Water for the World

Selecting Pumps

Technical Note No. RWS. 4.P.5

The preferred method of delivering water from the source to the point of use is by gravity flow because no external power source or mechanized apparatus is required. Very often, however, a water source is at a lower elevation than the point of storage or use, the rate of flow must be increased, or the water must be boosted due to friction losses in the pipe. When any of these conditions occur, some method of pumping must be used. See Figure 1.

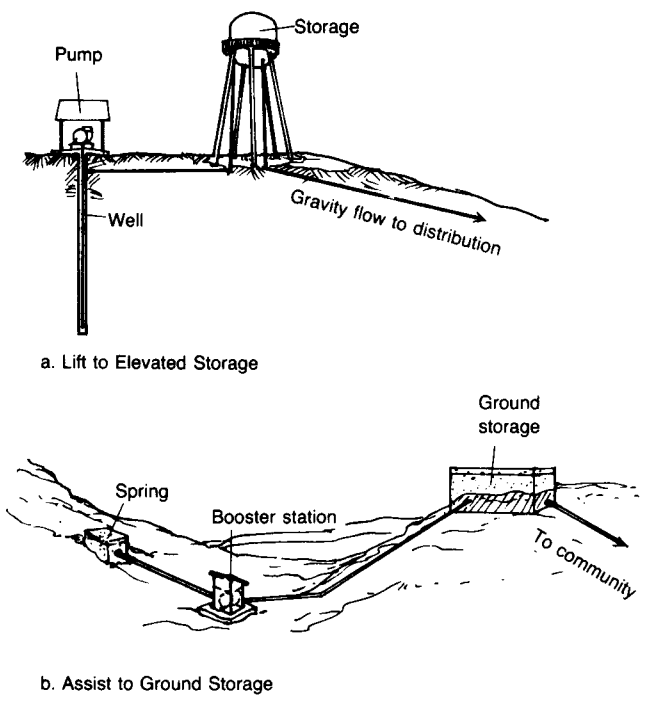

Figure 1. Situations Requiring Pumps

Useful Definitions

DEEP WELL PUMP - Any pump capable of pumping water from wells where the water is more than 10m below the ground surface.

FRICTION LOSSES - The energy required to overcome friction caused by pipe roughness, restrictions and changes in direction; usually expressed in meters of water or "head".

GRAVITY FLOW - Flow of water from high ground to low by natural forces.

HEAD - Difference in water level between the inflow and outflow ends of a water system.

PRIME - To put water in a pump to start it pumping.

PUMPING HEAD - The height of water a pump produces when pumping; it includes the height of the highest point in the system plus the equivalent height to overcome friction; expressed as meters of water.

SHALLOW WELL PUMPS - Any pump which cannot pump from depths of over 10m below the level of the pump.

SUCKER ROD - The rod which connects a windmill or hand pump to the pump cylinder in the well.

SUCTION LIFT - The difference in elevation between the inlet (suction) side of a pump and the water level in the well when the pump is pumping plus friction losses; expressed in meters of water.

Types of Pumps

Pumps commonly used in domestic water systems can be classified as centrifugal, shown in Figure 2, positive displacement (piston), shown in Figure 3, or impluse (ram), shown in Figure 4. The type of pump chosen depends on the volume of water required, pumping head and type of power available.

In general, where only animal, human or wind power is available, positive displacement pumps are the best choice. These normally deliver low quantities of water and would probably be the choice for Level 1 systems described in "Methods of Delivering Water," RWS.4.M.

Impulse pumps, also known as hydraulic rams, are water driven. They are simple and economical to operate and maintain and are the pump of choice when the right conditions exist.

Centrifugal pumps include single stage suction, jet, submersible and line shaft turbines. These classes of pumps require electric motors or internal combustion engines for power and one would normally be selected for Level 2 or 3 systems as described in "Methods of Delivering Water," RWS.4.M.

Pumps can be divided into two categories based on their power source.

Category 1. Pumps which can be powered by animals, humans, wind or water. These pumps usually produce low volumes of water at or near the source. They include bucket, positive displacement and impulse pumps.

Category 2. Pumps which are usually powered by electric motors or external combustion motors. These pumps include single stage suction, jet, submersible and line shaft turbines. They produce medium to high quantities of water compared to Category 1 pumps. The positive displacement pump mentioned in Category 1 can be power driven to produce relatively high quantities of water.

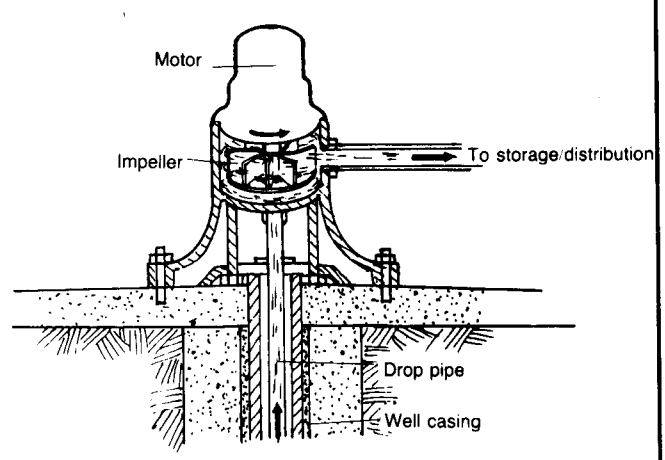

Figure 2. Centrifugal Pump

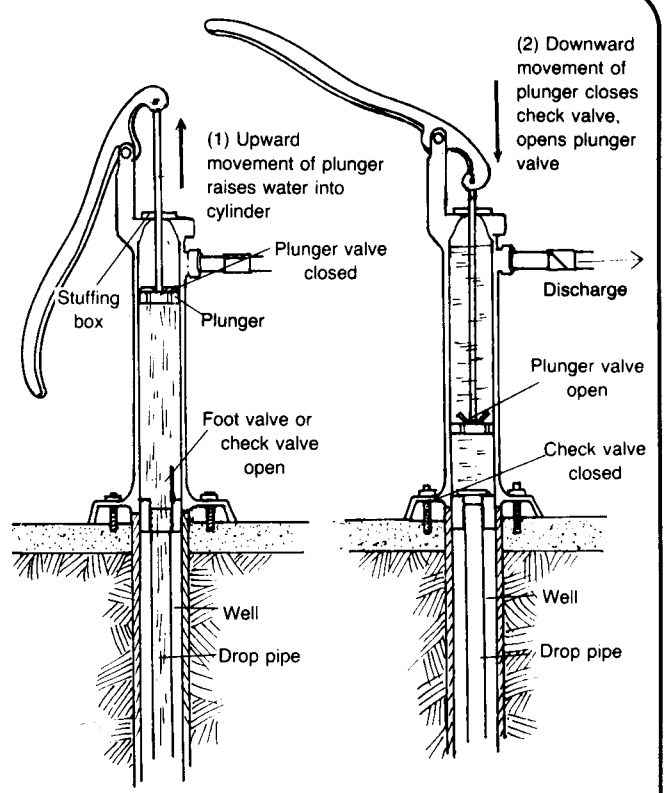

Figure 3. Positive Displacement Pump

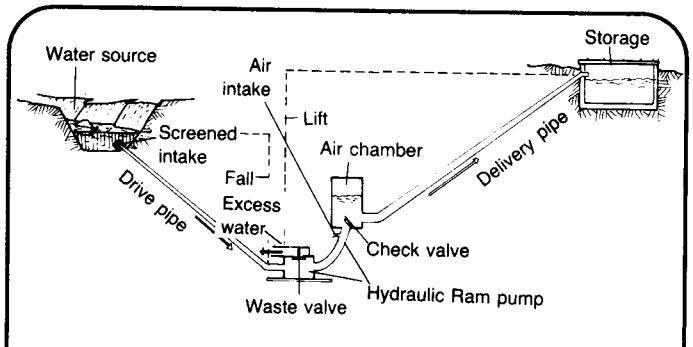

Figure 4. Impulse Pump (Hydraulic Ram)

Within categories, there is a distinction between shallow and deep well pumps. See Figure 5. Shallow well pumps are those which can pump from a depth of 7m or less, which is the maximum practical suction lift at sea level. Deep well pumps can pump from deeper depths depending on pump design.

Category 1 Pumps

Bucket. This type of pump may be considered where relatively large diameter dug wells are used, there is a relatively short distance to water and low quantities of water are needed or available. Several variations exist including:

- Rope and Bucket. In shallow wells, it is common to throw a bucket tied to a rope directly into the well. In deeper wells, leverage is required or an animal is used to raise the water. This is undesirable from a public health viewpoint as contamination can be and usually is introduced into the well by careless placement of the rope and/or bucket. For this reason, rope and bucket should not be considered unless other alternatives are not available. See Figure 6a.

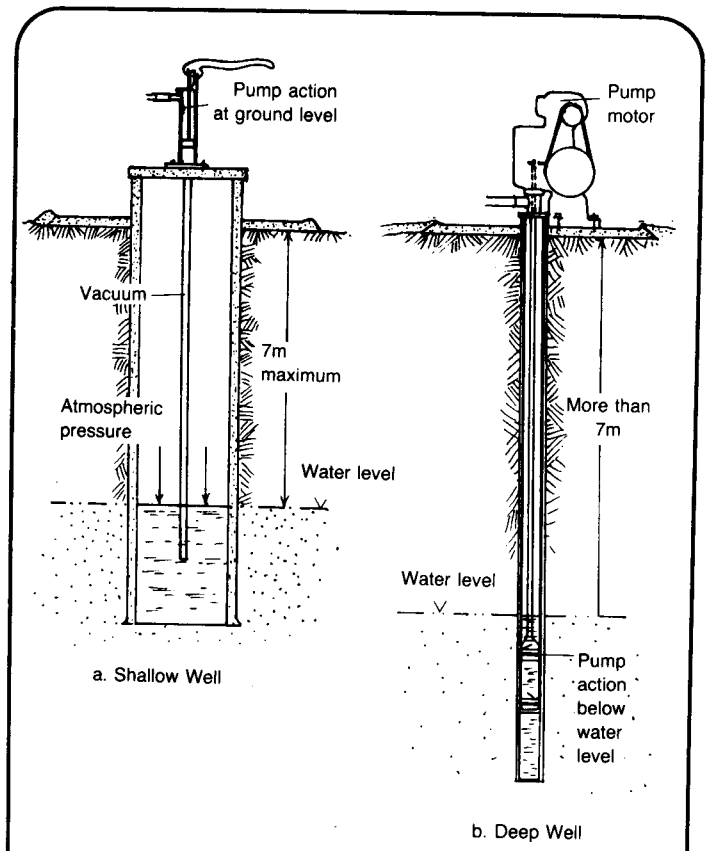

Figure 5. Shallow and Deep Well Pumps

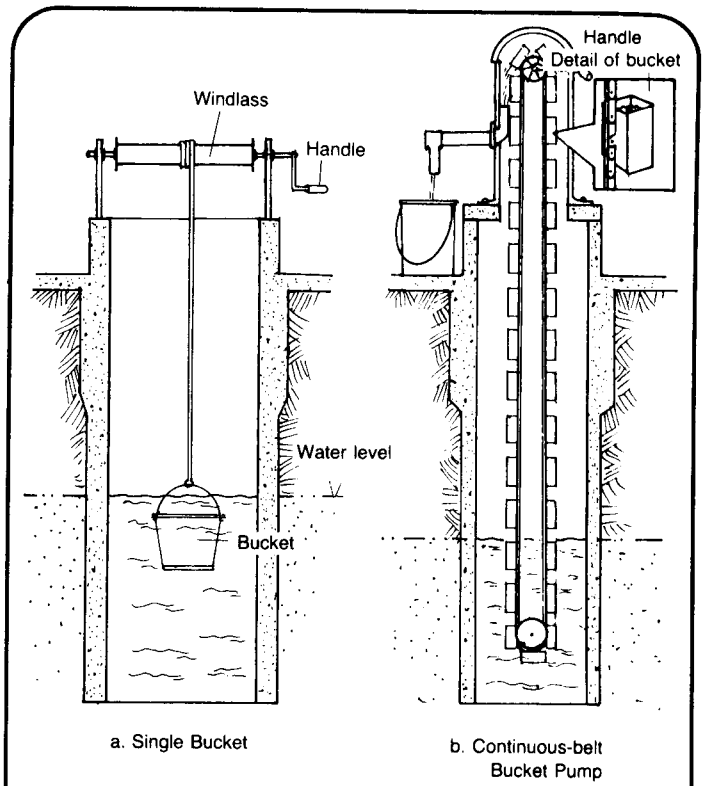

Figure 6. Bucket Systems in Shallow Wells

• Continuous-belt Bucket Pump. This can be made much more sanitary than a rope and bucket but is much more expensive to install. Essentially, this method involves attaching small buckets to a continuous loop as shown in Figure 6b.

Impulse (Hydraulic Ram). A hydraulic ram has very few moving parts and is very economical to operate and maintain. Hydraulic rams may be used singly or in tandem depending on the amount of water available and required. The water is raised to a higher elevation by the force of falling water which creates a drive force within the ram by compressing air. This in turn pushes a small amount of the falling water to a higher elevation. See Figure 4.

In order to work, most rams require a flow of at least 12 liters per minute and a fall of 50cm. The essential elements of the system include a source at a higher elevation than the ram, a drive pipe, ram, delivery pipe and storage. Water used to drive the ram may be different than that to be pumped. However, there is a potential for cross-contamination when this is done. Since only a portion of the water delivered to a ram is pumped to a higher elevation, the source must produce several times as much water as is needed. The water must be free of trash and sand since these can plug the pump. If these conditions exist, along with a good head, then a hydraulic ram is a good choice. It requires no external power source other than water and pumps 24 hours per day with very little maintenance.

Positive Displacement. This pump consists of a cylinder containing a piston and is called a positive displacement pump because it displaces an amount of water equal to the distance the piston travels. See Figure 7. Double acting pumps are available. They pump on the upward and downward or forward/backward stroke of the piston and thus tend to be more efficient. The cylinder may be located above or in the water. When the cylinder is above water, suction is required to lift the water to the piston. This type of pump

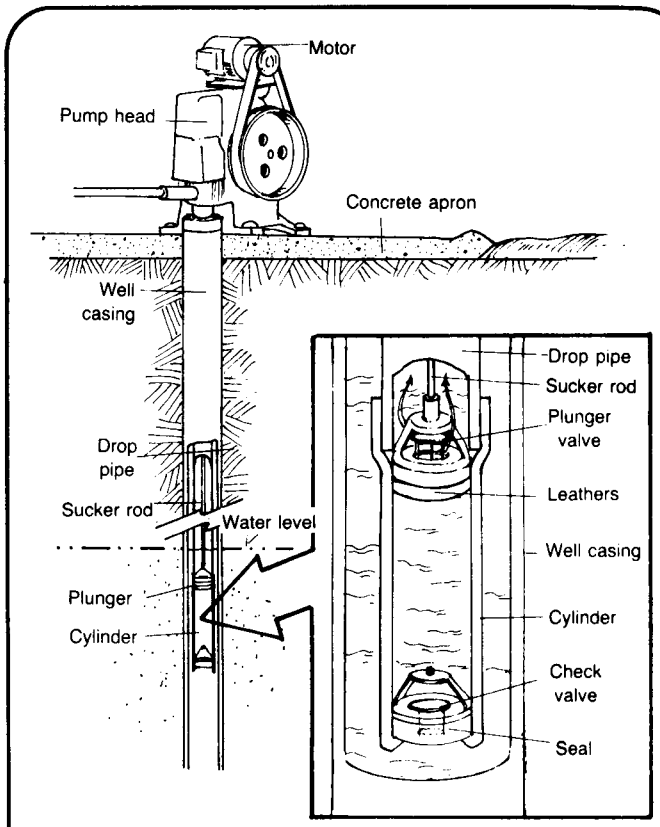

Figure 7. Motor Driven Positive Displacement Pump (Submerged Piston)

usually requires "priming" and is less desirable than a pump with the cylinder in the water. Priming a pump is a possible cause of contamination and a source of priming water is needed.

The cylinder can be driven by a variety of power sources including a hand pump, windmill or motor. The amount of water which can be produced is limited by the suction lift, if the cylinder is above water level; the diameter of the piston; the length the piston travels; and the number of times the piston is moved in a given time period. When the cylinder is located in the water, a sucker rod is required. This rod connects the drive mechanism to the cylinder and is usually made of steel. Due to the weight of the steel sucker rod, a pumping depth of 60-80m for a hand pump should be considered maximum. If motor-driven, positive displacement pumps can pump from depths exceeding 300m if sufficient power is available. These pumps can be used in

small diameter wells by selecting a small diameter cylinder or by using the well casing itself for the drop pipe when the cylinder is built into the pump.

Positive displacement pumps are the pump of choice, if only hand or wind energy is available or if motors are available and great pumping depths and low flow requirements are encountered.

Category 2 Pumps Motor-driven pumps may be divided into shallow well pumps and deep well pumps.

Shallow Well Pumps. These must be located within at least 7m vertically of the water surface when at sea level and closer at higher elevations. For every 300m of elevation above sea level, the pump will need to be 25cm closer to the water. This is because they rely on a vacuum in the suction side of the pump to get water to the pumping mechanism. The actual suction capability varies with the pump being considered.

Shallow well pumps include surface-mounted positive displacement piston pumps and centrifugal pumps, which in turn include shallow well jets, turbines and straight centrifugal pumps. The positive displacement pump might be chosen for relatively high heads and low flows. Centrifugal pumps would be used for higher volume and lower pumping heads. Centrifugal pumps are more readily available.

Deep Well Pumps. These can pump water from over 7m deep. Types of deep well pumps include a submerged piston pump shown in Figure 7, a submersible pump shown in Figure 8a, a line shaft turbine shown in Figure 8b, and a jet action pump, shown in Figure 8c. While piston pumps can theoretically pump from very great depths, there are practical limitations because of the weight of the sucker rod. This, combined with other limitations, indicates that 300m would be an upper limit.

- Line Shaft Turbines. Like the positive displacement pumps, the line shaft turbines have the motor at the surface. However, a drive shaft connects the motor to the pump. The deeper the well, the more shaft guides required along the drive shaft and the greater the possibility of guide failure. In addition, the shaft needs to be relatively straight and plumb which requires a very straight bore hole for the well. Since it is extremely difficult to keep deep wells plumb, the pumping depth is often limited. For this reason, practical pumping depths in small diameter wells, 12-24mm, are usually limited to 12 to 35m. Large diameter wells, 30mm and greater in diameter, can be pumped at much greater depths. Failing guides are still a problem as is the possibility of breaking a shaft. These pumps can pump against relatively high heads and at high volume by adding to the pump bowls.

- Submersible pumps. These have the advantage of being usable in less plumb wells and they can usually be set at greater depths. Since the sealed electric motor is below the pump, the whole unit must be pulled for repairs. Because there are no moving parts connecting a motor at the surface to the pump, installation is not complicated. Operation and maintenance problems are reduced since there are fewer moving parts. These pumps can produce water from great depths, but the greater the depth, the larger the motor and the electric cable to the motor. This can be very expensive as special electric cable, capable of being operated in water, is required. Also, 240 volts and/or three-phase power may be necessary. For these reasons, 150m should be considered an upper limit. At this depth, special pump pulling equipment would be required. If electrical service is intermittent, or only available during evening hours, no electrically powered pump can be used.

Table 1 compares different types of pumps according to a number of different factors.

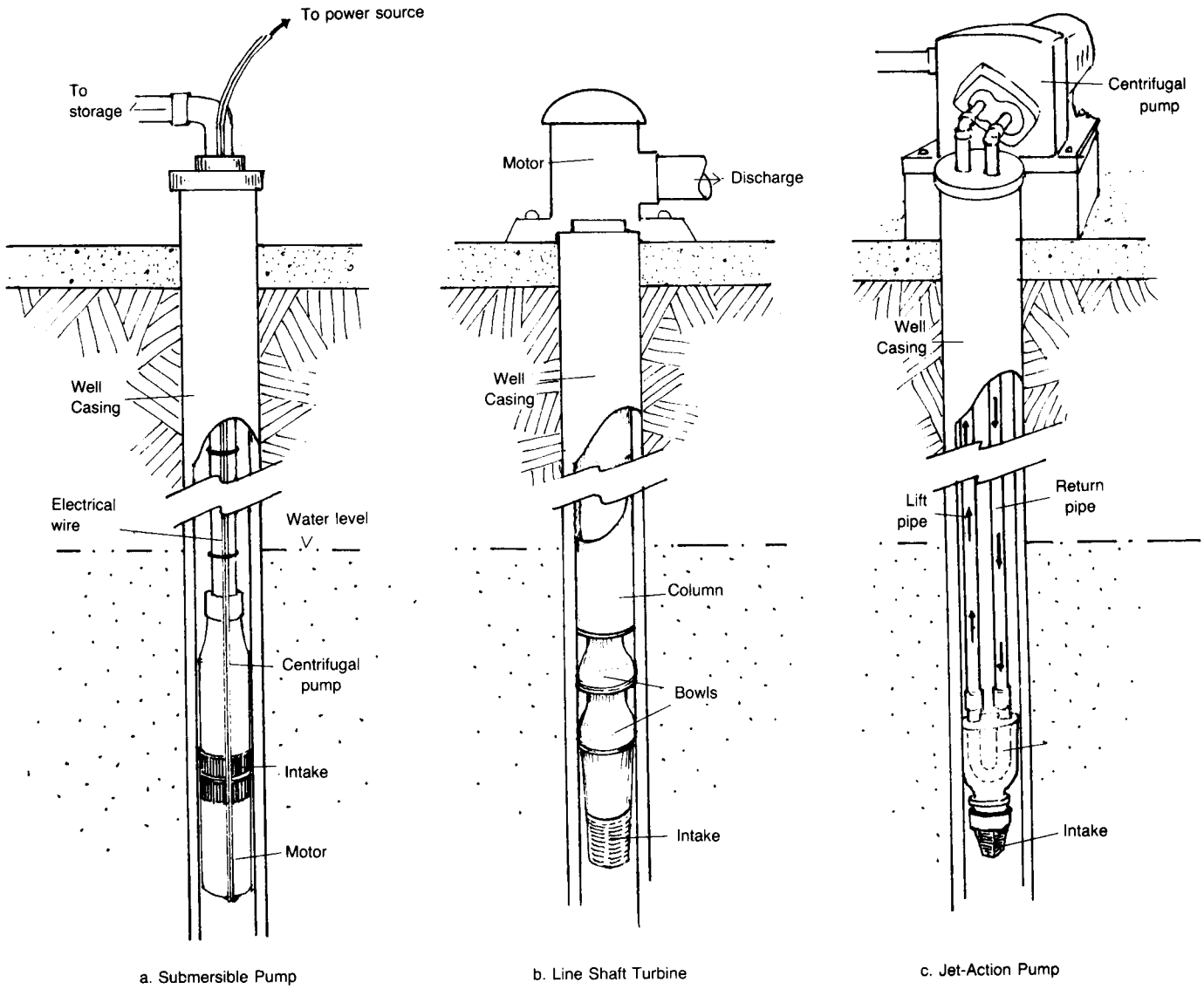

Figure 8. Examples of Deep Well Pumps

Table 1. Comparison of Different Types of Pumps

	Wind, Water, Animal Powered					Electric, Fossil Fuel Powered			
	Rope and Continuous Bucket	Impulse Hydraulic Ram	Positive Displacement			Straight Centrifugal	Centrifugal Jet	Submersible	Line Shaft Turbines
			Hand	Wind	Motor				
Capacity liters/minutes	15 to 70	—	10 to 50	0 to 100	12 to 150	Very wide range, almost unlimited	18 to 300	40 to 240 and higher	120 to 360 and much higher
Lift from water to pump (m)	1 to 30	—	—	Medium to high 8 to 250	Low to high 8 to 500	Low, less than 8	Low to medium 8 to 25	—	Medium
Lift from pump to higher level	Normally none	—	0 to 3 Normal	0 to 3 Normal	Limited by strength of pipe	Wide range 6 to 500	Usually 6 to 100	30 to 400 and higher	5 to 500
Diameter well required (cm)	Large 100	Not used with wells	6	6	6	6	12 with jet in well	12	12
Efficiency	Low	Low	Low 25 to 60%	Low 25 to 60%	40 to 60%	50 to 85%	40 to 60%	65 to 85%	65 to 80%
Relative cost	Low to reasonable	Reasonable	Reasonable	Reasonable to high	Reasonable	Reasonable	Reasonable	Reasonable but high at greater depth	Higher
Operation and Maintenance	Very simple	Simple	Simple, needs occasional maintenance	Simple, needs occasional maintenance	Simple, needs attention	Simple, needs attention	Simple, needs attention	Simple, needs attention	More difficult, needs constant skilled attention
Advantages	Easily understood, very simple	Simple, few moving parts	Easy to understand, low cost	—	Easy to repair or replace	Easy to repair or replace	Easy to repair or replace	Pump and motor in well less subject to vandalism	Can be operated by alternate power sources, high volume
Disavantages	Limited use, low efficienty	Needs constant flow of water	Low efficiency, required some maintenance	Dependent on wind	Needs attention	Requires attention for bearing lubrication	Requires attention	Difficult to pull, needs special electrical cable for wells	Difficult to repair if bearings fail