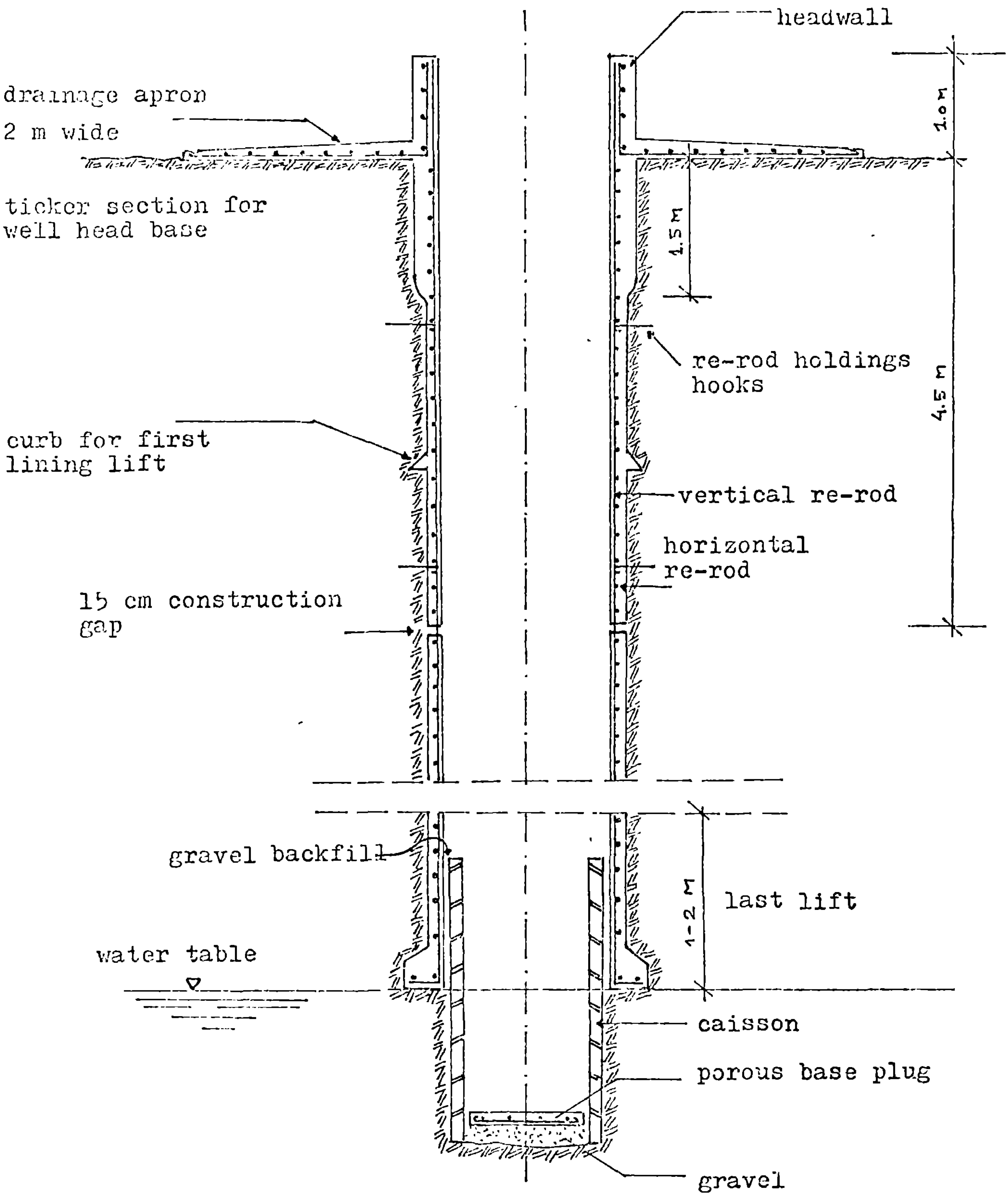


Fig.21 Cross section through finished well

5.5 Other types of dug wells

A dug well having a reduced diameter in the upper well section can be constructed in the following instances:

a) Sometimes, the aquifer is found two meters deep. This is especially so when the aquifer is in weathered bedrock(granite or quartzite), and when laterite or gravel are found less than 2 meters deep but when the water level is more than two meters deep.

b) A well situated on the river bank risks being flooded during the wet season when the water level reaches its highest point, and the hand pump must be located high enough on the river bank. On occasion, due to the low permeability of the river bank which may be clay, special provision should be made to transport water from the river to the well. To achieve this, a trench about 1 meter wide is dug from the middle of the river to the bank, and the trench bottom is at the level of the well bottom. The trench will be excavated after construction of the well. The open space around the well and the trench will be filled with sand from the river. On top of the sand in the trench a clay seal should be placed to prevent contaminated water from seeping through sand into the well. In the method described above, the aquifer is, in fact, extended to the well allowing water to flow into it.(Fig. 22).

The method of well construction is described below (Fig. 23). After digging to the required depth, the filter rings are set in position in exactly the same way as in standard well construction up to the upper boundary of the aquifer. On top of the highest filter ring, a prefabricated reinforced concrete cover with a hole in the center is put in position. Atop this cover, either small diameter rings or PVC-pipe wide enough to enable a pump cylinder to pass through can be used. Again the space between the filter rings and the undisturbed soil is filled with gravel up to the top of the aquifer and a concrete seal is poured on top of it. For reinforcement, 10 mm. diameter rods placed every 10 cm. running both ways at right angles to the concrete cover are necessary to bear the weight of to backfill on top of it. After backfilling the rest of the hole and

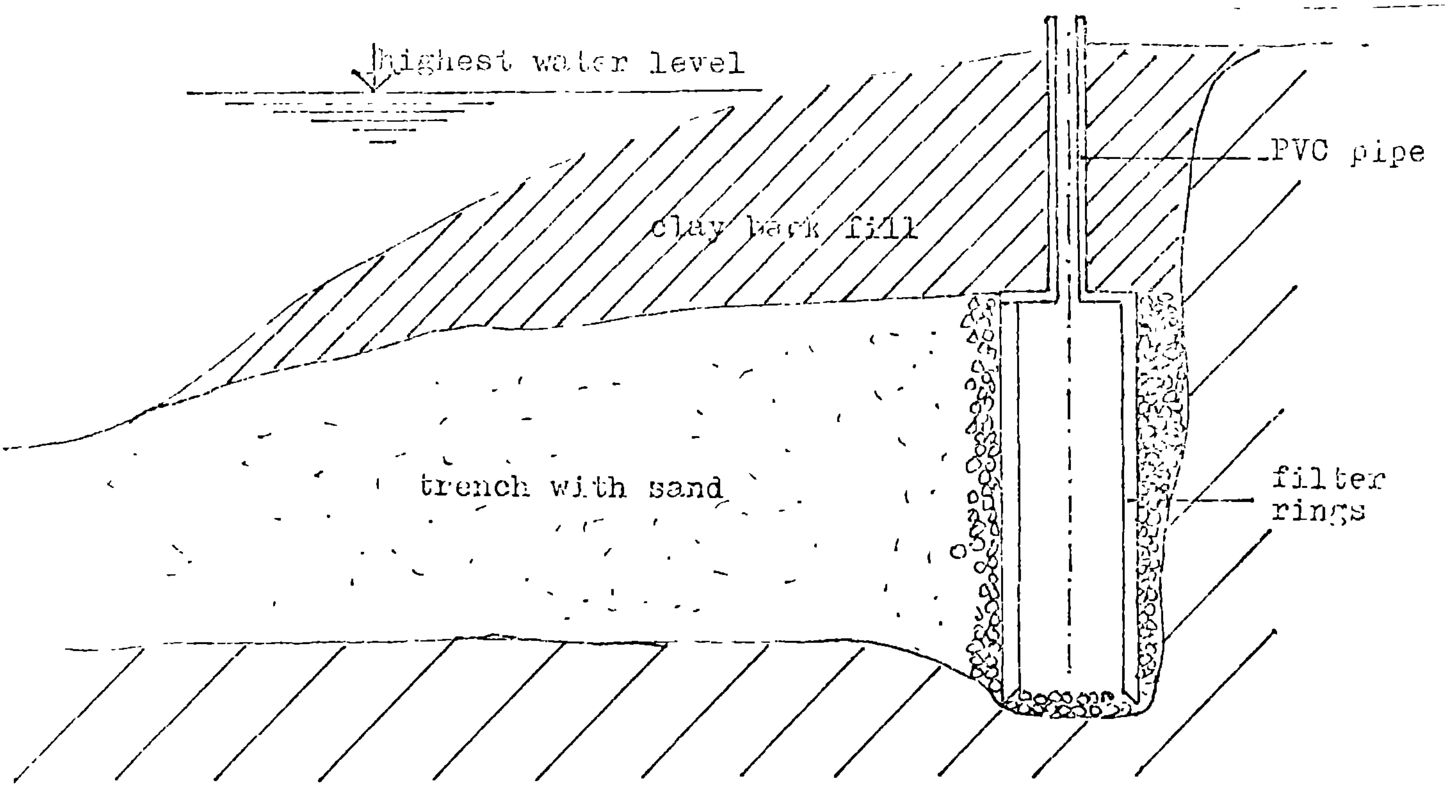


Fig.22 River well

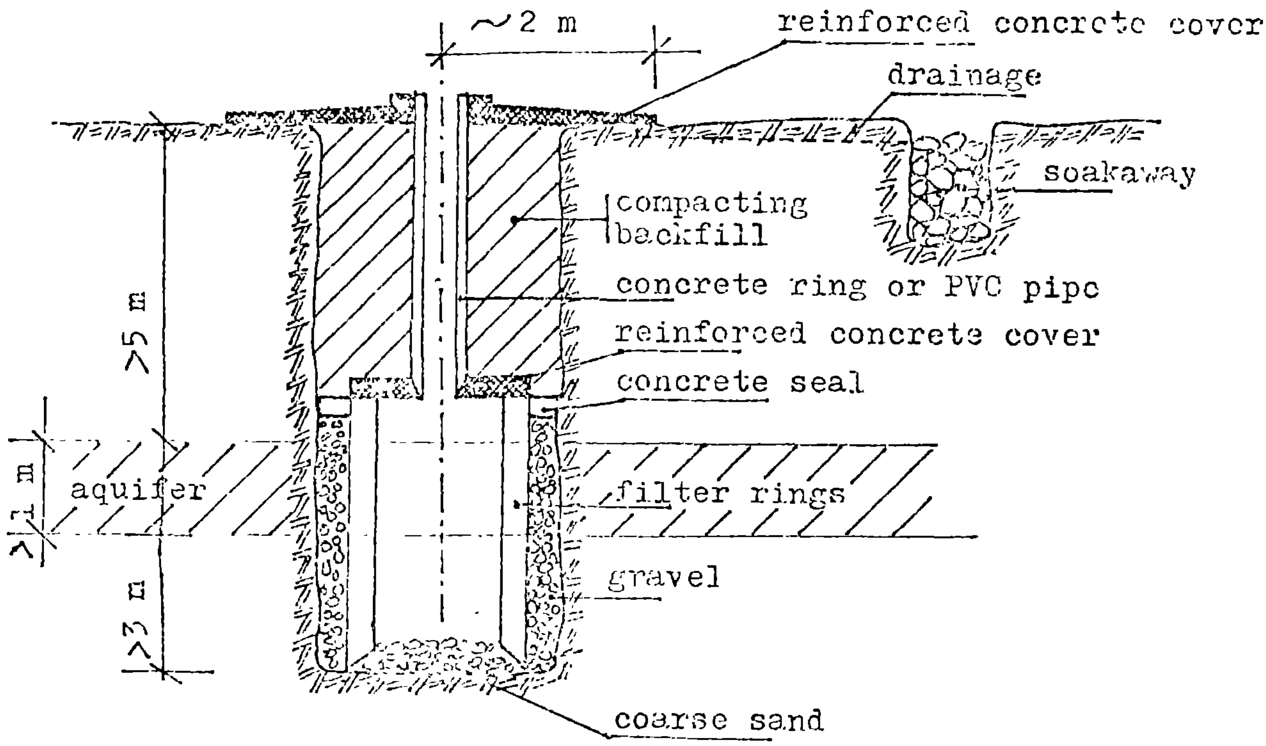


Fig.23 Dug well with reduced diameter in upper well section

compacting the soil in 15 cm. layers, a reinforced concrete cover slab is built around the smaller diameter rings. The diameter of the slab which is cast in place should be about 4 m.. Bolts which the pumpstand can be fastened to are cast in. For reinforcement, 6 mm. diameter rods are placed every 10 cm. running in both directions at right angles in order to avoid cracking due to settling backfill. To restrict settling as well as possible, attention should be paid to the proper compacting of backfill.

5.6 The use of explosives

Many times traditional well diggers will abandon the construction of a hand dug well because of hard geological strata (solid rock) which are met before water is reached.

It is, of course, possible to penetrate most hard formations with the exception of solid basement rock with the use of sledge hammers and chisels. Nevertheless, bedrock such as granite may be tackled by traditional diggers using the method of lighting a fire on the exposed rock surface and when it is hot enough, large amounts of cold water are poured over it. The sudden change in temperature will provoke contraction of the surface, which results in cracks several centimeters deep. The cracked layer can be removed by a pick or crowbar. This method is very slow and seldom used.

Explosives make a very valuable tool for well sinking through hard rock, but explosives are costly and, in inexperienced hands, might prove to be very dangerous. There are many types of explosives manufactured today. The practical effect of the explosion from a detonated charge down shot-holes within the rock is to set off an extremely powerful blast in all directions so that the expansion produced by the explosion will lift the material above and shatter the rock around the charge.

Usually, in a 1.3 meter diameter well, three charges are laid at the same time in the form of an equilateral triangle. The shot-holes are about 30 cm. from the side of the shaft. The first operation is to drill three shot-holes, each about 1 meter deep. The shot-holes could be drilled with the use of compressed air tools or using a sledge hammer and jumper bar. When the shot-holes have been drilled to the required depth and cleaned out, they are packed with explosives. The quantity of the explosive depends on the type of rock, the depth of the drilled shothole and the quality of the explosives. The explosive is in the form of sticks about 25mm. in diameter and 100-200 mm. long. In one hole, several sticks can be placed. When the last stick is inserted, a detonator is used to start the explosion. Detonators are different types of explosives. When the detonator is inserted into the explosive and fired, a small explosion takes place. The shock propagates an explosion through the main body of the explosive(stick). The detonators may be fired either by an electrical trigger or a burning safety fuse. However, a description of the detailed use of explosives is not the purpose of this instruction.

5.7 Disinfection of the well before and during use

The disinfection of water is vital wherever water pollution is possible. Two principal disinfecting methods may be used:

- Physical methods. Disinfection may be achieved by boiling, although this method has limited applications; by bacterial filters, which do not remove viruses and by ultraviolet irradiation, which is impracticable on a large scale and in rural areas.

- Chemical methods. The use of ozone is effective but expensive and impracticable in rural areas. Potassium permanganate is an oxidizing agent with questionable effectiveness against pathogenic organisms, except possible the cholera vibrio. Iodine is an excellent disinfecting agent, particularly for small-scale domestic application. It is too expensive for large-scale use. Water disinfectants based on iodine are available commercially in tablet form as well as tincture of iodine in liquid form. A contact time of 20 -30 minutes is needed for effective disinfection. Two drops of a 2% ethanol solution of iodine suffice for 1 liter of clear water.

Among all the disinfectants already mentioned, free and combined chlorine is the most suitable for sterilizing drinking water. Different chlorination procedures may be used in different circumstances. A suitable method should be selected to satisfy particular needs. Chlorine is the most satisfactory disinfectant for large-scale use. Apart from its germicidal effect, chlorine has several important secondary properties of value in water treatment: it oxidizes iron, manganese and hydrogen sulfide; it destroys some taste and odor-producing- constituents; it controls algae and slime organisms, and aids coagulation. Chlorine readily kills bacteria, schistosoma larvae, some viruses and, in large doses, amoebic dysentery cysts. Chlorine enters into chemical combination almost instantaneously with organic matter in water, and in such combined form, it is of no use for disinfection. Sufficient chlorine must therefore be added to satisfy the "chlorine demand" of water in addition to the amount required for bacteriological action. This combination with other substances may give rise to a chlorine taste, but the presence of such a taste is not sufficient proof that a free chlorine residual exists.

In general, highly polluted water containing large quantities of organic matter is not suited for chlorination. Chlorine is also the easiest disinfectant to apply in liquid and powder form.

Liquid laundry bleach contains about 5% available chlorine and Javelle water about 1% which is about the strength of antiseptic solutions such as zonite and Milton Antiseptic.

Bleaching powder or chlorinated lime contains about 35% available chlorine when fresh. However, the strength of this powder rapidly diminishes after the can has been opened, or in cans which have been stored for a long time. Bleaching powder is easy to handle for rural operations, although it is bulky and comparatively unstable. When stored in a container that is opened once a day for 10 minutes, it loses about 5% of its initial available chlorine over a span of 40 days, but if left open all the time for the same period, the loss may be about 18%. In chlorine solutions made from bleaching powder and stored in a dark container, the chlorine loss over a 10-day period is not significant, but considerable loss will result in the same period if the solution is exposed to light. Both the powder and solution should be stored in a dark, cool, dry place in a closed container that is resistent to corrosion. Containers of wood, ceramic, plastic or cement are suitable. Concentration of the solution should not exceed 5%, as in higher concentrations, some chlorine may be lost in the sediment. The low chlorine content of bleaching powder and its weakening through storage means that bleaching powder has large amounts of inert material, and thus, transport and storage costs are high per unit of available chlorine. Nevertheless, when small quantities are used in remote rural areas, it may be the most suitable material to use.

Another type of powder is high-test hypochlorite which contains about 70% available chlorine. Cans of this powder should be kept as cool as possible. High-test hypochlorite is more stable than chlorinated lime and will retain its potency longer after the can is opened.

All solutions containing more than 10% available chlorine are unstable in warm climates. Chlorine solution should be kept in brown or green bottles and stored in dark places.

Chlorine can be secured in tablet form. Some commercial tablets available are those known as "Halazone", "Chlor-dechlor", and "Hydrochlonazone". Directions given on the package should be followed carefully.

a) Before use

The first disinfection should be made after a well has been constructed. The well should be thoroughly cleaned before it is prepared for use with a strong disinfectant. Open hand dug wells are particularly susceptible to contamination during their construction by well diggers. The most easily obtainable and safe disinfectant is chlorine in liquid or powder forms. In order to disinfect a hand dug well the following procedure may be used:

i) Mix 2 liters of ordinary liquid laundry bleach in 35 liters of water,(or 30 dkg. of bleaching powder in 30 liters of water, or 10 liters of Javelle water in 30 liters of water). If one uses bleaching powder, it must be stirred for 10 minutes and allowed to settle and then, the clear liquid should be poured off to prevent the white sediment from collecting on the bottom.

For a hand dug well, the sides must be scrubbed with this solution and then the remainder can be poured into the well.

To disinfect any pumping equipment, the solution may be poured down the well and the pump operated until the water pumped out smells distinctly of chlorine. Recycle the water back into the well and repeat the procedure of pumping and returning the water to the well for at least an hour.

ii) Mix a similar solution and pour it into the well allowing it to stand overnight.

iii) Pump the water from the well until the odor of chlorine disappears. Sometimes, chlorine may persist in a well for a week or more, depending on the volume of water in the well and the pumping rate. The remaining chlorine in the well will disappear slowly in time as it oxidises.

b) <u>During use</u>

Disinfecting the well immediately after construction will not keep the well water sterilized for more than a few days. Contamination that enters the well during its use may seriously endanger the health of well water consumers.

Simple chlorinators which dispense a chlorine solution at a constant rate can be bought or made with materials available in most developing countries. Chlorine should not be added to water flowing straight to a tap or it will not have enough time to disinfect the water before use. It should be added to the water in a well or entering a storage tank, because it requires at least half an hour to act. If the chlorine is being added to a water supply, the amount of chlorine in the water must be checked regularly because the amount required will vary with the level of pollution. The free chlorine residual(the amount of chlorine still left to kill bacteria) should be at least .3mg./liter (.3 parts per million). A residual of 2 mg./liter is needed to kill amoebic cysts. If not enough chlorine is added, it all may be absorbed very quickly by organic matter in the water, and therefore, it is useless to chlorinate water if you are not adding enough chlorine.

The following simple methods of hypochlorite chlorination using non-mechanical appliances may be easily adapted to suit small rural water supplies and public, private or domestic wells.

i) Diffuser hypochlorinators

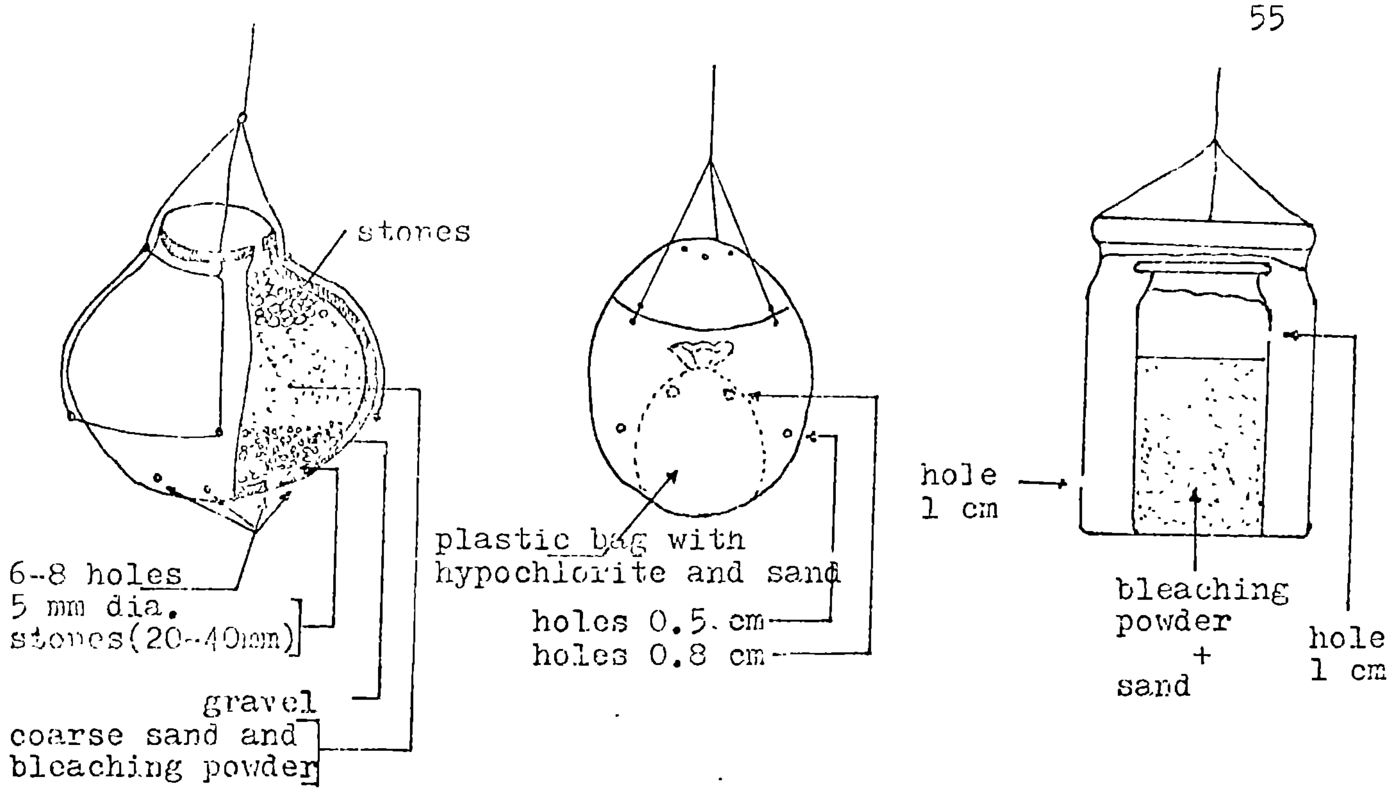
The simplest type of chlorinators are earthen pot, coconut shell and double-jar diffusers (Fig. 24).

-Pot diffusers contain a mixture of coarse sand and bleaching powder, and are hung in a well(Fig. 25) about 1 meter below the low water level. The pot should have 10-15 liter capacity with 6-8 holes 5 mm. in diameter at the bottom of the pot. 20-40 mm. diameter stones will fill the bottom and mouth of the pot. Between two layers of stones, the pot will be filled with a moistened mixture of 1.5 kg. of bleaching powder and about 3 kg. of coarse sand(size 1.4-1.6 mm.). It will have an open mouth. All figures concerning the size of the pot and the quantities of bleaching powder, stone and coarse sand are approximate. Trial runs should be made in each case to ascertain the quantities required in relation to well size and differences in withdrawal rate. This check should be carried out on the water as supplied, not just after chlorination.

- Coconut shell diffusers are used in different Asian countries. A big coconut shell with the husk removed and the kernal scraped out is cut into two parts. A plastic bag containing a mixture of bleaching powder (about 2 kg.) and clean sand in equal parts is placed inside the lower part of the shell(the mouth of the bag is closed) and two parts are then fastened together. Three holes (each .5cm. in diameter) burnt through the container body just below the center, and two holes (.8cm in diameter) punched in the middle of the plastic bag enable the disinfectant to pass out through the shell into the water to be disinfected. The shell chlorinator is hung about 30 cm. below the water surface(Fig. 25). This device can disinfect small domestic wells with daily withdrawal rates of about 90 liters for about 3 weeks giving a residual chlorine level of about .2 -.1 mg./liter. When the residual chlore falls below .1 mg./liter, the plastic bag should be refilled with fresh chemical.

- Double-jar diffusers are suitable for a well serving up to 20 people. An inner cylindrical pot(about 16 cm. in diameter and 28 cm. high) should be filled with a moist mixture of 1 kg. of bleaching powder and 2 kg. of coarse sand(2mm) to a level about 3 cm. below a hole (1 cm. in diameter). The pot is placed inside an outer cylindrical pot (25 cm. internal diameter and 30 cm. high). The outside pot has a hole (1 cm. in diameter) about 4 cm above the bottom. The mouths of the pots should be covered with poly-ethylene sheets. The whole device is hung in the well about 1 meter below the low water level.(Fig. 25). This chlorinator is suitable for a well serving up to 20 people and needs to be refilled every three weeks.

Chlorine can be added to the well using many other devices, but they will not be described in this instruction.



Pot   Coconut shell   Double jar

Fig.24 Diffuser hypochlorinators

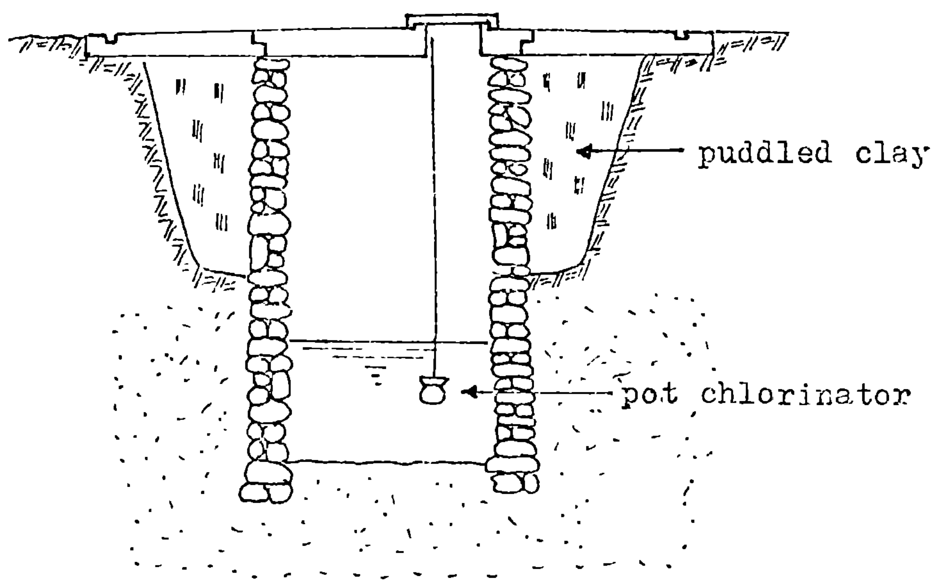


Fig.25 Disinfection of a well

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