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STUDY OF HANDPUMPS FOR SHALLOW TUBEWELLS IN DEVELOPING COUNTRIES WITH REFERENCES TO NEPAL

by

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A special study submitted in partial fulfillment of the requirements for the Diploma of the Asian Institute of Technology

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ABSTRACT

This study consists of a brief discussions regarding hydraulic characteristics of an aquifer, component parts, hydraulics of wells, different types of handpumps in developing countries and its evaluation.

The study was conducted mainly to collect available information in connection with the design and construction of shallow tubewells for both drinking and irrigation purpose and how to utilize these evaluation in further ground water development is discussed.

After analysis of the hydrological and geological condition of Nepal with the collected information from the study, it is found that the aquifer and water table is suitable for utilizing shallow tubewells for drinking and irrigation in a large of the Terai part of Nepal.

ACKNOWLEDGEMENT

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I INTRODUCTION

1.1 PRESENT SITUATION

The level of public water supply service in Nepal is very low. The population covered by the piped water supply at present amounts to a mere 7.5 percent of total population. Less than one percent of population is provided with sewerage and sanitary facilities of any kind. Most of the people privileged with the said facilities live in urban areas. Some 73,000 cubic meter of portable water is supplied daily for those spread in 42 districts of Nepal. Rest of the people depend on natural streams, local springs and wells to meet their daily water requirements or needs.

In the Terai (plains) the sources of supply is the ground water from medium depths varying from 100 meter to 200 meter below ground through deep tubewells. In the inner Terai and the hilly regions the source of supply is either springs, streams or rivers. The river water is generally collected through slotted lateral pipes layed under the river bed. The water scarcity is more acute in the hilly areas. There are places, where people carry a few buckets of pots of water for daily use from distance as much as five kilometer involving several climbs. Water treatment prior to distribution is only limited to 4 towns out of the 29 in the country.

1.2 POPULATION

The implementation of water supply projects in Nepal started many years ago but until the 5th Five year plan, only a very low priority was accorded to this development sector. It is estimated that the total population served by some form of water supply system in currently only 10 percent of the total (16 million total of which 15.5 million live in the rural areas).

The rural population in the terai was 3.97 million in 1971, representing nearly 40 % of the total rural population then. This is expected to grow to 6.8 million by the year 2000.

Even though the rural population in the terai have access to ground water, most of the wells are both unreliable and unsafe and the hardship experienced by this large number in the terai merits consideration. Hitherto no organised programme has been developed to aleviate the hardship experienced by the rural population living in the terai.

1.3 HYDROGEOLOGY

In the terai plains, the only possible solution which is economical and safe is tubewell handpumps. In most parts of terai the groundwater table is quite high. Thus, installation of shallow tubewell is fairly easy.

For those areas in which illuvium occurs, and where the water is always within the below ground level, handpump will be installed.

1.4 PLAN AND TARGET

The government of Nepal laid down that coverage is to be one handpump per 200 people by 1990 for the provision of pumps. In addition, the wells shall be sited so as to minimise the water carrying distance to 150 meters. It is proposed to lower the ratio of user per well from 200:1 in 1990 to 75:1 by the year 2000 which implies approximately 32,000 handpumps need to be provided between 1980 and 1990 and some 70,000-80,000 additional handpumps will be needed between 1990 and 2000. The area to be covered by these tubewell is thought to represent about 80% of the Terai.

Ground water at shallow depth is available in plenty in the terai and by the construction of shallow tubewells equipped with handpumps it would be possible to make available access to safe water to these people speedily and at very low unit cost. The suggested well construction programme would comprise of improving the existing shallow dug wells and equipping same with handpumps or construction new shallow tubewells.

During the 6th Five year plan, starting in 1980-81, the government has set a target of 40 % of the total population to be served by such projects.

1.5 WATER SUPPLY

It is the policy of His Majesty's Government of Nepal that all town should have a piped water supply. By 1990 this will be the case; however, this does not imply complete coverage of the population in those towns, since the boundries which apply to town panchayats are drawn from social rather than geographic reasons. Also, in some towns, it will be more rational to supply certain areas through community handpump where the geology makes this a possibility.

His Majesty's Government policy in the hills and midlands is aimed at reducing the water collection journey, improving water quality and providing an adequate supply. By 1990 it is required that shall be at least one water supply system in each in every village panchayat in the country. To meet this requirement 2266 gravity piped water supply systems has been planned for implementation in the hills in the midlands between 1980 and 1990.

Rural water supplies in the Terai will depend entirely on the geology and aquifer levels in each areas. Wherever possible, shallow tubewells with handpumps will be used, in other areas, deep tubewells, generally with some motor driven pump, will be used.

The use of shallow tubewell is increasing gradually in the Terai of Nepal for its lower cost and better management. So efficient and economic utilization of ground water through shallow tubewell can be achieved by proper design and construction of the well.

1.6 OBJECTIVE OF THIS STUDY

The objective is to study shallow tubewells both for drinking and irrigation purpose in the Terai parts of Nepal. To provide reasonable access to safe water to the rural population in the terai and thus alleviate the hardship being experienced by them at present. The main purpose of this study is to collect available information concerning design and construction of shallow tubewell and the improvement of the existing shallow dugwells to sanitary standerd and equipping same with handpumps or construction new shallow tubewells.

1.7 SCOPE OF STUDY

This study includes the evaluation of the different types of handpumps for shallow tubewells in different countries. Shallow tubewell and its component parts, well hydraulics, characteristics of well strainers etc. are studied for finding the design criteria of a shallow tubewell. Finally the importance and feasibility of optimal design of shallow tubewell is discussed with specific context of Nepal.

II SHALLOW TUBEWELL AND ITS COMPONENT PARTS

A water well is a hydraulic hole in the earth down to a supply of water excavated for the purpose of bringing ground water to the surface. The shallow tubewell is a type of well used for mainly both drinking and irrigation purpose. A complete shallow tubewell can be divided into the following parts. (a) the aquifer, (b) the well, (c) cylinder, (d) pump rod, (e) plunger, (f) cup seals, (g) valves.

2.1 AQUIFER

Presence of an aquifer is essential to construct a tubewell. The formation or strata within the saturated zone below the ground surface, from which ground water can be obtained for beneficial use, are called aquifers. The aquifers are originated by the forces of nature and are indepedentent of influence of man. The most common aquifer materials are unconsolidated sands and gravels, which occur in alluvial valleys, old stream beds covered by fine deposits (buried valleys), coastal plains and glacial deposits.

The spaces of portion of the rocks or soil not occupied by solid materials are called pores or pore spaces. These pore spaces between grains are filled up with water entering the ground through rainfall and passing under the ground through hydraulic head.

2.2 WELLS

The aquifer and ground water are natural and man can do very little to change it. Man has, however, developed the technology to extract the water for many uses including irrigation the water wells. Placing a water well does not change the aquifer permeability nor the amount of water stored in the aquifer. The well takes advantage of natural conditions and serves as a place for collection and removal of water from the aquifer. Irrigation wells differ from those used to supply water for domestic purposes because of the large volumes of water that have to be pumped from them for irrigating even small farms. Efficient and economical utilization of ground water through wells depend on the design of the wells.

2.3 CYLINDER

The main function of the cylinder is to house the plunger assembly and the suction valve. The water seal formed by the moving contact between the cylinder and the plunger cup seal creates the partial vacuum which makes suction lift possible.

The length of the cylinder is a function of the stroke length which is typically 12.5 to 25 cm for handpumps. Additional length is required for cups and for the plunger and suction valve assemblies. This is because of the tolerances in measurement of drop pipe and pump rod lengths and also to prevent operator abuses such as driving the plunger into the suction valve with excessive handle lift.

The cylinder which wears rapidly is sometimes constructed double length allowing the plunger depth to be reset and pumping to be continued without replacing the cylinder.

Generally, the diameter of the cylinder decreases with increasing pumping head.

The range is from 7.5 cm to 10 cm for shallow wells and 5 cm or less for deeper wells.

Surface smoothness of the cylinder wall is the key factor in the life expectancy of plunger cup seal. This is the reason why brass cylinders are commonly used rather than cast iron cylinders despite the lower cost of the latter.

Even though, the average smoothness is about the same, the harder, sharper, peaks in the steel pipe tend to tear and abrade the cup more rapidly. The cups wear much faster in iron cylinder than in steel cylinder.

Recently, the used of PVC cylinders is encouraging. Tests indicate that leather cup wears in PVC cylinders is comparable to that in brass cylinders. Being relatively soft, PVC is more likely to be subjected to scouring by silt and other solid impurities in the water and by the plunger when the cup was worn out.

In summary, brass is the industry standard, cast iron is used when low cost is paramount, and PVC is not widely used as yet but has much potentials.

2.4 PUMP ROD

The function of pump rod is to connect the handle and the plunger assembly. The rod and its connectors must be strong enough to support the forces which include water pressure exerted on plunger, submerged weight of the pump rod and plunger assembly, the sliding friction at bearings and the cup seals. During the ascent of the plunger, the rod is in tension, when descents, the pump rod will be in compression if the handle is operated faster than the natural gravitational fall of the rod and plunger. However, tensile stress generally establishes the minimum rod diameter. Normally, the diameter of the pump rod ranges from 10 mm to 12 mm and the rod is round in shape.

The principal operating problems with pump rods are disconnections with the handle, the plunger or between links and corrosion. Disconnections may be reduced by the use of lock nuts at couplings, proper threading and thread engagement. Corrosion-resistance is improved by the use of galvanized steel or alloys.

2.5 PLUNGER ASSEMBLY

The purpose of the plunger assembly is to lift the water to the pump spout during its upward stroke. It also helps to support the discharge valve. When designing the plunger assembly, strength is the first priority to be considered. The opening and closing of the design discharge valve are related to the movement of the plunger assembly.

The assembly typically consists of a cage connection to the pump rod, discharge valve, cup seals and cup seal followers and spacers. Futher discussions on cup seals and valves are presented below.

2.6 CUP SEALS

The major function of cup seal is to prevent backflow of water between the plunger and the cylinder walls during pumping. Leather or flexible materialis folded or cupped over the plunger face . As the plunger ascends, the lips of the cup is pressed against the cyliner wall to form a seal. The descending of the plunger causes the inward movement of the lip, thus reduces friction and wear. The repeated sliding friction between the cups and the cylinder wall eventually wears away the cups and periodic replacement of the cups is necessary.

Indeed cup seals should be non-toxic, durable, low friction coefficient, resist mildew, fungi and other biological attack . It should be readily available and flexible enough to fill cylinder of different shapes and sizes.

Leather has been the material used, as it is relatively cheap and available worldwide. PVC cups are now being used in several programs. One of the main advantages is their longer service life.

2.7 VALVES

Generally, there are two valves within the cylinder; one valve in the plunger assembly called the plunger or discharge valve, the other in the bottom or suction end of the cylinder know as the suction or foot valve. Both the valves mentioned are check valves, since the valves only allow the water to flow in one direction.

The discharge valve closes during upward movement with the plunger to discharge the water above it and opens during its downward movement to refill, so that to replace the water discharge during the preplous cycle. The suction valve opens during the upward movement of the plunger and closes during downward movement. Its function is to eliminate the labor of repriming to restart pumping.

The valve should be water-tight, especially for the suction valve which must hold water for hours overnight if the pump is to maintain its prime.

The valve openings should be large enough to minimize frictional head losses. The valves should close quickly to minimize backflow. However, the valve opening is restricted by the cylinder diameter and the space needed for cup seals, followers, spacers etc.

III HYDRAULICS OF WELLS

Shallow tubewells operate according to certain fundamental principles. Water flows into the well from the surrounding aquifer because the pumping of the well creates a diffrence in pressure. Before pumping the water in the well stands at height equal to the static water level or static water pressure in the saturated sand around the well. When pumping starts, the water level in the well drop down and the water starts to flow into the well from the water bearing formation, because water level or pressure inside the well during pumping, is lower than that in the aquifer outside the wall.

To understand the principle of water entering a well, the following terms should be understood first.

3.1 POROSITY

Porosity of a material is the portion of its total volume that consists of open or pore spaces. When these open spaces are in geologic formation, they become potential areas of ground water saturation and avenues of ground water movement. The size of the pores and total pore spaces of an aquifer varies with the type of formation material. Porosity represents the amount of water the aquifer will hold, but it does not determine the case with which water will move through those pore spaces. Ground water stored within the pore spaces that will not easily move through these openings is not useful for withdrawal by shallow tubewells. When pore spaces are very small, as in clay, water remain attached to the surfaces through capilarity at points of grain contact and become unmovable.

3.2 PERMEABILITY

Permeability is the capacity of water to flow through a porous material. When this material is sand, silt and gravel of geologic formations that are saturated with ground water, permeability becomes an important factor in removing water from the ground through shallow tubewells. Permeability also depends upon the size and sorting of material that makes up the geologic formation and aquifer. In general, the coarser the material and the more uniform the practicle sizes, the easier it is for water to move through the open spaces. Water with its capillary characteristics will cling to the small pore spaces of the small grain sizes. Very fine sand and silt have a high percentage of voids, but the small size of the voids restrict movement of water because of its character. Various sand sizes and silt mix together will fill potential voids thus maintaining many small voids as well as a limited number of voids. This mixed material has poor aquifer potential also. Hence it can be considered, in general, that the coarser the material, the better the aquifer.

3.3 COEFFICIENT OF PERMEABILITY

For ground water use, permeability of sand and gravel is an important element. For convenient use in ground water and well evaluation, the coefficient of permeability is the rate of flow of water in liters per square meter of the aquifer under a hydraulic gradient of one meter per meter at the prevailing temperature of water.

3.4 COEFFICIENT OF TRANSMISSIVITY

The coefficient of transmissivity of ground water can be defined at the rate at which water will flow through a vertical strip of the aquifer one meter wide and extending throughout the full saturated thickness of the aquifer under a unit hydraulic gradient. The value of the transmissivity, can be determined from aquifer pumping by measuring one or more wells, the decline of head with time under the influence of a constant pumping rate.

3.5 COEFFICIENT OF STORAGE

The coefficient of storage of an aquifer is the volume of water released from storage or taken into storage per unit surface area of aquifer per unit change in head. This coefficient of storage, is a dimensionless term.

3.6 PRINCIPLE OF WATER ENTERING A WELL

Except in certain cases, ground water flow is almost exclusively laminar. HAGEN (1893) and POISEUILLE (1846) showed that the velocity of flow in capilary tubes is proportional to the slope, of the energy gradient. DARCY (1856) confirmed the applicability of the principle to flow in uniform sands and the resulting equation is Darcy's law.

$$V = KS$$

The term, K, in DARCY's law is reffered to as the hydraulic conductivity or coefficient of permeability. When water is lifted from the well creating a new lower water table or level in the well called the pumping water level. This pumping water level then creats a head difference between it and the original static water level, called drawdawn. Principles of DARCY's law indicates that the ground water will flow towards the well because of the head difference and the rate depend on the permeability of the aquifer. The water flows radially toward the well from all directions. As the water moves closer and closer to the well, it must pass successively through smaller and smaller areas. The same volume of water passing through smaller area requires an increase in the velocity.

According to the DARCY's law, hydraulic gradient of a porous material varies directly with flow velocity. The greater the flow velocity the greater the head differential. The hydraulic gradient or head differential required to move the ground water at gradually increasing velocities becomes steeper and steeper toward the well.

IV WELL STRAINERS

The strainer or screen as it is often called, is placed in the well to hold the sand or gravel aquifer in place while allowing the ground water to enter the well. Ideally then strainer open area should be equal to or greater than that of the adjacent aquifer void percentage thus allowing unrestricted inflow of ground water into the well. But strainer costs, construction methods and materials prevent this is many cases. The greater the open area of strainer, the lower the entrance velocity of water into the well resulting in a more productive, longer lasting and more economically operated well. The recommendations on safe limit of entrance velocity of the flow into the well vary considerably. BENNISON (1947) proposed that a velocity of 0.03 to 0.075 m/s through the individual opening of the screen will keep the sand movement and head losses to the minimum. LINSLEY and FRAZANI (1964) observed that the entrance velocity should be kept below 0.15 m/s in order to minimize sand movement and head losses. The total strainer open area for a shallow tubewell can be varied by adjusting the length or diameter of the screen.

A transmitting capacity of 0.03 m/s is commonly used when considering the hydraulic characteristics of the screen itself. This entrance velocity can be determined by dividing the well yield by total open area of the strainer. Generally, the aquifers of lower permeability are composed of fine grain materials which have a tendency to clog the strainer when its comes into contact with the wire net openings. The greater the velocity of water in the aquifer the greater is the tendency for fine materials to gradually migrate towards the screen, ultimately blocking off some of the openings.

V SHALLOW TUBEWELL DESIGN

Generally the wells are designed for different purposes such as irrigation, drainage, sanitation and domestic and industrial works. So the design requires particular attention taking into account its purpose. Designing a water well involves selecting the proper dimensional factors for the well structure and choosing the material to be used in its construction. Shallow tubewells should be designed and constructed to take advantage of the natural conditicn at a given location.

The shallow tubewell utilizing suction lift pumping has lift limitations. And so this requires the use of all technology possible to achieve maximum benifit from the limited lift. Efforts to reduce the drawdown in the well must be made.

For designing the well the following criterion should be considered.

1. Placing the screen opposite the best layers.
2. Seperating screen to intercept more aquifer.
3. Maintaining low friction head loss in the system.
4. Placing adequate strainer length to collect intercepted water.
5. Placing strainer with openings compatible to the adjacent formation.

The design elements in shallow tubewell include the well diameter, well depth, well screen and its placing.

5.1 WELL DIAMPTER

Choice of a proper well diameter is important for tubewells because it affects significantly the cost of the structure. The diameter of a shallow tubewell is usually the same from top to bottom. The diameter of the intake section of the well should be such as will ensure good hydraulic efficiency of the well. The yield of a well is the function of the diameter of its intake portion but they are not directly proportional. An increase in well diameter increases slightly. Keeping the hydraulic properties of the aquifer as constant, doubling the diameter of the screen in a water table aquifer will increase the discharge only about 11 percent.

5.2 WELL SCREEN

A well screen is a strainer, which seperates the groundwater from the granular material in which pores it is contained. The well screen elements refer to the length of the screen, its diameter total open area and size and arrangement of the slot openings. A well screen should fulfill the following requirements.

1. Resistance to corrosion and deterioration.
2. Enough structural strength to prevent collapse.
3. Suitability to prevent excessive movement of sand into the well.
4. Minimum resistance of flow of water into the well.

Strainer opening should be as large and as many as is practical and still be capable of preventing the sand of the aquifer from entering the well. As because the greater the size and number of opening the lower the water entry velocity and hence head loss. Moreover, greater velocity of water has a tendency to more fine particles towards the screen where they are trapped against the wire mesh tending to clog it and reduce the effective open area. So the entry velocity must be kept in the lower side for an efficient well. Strainer length and diameter determine the open area exposed to the aquifer. But as for shallow tubewell diameter is normally fixed, length of screen is a key factor for a good well. For preventing the rapid clogging, the screen length can be determined on the basis of Walton's (1962) equation.

$$h = \frac{Q_o}{A_o V_e} \qquad (5-1)$$

where, h = length of screen, m

Q_o = maximum expected discharge capacity of well, m^3/s

A_o = effective open area per meter length of the well screen, m^2/m

V_e = entrance velocity at the screen, m/s

Details of screen has been discussed in the previous chapter.

5.3 PLACEMENT OF SCREEN

Placing the screen opposite the most permeable portion of the aquifer is the most important principle in the shallow tubewell design. Because of the variation in the geological conditions from well to well, strainer must be placed on an individual well basis and should be the responsibilities of the field personnel who are actually drilling and constructing the well. For a homogenious layer strainer percentage should be as follows:

less than 7.50 m thick - 70% is adequate.

7.50 - 15.00 m thick - 75% is adequate.

more than 15.00m thick - 80% is adequate.

These strainer length will result in obtaining at least 90% of the maximum specific capacity of the complete aquifer. Proper placement of a strainer in the layer is shown in fig.5.1.

Two basis principles of placing the screen opposite the best aquifer and seperating the strainers can be incorporated into the following construction key. This will be adequate for most conditions encountered. Let it be assumed that 3 (three) 3.0 m strainers will be used. Placing of screens depending on different layer conditions will be

A - If best aquifer totals 15.00 m or more

(i) - and aquifer in one continuous layer - three strainers should be placed alternating with casing.

(ii) - and aquifer in seperate layers - one strainer should be placed in each seperate layer.

B - If best aquifer totals 9.0 m to 15.0 m

(i) - and best aquifer all in one layer - two strainers alternating with casing should be placed.

(ii) - and best aquifer in seperate layers - one strainer in each seperate layer should be placed using maximum of two strainers.

(iii) -also one strainer in the second best aquifer should be placed but seperated from other strainers.

C - If best aquifer is less than 9.0 m

(i) - and aquifer all in one layer - one strainer in center of the layer should be placed.

(ii) - and aquifer in two layers - one strainer in each layer should be placed.

(iii) -and if second best aquifer is in one layer - two strainers alternating with casing but seperated from other strainers should be placed.

(iv)- and if second best aquifer is in layers - one strainer in each layer but seperated from other strainers should be placed.

Layer less than 3.0 m thickness should not be considered as layer for strainer placing.

The commonly used materials such as brass and galvanised steel are suitable and often available, and can be driven into place where necessary. This type of strainers are expensive for tubewell.

Plastic such as PVC and ABS is very useful for screen production where driven is not necessary. PVC is a cheap and easily available in the country. It is light and strong. It is non-corrosive and inert to salt action. It pipes are manufactured in the length of 1.5 m and 50 mm diameter for strainer. PVC pipes are being extensively used in the country for strainer and other purposes.

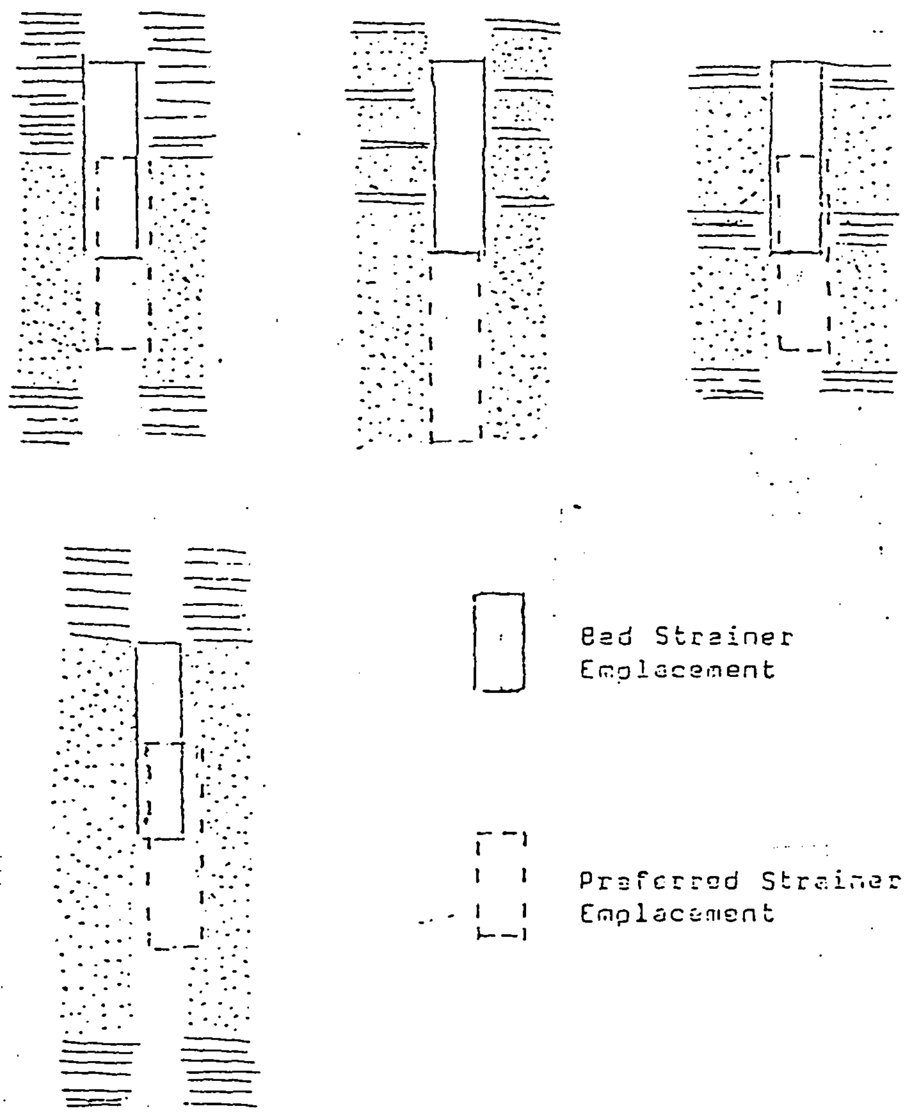


Fig.5.1 Example illustrating the placement of strainers

(From "Design of tubewell", Tubewell theory and practice, 1979)

VI PUMP TYPES IN DETAIL

6.1 BANGLADESH

As of December 1977, approximately 663,000 handpump tubewells existed in Bangladesh. In general, 75-85% of the hand pump tube-wells are in operation.

UNICEF helped in developing a local pump called "NEW NO. 6", which incorporates some ideas suggested by the Battelle work, but which is about half the size, because of a need to economize in materials. This low lift pump is currently being manufactured in tens of thousands in local foundries, (Fig.6.1).

The reasons for the success of the pump/tube-well program in Bangladesh seem to be the high motivation of the people towards this type of water supply, and the organization of the maintenance service. The fact that people value their pumps and wells more than in some other countries is indicated by the large number of private individuals who have invested in a private pump for their own household.

6.2 INDIA

The national water supply and sanitation program of India was initiated on an organized the India mark-II pump, (Fig.6.2). This hand-pump is an improvement on old cast-iron

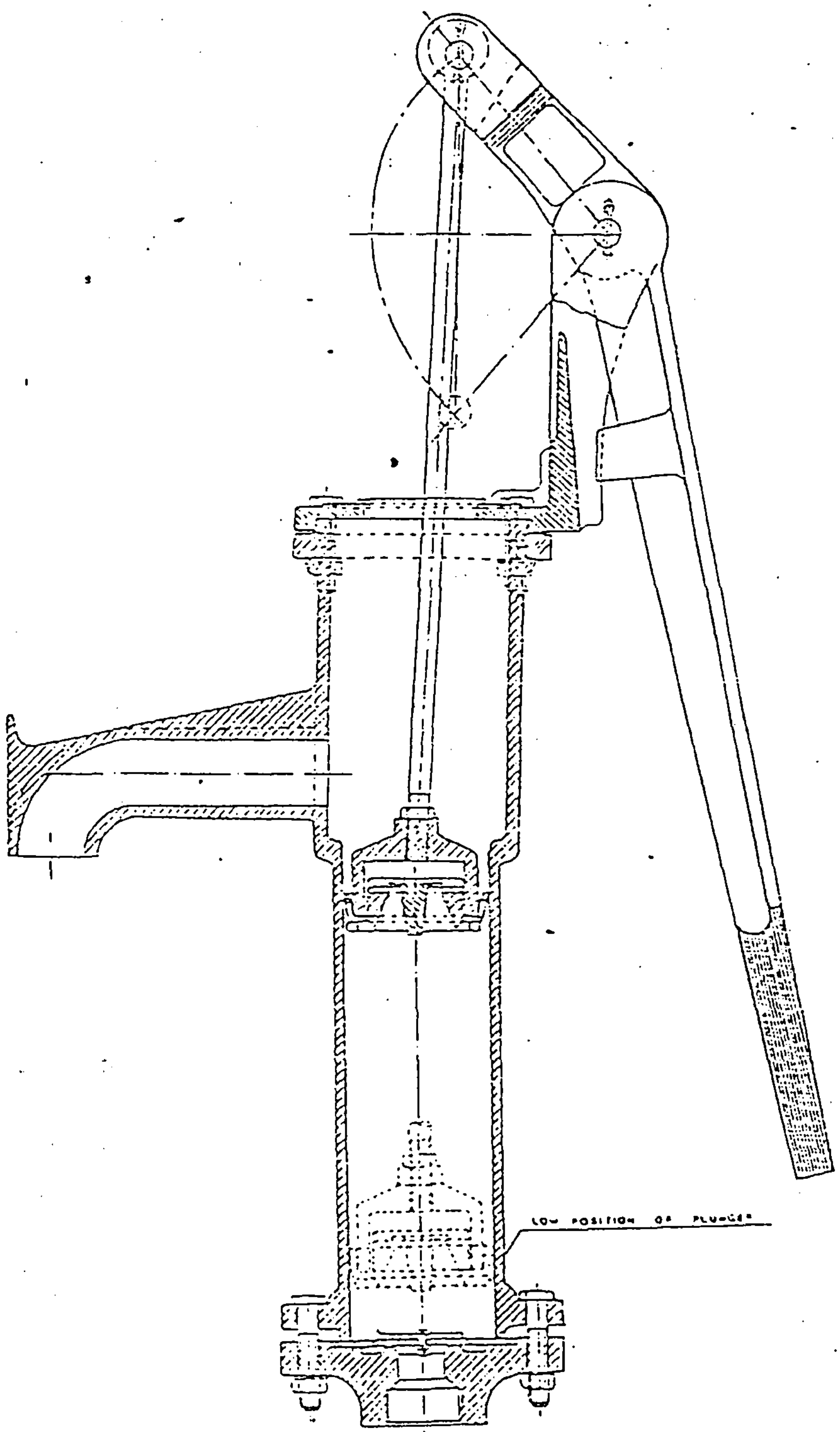


Fig.6.1 New No.6 Handpump (Bangladesh)

(From "Handpumps for Developing Countries", ENFO, 1983) pumps which could not withstand the wear and tear of heavy use. The mark-II is manufactured of standard steel components available in India. The cost of the handpump is US $150. With the rising main, pump rods and cylinder, the cost increases to $200. Many state of India are now taking a renewed interest in hand-pumps. A number are experimenting with variants of the three-tier system, by removing the block level and strengthening the district level team.

The success of the three-tier programmes lies in a combination of community participation and good technology. The tough India mark-II hand-pump has greatly reduced maintenance needs. It is replacing the old cast iron pumps designed for western family use, which cannot survive the tough treatment of non-stop use by hundreds of villagers.

The annual cost of the three-tier maintenance system has been estimated at about $ 19,000 for 500 pumps.

6.3 NEPAL

There are different design of hand-pumps used in the terai region (plain area) of Nepal-including imported, semi-local and local. The prices of the imported handpumps are in the range of US$ 50-200, depending on the working depth from 8 to 25 m. The value of imported parts are about 20-40% of the local prices.

In a comparatively analysis that all hand-pumps cannot be installed and maintained by a central government unit.

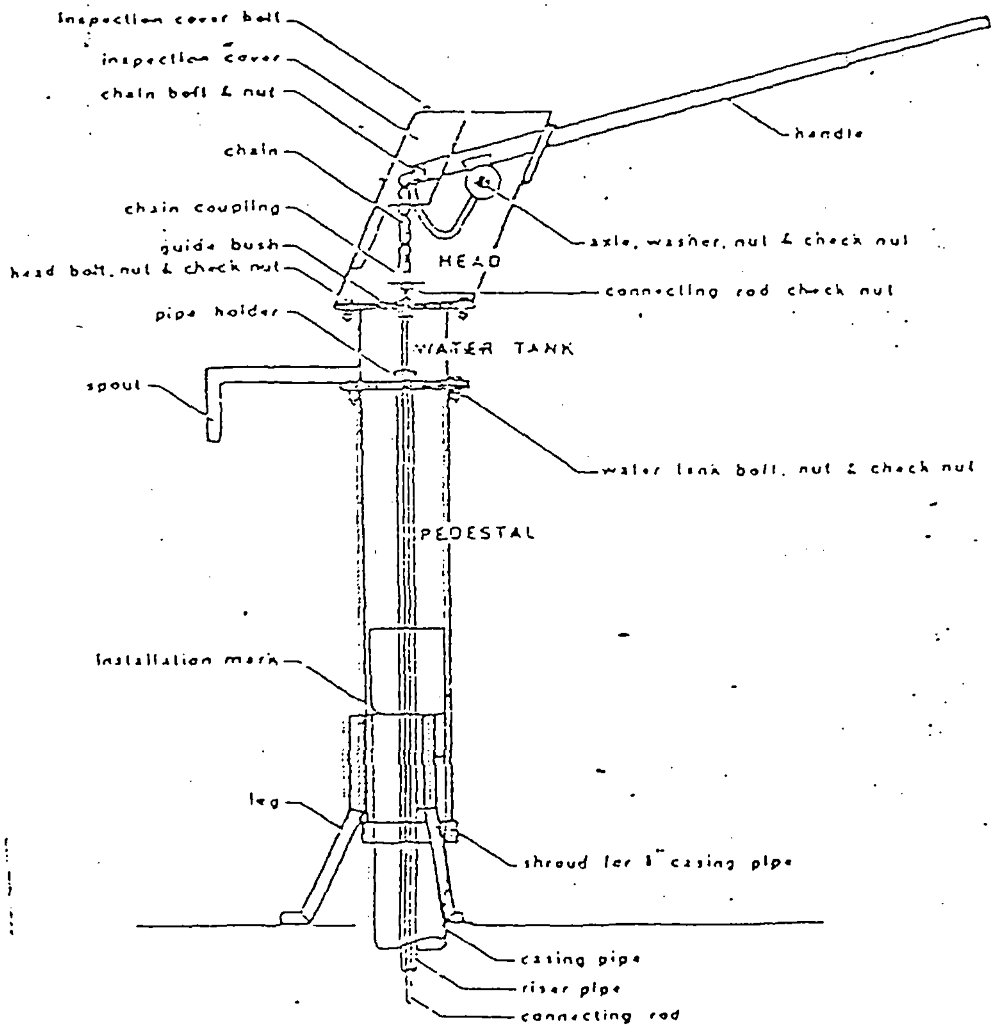


Fig.6.2 INDIA MARK-II HANDPUMP

(From "Handpump for Developing Countries", ENFO, 1983)

Pumps can be successfullyhandeled only at the small community level. Experience in Nepal has shown that the more successful programs are locatedin those areas where maintenance is carried out within the community itself.

In the eastern and western parts of terai with the joint co-operation of HMG of Nepal and UNICEF is developing Bangladesh type No.6 handpumps. This type of hand-pumps has been designed and developed by UNICEF in Nepal. It is entirely built of PVC screen, PVC sandtrap, HDP and GI pipes, available in most countries, which makes local manufacture suitable. It is light weight and can be installed by hand. Maintenance is easy since the pipe can be sawn apart and glued together again. The pump is now being tested in the terai regions of Nepal.

6.4 AIT-PVC Handpump

Based on the field monitoring and laboratory test results, a final design, called the AIT-PVC handpump, was developed. It is incorporated the following features. A new type of fulcurm link, hinged at both ends by means of ball bearings, was introduced in the design. This fulcrum link replaces the type used in the department of mineral resources (DMR) handpump, which failed frequently either at the joints or at the link itself. Details of the above-ground components are shown in the fig.6.3.

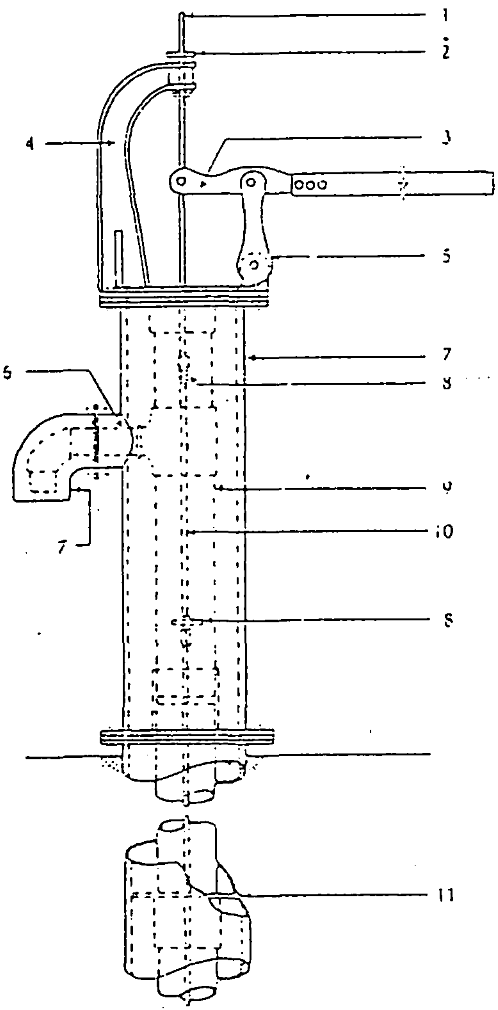


Fig.6.3 *Above-ground components of AIT-PVC handpump: (1) round steel bar; (2) bar guide; (3) handle; (4) frame; (5) handle-support unit with ball bearings; (6) PVC faucet; (7) steel casing; (8) coupling; (9) PVC pipe; (10) steel*

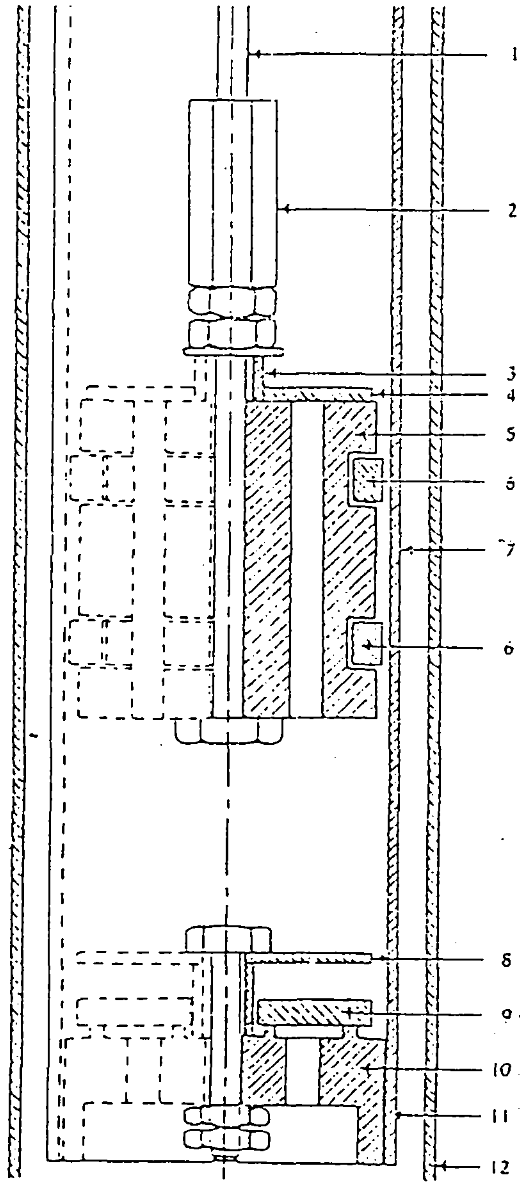


Fig.6.4 *Below-ground components of AIT-PVC handpump: (1) steel rod; (2) coupling; (3) brass guide; (4) PVC piston valve; (5) PVC piston; (6) PVC piston ring; (7) PVC pipe; (8) stainless-steel plate; (9) rubber foot-valve plate; (10) PVC foot valve; (11) solvent cement glue; and (12) steel well casing.*

(From "AIT-PVC Handpump", Village handpump technology, IDRC, 1982)

The riser pipe is made of standerd 7.5 cm diameter pvc pipe 4 m long. This pipe is also used as the cylinder. The only part not made of PVC is the 11 cm pump rod. Initially, a standerd hollow 2 cm diameter PVC pipe was used for the pump rod but this was not strong or durable enough to withstand the pumping force. Even the steil pump rod was found to be insufficient and, as a result, a spacer is introduced at the joint of the pump rod to minimize vibrations. Details of the below-ground components are shown in Fig.6.4.

On a trial basis, three AIT-PVC handpumps were installed in wells located in three different regions and their performance was monitored.

The cost of an AIT-PVC handpump was estimated and compared with the DMS and ARD handpump (table 6.1). Two seperate components are considered in the cost analysis, the above-and below-ground components. For the below-ground components, only the cost of the piston and cylinder are given because the length of the riser pipe depends on well depth.

The cost of DMS and ARD handpumps are based on mass-production, whereas the cost of the AIT-PVC system is based on a single order. Thus the cost of the AIT-PVC handpump could be reduced further if the pump were mass produced. The cost of the AIT-PVC handpump was 3100 baht, whereas the DMS and ARD handpumps were 2600 and 3200 baht, respectively.

Table 6.1
Cost comparision of three types of Handpumps in Thailand

Type of Handpump	Cost (Baht)	Remarks
Above-ground		
DMR	2100	Mass production
ARD	2500	Mass production
AIT-PVC	2300	Single order
Below-ground		
DMR	700	Mass production
ARD	700	Mass production
AIT-PVC	800	Single order

23 Baht= US$1

6.5 THE AID HANDPUMP

The AID handpump is a single action, reciprocating, positive displacement pump designed in 1966 by Battelle Columbus laboratories for the U.S. agency for International Development (AID). Specifications for the design includes long and unskilled labor, potential for manufacture in developing countries, and easy operation by women and children. The shallow well version, with the piston and cylinder assembly incorporated into the above-ground pump stand, is suitable for wells where ground water is located at the depth of less than 7-8 m, as shown in Fig.6.5.

The AID pump has been used in various countries such as Thailand, the Philippines, Nigeria and Bangladesh, Guatamala, Sri Lanka, Tunisia, Ecuador (Mc Junkin, 1977), and it has also been introduced in Nicaragua, Costa Rica, the Dominican Republic, and Indonesia (Potts et al., 1979).

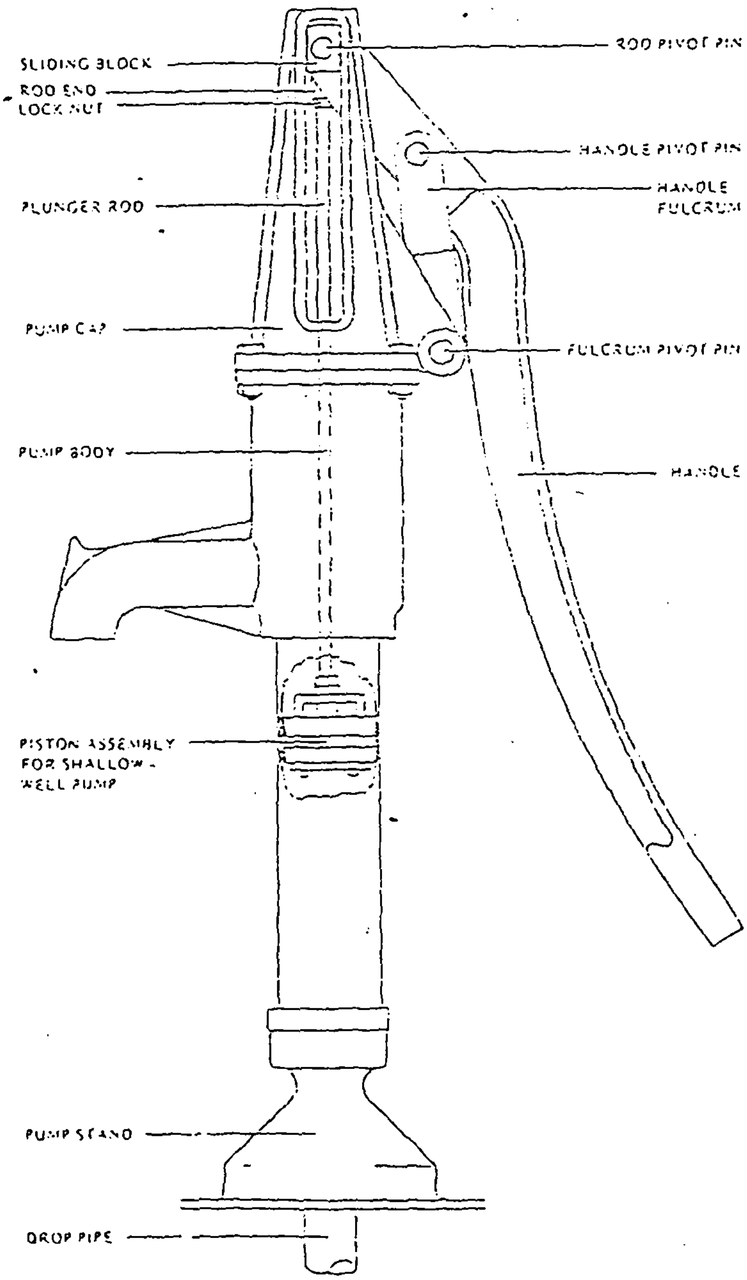


Fig.6.5 The AID Handpump

(From "US AID Handpump program in Tunisia", WASH, 1983)

Potts et al. (1979) claim that implementation programs have shown that the AID handpump is "very adaptable to manufacture in many developing countries and offers many benifits, such as spare part availability, easy maintenance, low cost, durability, employment creation, increase of local income, and reduction of foreign exchange outflow". On the other hand, Pacy (1980) states that efforts to arrange field tests for this pump in Thailand, Nicaragua and Bangladesh "have been disappointing, mostly for non-technical reasons, and the design is still not proven".

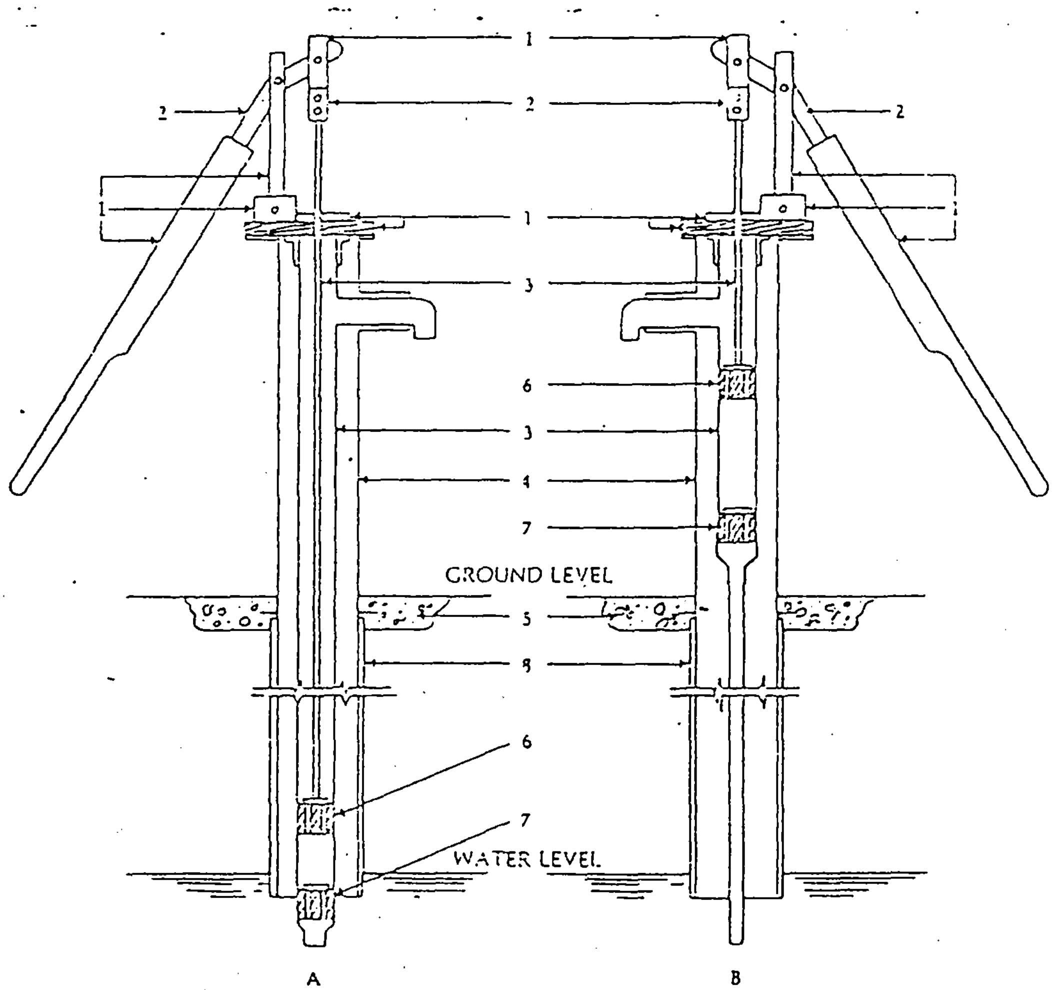
6.6 THE WATERLOO PUMP

This type of handpump-also called the "IDRC pump"-was originally the result of an IDRC-sponsored design centered on developing a simple, low cost piston and foot-valve assembly for a manual, shallow-well pump. The piston and foot-valve assembly was developed at the University of Waterloo, Canada in 1977. The Waterloo differs from others in that it has been designed specifically for fabrication in developing countries, using existing locally available resources.

The IDRC pump has been undergoing field tests in Malawi and Ethiopia. It has also been used in comparative studies in Nicaragua and Costa Rica, where it was tested alongside the Battelle pump. According to Pacy (1980), the verdict released in January 1978 was that the IDRC pump has "good points", and is suited to a "lower level of technology" than the Battelle pump, and it would be especially appropriate where "foundry facilities are not available but local manufacturing is desirable".

In 1978, research projects were set up in two countries in Africa (Ethiopia and Malawi) and four countries in Asia (Malaysia, the Philippines, Sri Lanka and Thailand) to field test the pump under various environmental conditions and levels of technical sophistication with different user groups.

During laboratory and field tests, several defects were observed and so modifications were made. For example, the Asian Institute of Technology has proposed a modified version, which is called the "PVC-AIT" handpump. The resulting design from this inter-country IDRC sponsored project was later generally called the "IDRC-PVC" handpump, as shown in Fig.6.6.



(A) Lift and (B) suction pumps: (1) wooden parts; (2) galvanized parts; (3) PVC parts; (4) mild-steel stand; (5) concrete; (6) piston; (7) foot valve; and (8) casing pipe.

Fig.6.6 THE WATERLOO PUMP (IDRC)

(From "Village Handpump technology", IDRC, 1982)

VII. CONSTRUCTION METHODS

The term well drilling methods is being used here to include all method used in creating holes in the ground for well construction purposes. As such, it includes methods such as boring and driving which are not drilling methods in pure sense. The classification is one of convenience in the absence of a better descriptive term. The limitation of well diameter (10 cm and less) exclude the dug well from consideration. The section that follow describe (a) boring method (b) driving (c) jetting (d) hydraulic percussion (e) sludger method.

7.1 BORING METHOD

Boring of small diameter well is commonly undertaken with hand-turned earth augers, though power-operated augers are sometimes used. Two common types of are shown in Fig. 7.1. They each consist of a shaft with wooden handle at the top and a bit with curved blades at the bottom The blades are usually of the fixed type, but augers with blades that are adaptable to different diameters are also available. Shafts are usually made up of 1.5 m sections with easy latching couplings.

The holes is started by forcing the blades of the bit into the soil with a turning motion. Turning is continued until the auger bit is full of material. The auger is then

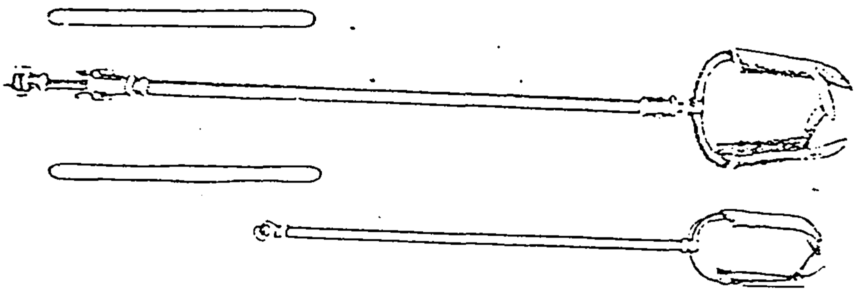


Fig.7.1 HAND AUGERS

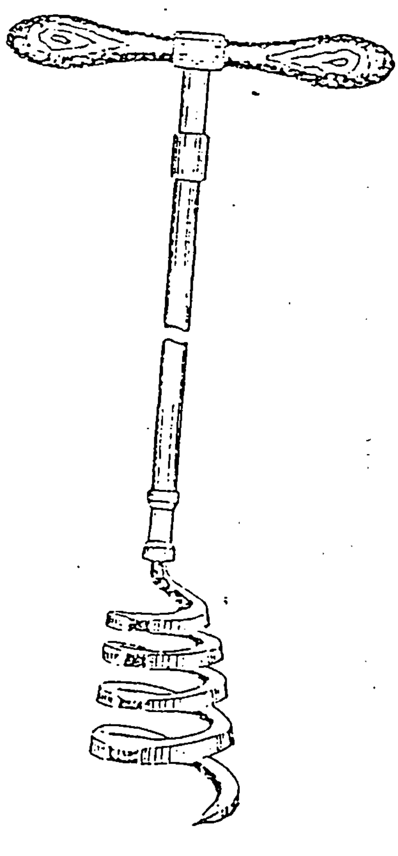


FIG.7.2 SPIRAL AUGER

(From "Well Construction", Water well manual, 1971)

lifted from the hole, emptied and return to use. Shaft extensions are added as needed to bore to the desired depth. Wells shallower than 4.5 m ordinarily require no other equipment than the auger. Deeper wells, however, require the use of a light tripod with the pully at the top, or a raised platform, so that the auger shaft can be inserted and removed from the hole without disconnecting all shaft sections.

The spiral auger shown in Fig.7.2 is used place of the normal cutting bit to removed stones or boulders encountered during boring operations. When turn in a clockwise direction, the spiral twists around a stone so that it can be lifted to the surface.

The method is used in boring to depths of about 15 m in clay, silt and sand formations not subject to caving. Boring in caving formations may be done by lowering casing to the bottom of the hole and boring ahead little by little while forcing the casing down.

7.2 DRIVING METHOD

Driven wells are constructed by driving into the ground a well point fitted to the lower end of tightly connected sections of pipe. The well point must be sunk to some depth within the aquifer and below the water table. The riser pipe above the well point functions as the well casing.

Equipment used includes a drive hammer, drive cap to protect the top end of the riser pipe during driving, tripod, pully and strong rope with or without a winch. A light drilling rig may be used instead of the tripod assembly. Well points can be driven either by hand methods or with the aid of machines. Fig.7.3 shows the assembly for a purely hand-driven method. The drive-block assemblies commonly operated by a drilling rig or by hand with the aid of a tripod and tackle are shown in Fig.7.4.

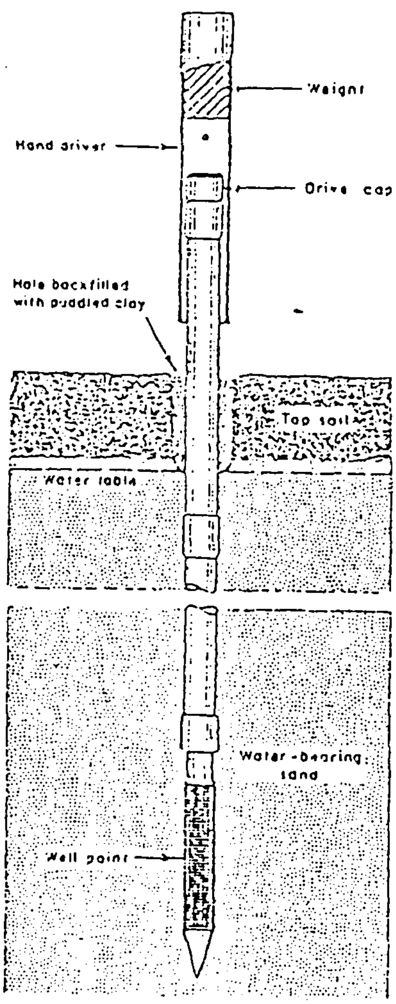


Fig.7.3 SIMPLE TOOL FOR DRIVING WELL POINTS TO DEPTHS OF 15 TO 30 FT.

(From "Well Construction", Water well manual, 1971)

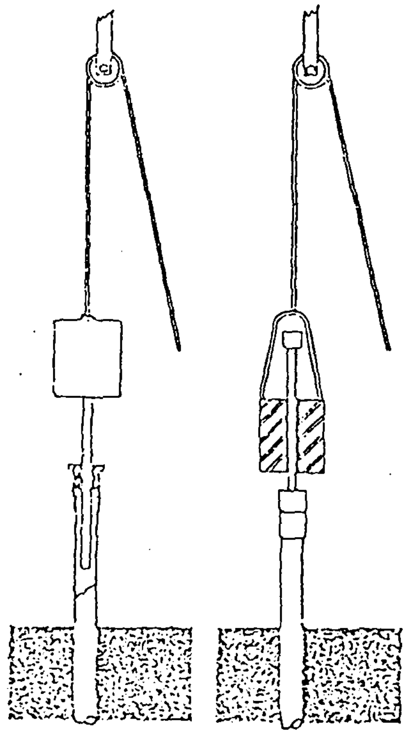


Fig. 7.4 DRIVE-BLOCK ASSEMBLIES FOR DRIVING WELL POINTS.

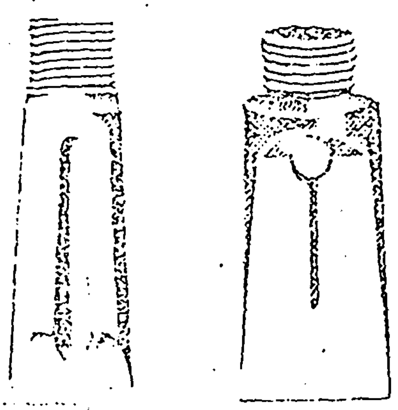


Fig. 7.5 BITS FOR JET DRILLING. (From Fig. 17, *Wells*, Department of the Army Technical Manual TM5-297, 1957.)

(From "Well Construction", Water well manual, 1971)

Whatever the metod of driving, a starting hole is first made by boring or digging to a depth of about 0.6 m or more. As driving is generally easier in the saturated formation, the starting hole should be made deep enough to penetrate the water table if the latter is sufficiently shallow. The starting hole should be vertical and slightly larger in diameter than the well point. The well point inserted into this hole and driven to the desired depth, 1.5 m lengths of riser pipe being added as necessary. Pipe couplings should have recessed ends and tapered threads to provide stronger connections than ordinary plumbing couplings. The pipe and coupling threads should be coated with pipe thread compound to provide airtight joints. The well-point assembly should be guided as vertically as possible and the driving tool, when suspended, should be hung directly over the center of the well. The weight of the driving tool may range from 35 to 140 kg. Heavier tools require the use of a power hoist or light drilling rig.

Driven wells can be installed only in unconsolidated formations relatively free of cobbles and boulders. Hand driving can be undertaken to depths up to about 10m; machine driving can be achieve depths of 15 m and greater.

7.3 JETTING METHOD

The jetting method of well drilling uses the force of a high velocity stream or jet of fluid to cut a hole into the ground. the jet of fluid loosens the subsurface materials and transports them upward and out of the hole. The rate of cutting can be improved with the use of a drilling bit (Fig.7.5) which can be rotated as well as moved in and up-and-down chopping manner.

Simple equipment for jet drilling method is shown in Fig.7.6. A tripod made of 50 mm galvanized iron pipe is used to suspend the galvanized iron drill pipe and the bit by means of U-hook (at the apex of the tripod), single-pully block and manila rope. A pump having a capacity of approximately 600 liters per minute at the pressure of 140 to 200 kg/cm^2 ($\sim$200 bar) used to force the drilling fluid through suitable hose and a small swivel on through the drill pipe and bit. The fluid, on emerging from the drilled hole, travels in a narrow ditch to a settling pit where the drilling materials (cuttings) settle out and then to a storage pit where it is again picked up by the pump and recirculated.

The spudding percussion action can be imparted to the bit either by means of a hoist or by workmen alternately pulling and quickly releasing the free end of the manila rope on the other side of the block from the swivel. This may be done while other workmen rotate the drill pipe. The drilling fluid may be and is very often plain water. Depths of the order of 15 m may be achieved in some formations using water as drilling fluid without undue caving. When caving does occur, then a drilling mud as hydraulic rotary drilling should be used.

The jetting method is particularly successful in sandy formations. Under these conditions a high rate of penetration is achieved. Hard clays and boulders do present problems.

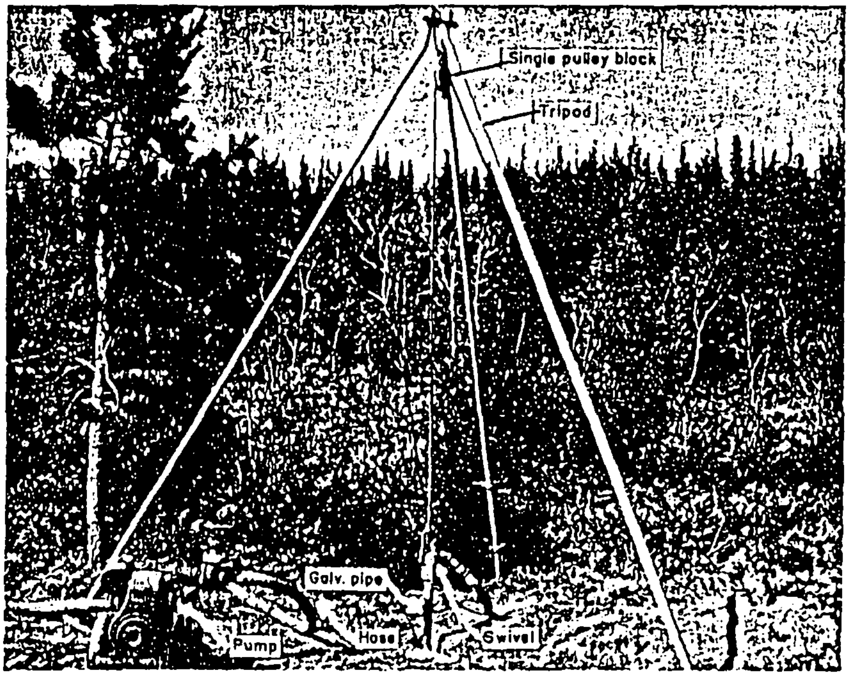


Fig.7.6 Simple equipment for jet drilling

(From "Well construction", water well manual, 1971)

7.4 HYDRAULIC PERCUSSION

The hydraulic percussion method uses a similar string of drill pipe to that of the jetting method. The bit is also similar except for the ball check valve placed between the bit and the lower end of the drill pipe. Water is introduced continuously into the bore hole outside of the drill pipe. A reciprocating, up-and-down motion applied to the drill pipe forces water with suspended cuttings through the check valve and into the drill pipe on the down stroke, trapping it as the valve closes on the up stroke. Continuous reciprocating motion produces a pumping action, lifting the fluid and cuttings to the top of the drill pipe where they are discharged into a settling tank. The cycle of circulation is then complete. Casing is usually driven as drilling proceeds.

The method uses a minimum of equipment and provides accurate samples of formations penetrated. It is well suited for use in clay and sand formations that are relatively free of cobbles or boulders.

7.5 SLUDGER METHOD

The sludger method is the name given to a forerunner of the hydraulic percussion method described in the previous section. It is accomplished entirely with hand tools, makes use of a locally available materials, such as bamboo for scaffolding, and is particularly suited to use in inaccessible areas where labour is plentiful and cheap.

In the sludger method, as used in Bangladesh, India and Nepal, scaffolding is erected as shown in Fig.7.7 and 7.8. Tubewells with a depth up to 50 m may be constructed using this method under suitable conditions. In Bangladesh and Nepal, the sludger method has been and continues to be extensively used for sinking numerous tubewells to tap the abundant, shallow groundwater resources present in that deltaic country.

Fig.7.7 BAMBOO SCAFFOLDING, PIVOT AND LEVER USED IN DRILLING BY THE SLUDGER METHOD. (From "Jetting Small Tubewells By Hand," *Water Supply and Sanitation in Developing Countries*, AID-UNC/IPSED Item No. 15, June 1967.)

To start the drilling operation, a hole of about 0.6 m diameter and 0.5 m deep is made into which water is poured. Some bamboo staging is erected above the hole. A piece of steel pipe is placed vertically in the soil, and drilling is carried out by moving the pipe up and down with a jerking action. For this, a bamboo rafter fastened to the pipe and supported from the staging is operated. At the foot of the drill pipe, soil loosened by the water enters into the pipe allowing it to penetrate in the ground. As the result of the jerking action of the drill pipe, the loosened soil and water is pushed upwards and comes out through the top of the pipe.

Fig.7.8 MAN ON SCAFFOLDING RAISES HAND OFF PIPE ALLOWING DRILL FLUID AND CUTTINGS TO ESCAPE. (From "Jetting Small Tubewells By Hand," *Water Supply and Sanitation in Developing Countries,* AID-UNC/IPSED Item No. 15, June, 1957.)

During the well sinking, one man sits on the top of the staging and takes care that the pipe is drilled perfectly vertically. At each upward stroke, he closes the top of the drill pipe off with his hand which introduces a suction action. This assists the loosening of the soil at the pipe bottom and the forcing up of the drilled soil. More pieces of pipe are added as the string of drill pipe sections penetrates deeper and deeper in the ground.

As the well sinking proceeds, soil samples are collected from the mud flow coming out at the top of the drill pipe. These are taken at each 1.5 m the drill pipe is sunk further, and then examined. The drilling operation is stopped when good water-bearing formations are sufficiently penetrated. The whole length of pipe is withdraw piece by piece taking care to keep the drilled hole intact. Immediately after withdrawal of the drill tubes, the well casing consisting of plastic pipes complete with strainer sections is fitted and lowered in the hole up to the determined depth.

An indication of the time and labour requirements for sinking a tubewell using the sludger method, may be obtained from an example concerning a well sunk in Kapilbastu district of Lumbini zone (Nepal) to a depth of about 25 m. The following data are quoted:

- Time required for drilling of the well 12 hours.
- Time required for construction of platform 5 hours.
- Labour engaged for drilling well

skilled 2 men.

unskilled 3 men.

- Labour engaged for construction of platform

skilled 1 man.

unskilled 1 man.

VIII EVALUATION

The need is great in most of the developing countries for rural water supply programs to serve the despersed population now travelling long distance to gather water for questionable quality. Handpumps, in general, are most appropriate in such an environmental because they offer lower per capita site development cost when compared to deep, drilled wells with motorized pumping and storage facilities serving the same number of people. On the other hand, deep, drilled wells usually offer a higher level of quality water. Either approach requires an effective maintenance component to be successful; however, as with lower per capita site development costs, handpumps also offer lower operation and maintenance costs because fulltime, daily caretakers are not necessary to activate pumping when storage containers need filling as with some piped systems.

Present handpump designs are leading to very high expenditures on repairs and maintenance, particularly transport costs. In most developing countries, as well as causing and unacceptably high proportion of water wells to be out of use at any given time. There is also a lack of reliable data on the performance of the different handpump designs. This data is required to facilitate selection from the array of available handpumps.

One of the main objectives of the handpumps project is to develop village-level operation and maintenance (VLOM) handpumps, which can be manufacturing in the developing countries and repaired by trained village operators. Unlike the conventional pumps, these light, simple pumps should be repaired without incurring the delay and expense of employing heavily equipped, highly skilled mobile maintenance units.

Within the first phase of the projects, the world bank contracted the Consumers' Association Testing & Research laboratries (CATR) to carry out a series of tests on handpump with the exprience of the Overseas Development Administration (ODA) testing programme. Twelve brands of deep and shallow-well pumps were selected for testing: Korat 608 A-1 (Thailand); Bandung (Indonesia); New No. 6 (Bangladesh); IDRC Ethiopia type BP (Ethiopia); AID/Battelle (Indonesia); Kwamoto Dragon No.2 (Japan); Mayno IV 2.6 (USA); Briau Nepta (France); Atlas Copco Kenya (Kenya); Nira AF-76 (Finland); Vereinigte Edelstahlwerke (VEW) A18 (Austria); Jetmatic (Philippines).

The test program included detailed inspection of the pumps as received, including their packaging, and engineering assessments with suggestions for design improvements and user trials.

During the field trials the monitoring team will operate district servicing crews, and regular inspections will be made of all pumps to evaluate performance and maintenance requirements. The standard monitoring forms were designed to enable valid comparisons to be made of installation, operating performance, resistance to accidental damage or vandalism, breakdown rates, cases of maintenance, and general acceptability of the pump in the community.

At present countries where field trials are in progress or under preparation are Sudan, Kenya, Malawi, Tanzania, Ghana (2 trials), India, Sri Lanka (2 trial), ROC, Thailand, the Philippines, Papua New Guinea, and the Dominican Republic. The countries and projects were selected on the basis that they have large-scale rural water supply programs and could have "a radiating effect" on their neighbors.

Local manufacture of the AID handpump in the developing countries are technically and economically feasible as a viable alternative to expensive imports that require extended purchasing lead time and drain national currency from local circulation.

Because of the comprehensiveness of AID handpump programs, which include the local manufacture of pumps and spare parts and depend upon local technicians for installation and maintenance of the pumps and sometimes users for monitoring them, the programs has met with varying degrees of success around the world.

Experience around the world has shown that some initial failures were rooted in the lack of the capacity to produce pumps of acceptable quality. In still other cases the pumps were improperly installed and maintained despite painstaking efforts on the part of outside experts working with officials and technicians, and in still other cases the pump and/or their parts simply wore out from use and inadequate maintenance. The latter problems appear to be the most frequent because of the logistics require to maintain pumps once they are installed and the difficulty developing countries have in managing such projects. Despite such set-backs, however, there is encouraging evidence that some countries are developing the capability to implement and maintain handpump programs.

Under the Georgia Tec contract the AID handpump was manufactured and field tested in Nicaragua and Costa Rica. After recommendation design changes, it was introduced in the Dominican Republic, Indonesia, the Philippines, Honduras and Sri Lanka. A handpump program is currently in progress in Ecuador and Haiti, and what appears to be an unsuccessful program is currently being phased out in Tunisia.

The International Development Research Centre (IDRC) has investad about CA$ 7,30,000 in a net work for water-supply projects in Asia and Africa over the last 6 years to help develop more effective pump systems for rural water supplies.

The technology developed and tested by IDRC-supported research projects is applicable to rural situations all over the world, not just to those few countries in Asia where field testing was carried out. The development of a handpump utilizing inexpensive PVC components, which can be manufactured locally and simply enough to be maintained at the village level, is a giant step forward in the struggle to provide adequate, clean, water supplies to the rural populations.

The technology has been tried, and proven. But the question remains: how can the desire to utilize it and maintain it to be best transferred to those who need itmost? When a handpump breaks down and remains out of service, the economic loss is considerable. The replacement parts and the possibility of vandalism and disappearance of parts if the pump is out of operation for more than a few days, result is considerable cost and loss of financial investment, not to mention the hardship and inconvenience to those who have to walk long distance to obtain water. One solution to this problem is to focus efforts on the development of locally fabricated handpumps that are inexpensive to manufacture and can be easily repaired at the village level with a minimum amount of expertise.

The Waterloo design, developed in 1976, does just this. The piston and foot valve are produced from (PVC), a material that is readily available in most developing countries. Their design is such that the piston and foot valve are interchangeable, i.e., the piston can be used as a foot valve and vice versa. This greatly reduces the number of spare parts needed for repair or replacement purpose.

Finally, the design takes advantage of a PVC pipe as the riser pipe and the cylinder section, the place where the piston sides up and down, is the riser pipe itself.

The technology developed and tested with support from the IDRC also clearly indicates that no universal design will function adequately under conditions with all user groups.

It is expected that the projects will make a significant contribution to the programs for low-cost water supply in developing countries and that the outcome of the project will be of benefit to the manufacturers and users.

IX. DISCUSSIONS AND RECOMMENDATIONS

The selection, development, and use of reliable handpumps that can be locally produced and installed and maintained at a reasonable price is a major step towards providing reliable, safe drinking water supplies to rural communities in developing countries. Due to many technical and economical factors, such as the complexity of engine-driven pump and the high cost of fuel, manual pumps will continue to be used in the most parts of the world, not only for potable water but also for domestic use, livestock, and irrigation.

Handpump for shallow tubewells are used for drinking and irrigation purpose in Nepal at the moment. The cost of the shallow tubewell is low, which amounts to nearly Rs. 2,000 in comparision to the cost of deep tubewell which is about Rs.6,000 at present (US$ 1=16.0 Nepalese Rupee). Although the discharge of a shallow tubewell is much lower than that of deep well, the demand of shallow tubewell is increasing day by day due to its low cost and easy management.

However, a number of pumps will need to be imported until local capability is established. The handpumps for this scheme are intended to be made locally. Negotiations to this end are in progress, to locate and arrange with interested manufacturers the casting and machining of a handpump similar to the "Bangladesh New No. 6 handpump", since that has proven to be reliable and meets the requirements for which it was designed. There is adequate local capability to produce these pumps; although the rate of production (some 32,000 units will be needed by 1990) is limited, it could well be expanded to include more of this type or the MOSTI (Manually operated shallow tubewell for irrigation) which is essentially similar. This would not only expand production of pumps, making it more economic, but would enhance irrigation production capability. HMG of Nepal, as lead agency in the negotiations, will be in a good position to coordinate the local manufacture of handpumps.

It is noted that in the Bhabhar zone, where percussion drilling will be needed the unit cost per well will be some Rs. 10,000 while in other areas where the sludger method of sinking wells is possible, the unit cost will be about Rs. 2,000. These unit cost must affect the choice of the well type to serve a particular community.

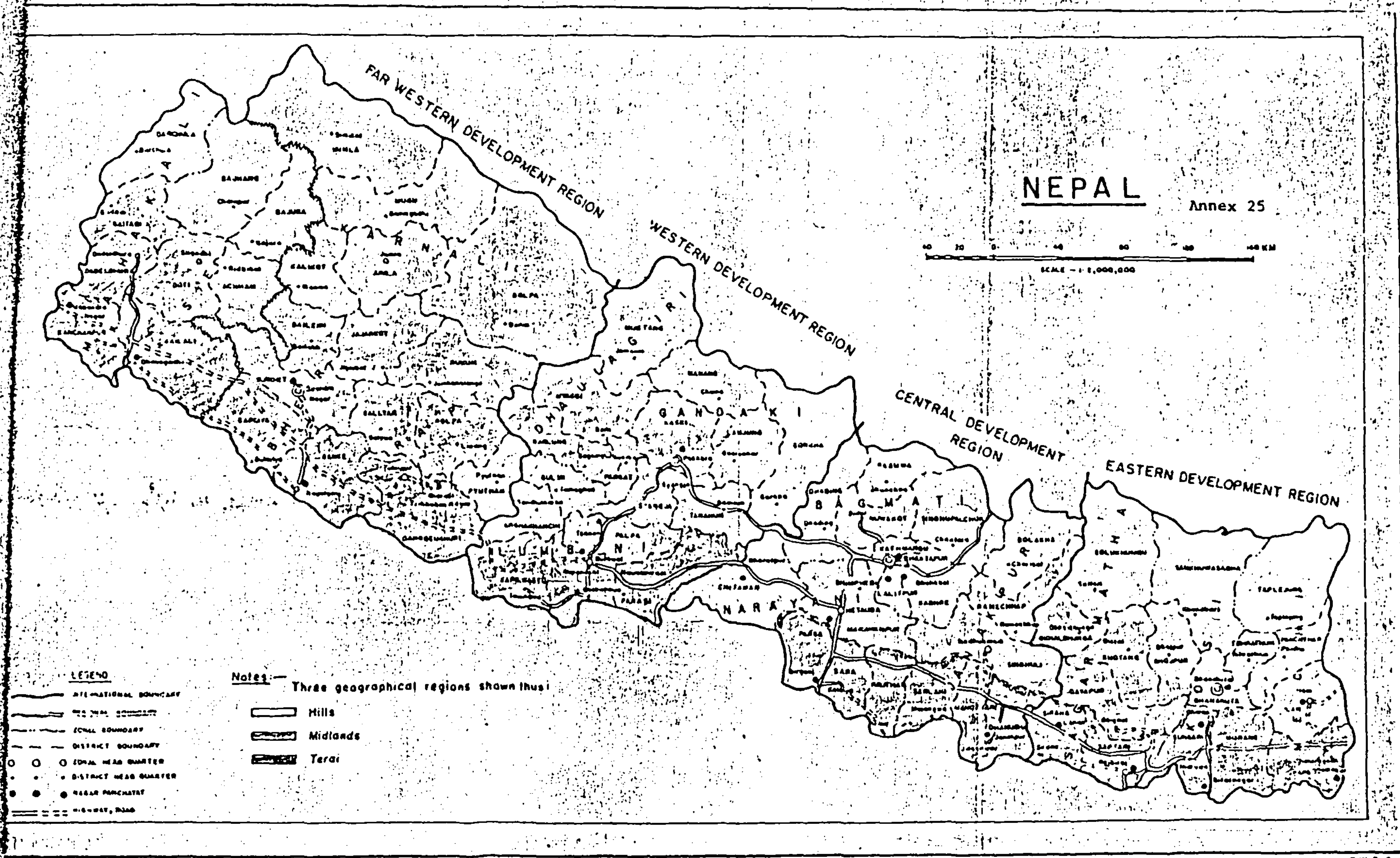
The isolated test boring, knowledge of existing tubewells and some intensive studies of HMG of Nepal Ministry of Panchayat and Local development, Department of WaterSupply and sewerage and other previous studies indicate existence of excellent and good aquifer for wells in the districts of Sarlahi, Dhanusha, Jaleshawar and Kapilbastu.

The static water level in the driest period, i.e., in the month of april and may is an important factor for for using shallow tubewell for drinking and irrigation in any place. Except in some places of the western parts of Nepal in Kapilbastu districts, the water table fluctuates 3.5 m to 5 m in the driest period in the other districts. These areas are also suitable for using shallow tubewell for drinking and irrigation.

Before sinking any shallow tubewell, the pumping test data if there be any in that area must be consulated. This will reduce the probability of failure and thereby extra cost involved in sinking an unsuccessful shallow tubewell. Using available well logs, expected average aquifer and ground water conditions should be determined. From this expected well depths and strainer distribution can be determined. The sand samples should be marked very carefully because the design of the tubewell is mainly based on these sand samples. If no well logs or previous test data are available, then test tubewell should be sunk in an area where to sink a large number of shallow tubewells.

The result of this study have brought to light the fact that the handpump technology, must first be tested under local conditions and modified according to the needs and opinions of the user group, environmental conditions, available materials, and level of expertise of those expected to adopt it and maintain it. Without this testing, the technology cannot be expected to meets the needs of the target group and will most probably fail.

In further regards to handpumps it is recommended that additional funding and efforts be made available to expeditiously upgrade, repair and maintain the inoperable handpumps. Installations throughout the developing countries that originally resulted from the different agencies. Many of this sites are in only a minor stage of disrepair, so the time and effort to correct the cause of malfunction should be slight. Other sites will require major repair of the well structure and replacement of the handpump. In any event, some system should be found that provides an effective follow-up-maintain routine (even if it means bringing in another local government agency).


NEPAL
Annex 25
FAR WESTERN DEVELOPMENT REGION
WESTERN DEVELOPMENT REGION
CENTRAL DEVELOPMENT REGION
EASTERN DEVELOPMENT REGION
GANDAKI
BAGMATI
NARAYANI
LEGEND
Notes:— Three geographical regions shown thus:
Hills
Midlands
Terai

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