Water for the World

Methods of Developing Sources of Ground Water

Technical Note No. RWS. 2.M

Ground water is water that is stored underground in porous layers called aquifers. It is found in most parts of the world and can be a reliable source of drinking water. Sources of ground water are usually free from disease-causing bacteria. There is usually less seasonal variation in groundwater quantities than in surface water.

Wells are used to develop or extract ground water. A well is simply a hole that pierces an aquifer so that water may be pumped or lifted out. Wells can be classified according to their method of construction. Five types of wells are: hand-dug, driven, jetted, bored, and cable tool. This technical note describes each of these methods.

Useful Definitions

AQUIFER - A water-saturated geologic zone that will yield water to springs and wells.

BACTERIA - One-celled microorganisms which multiply by simple division and which can be seen through a microscope.

GROUND WATER - Water stored below the ground's surface.

GROUT - A fluid mixture of cement and sand.

IMPERMEABLE - Not allowing liquid to pass through.

POROUS - Having tiny pores, or holes, which can store water or allow water to pass through.

Wells have five basic parts as shown in Figure 1: shaft, casing, intake, wellhead, and water-lifting device. The shaft is the hole that is sunk from the surface of the ground down into, and sometimes through, the aquifer. The purpose of the shaft is to provide access to ground water. The method of sinking the shaft differs with each type of well.

The casing lines the sides of the shaft. The purpose of the casing is to prevent the shaft from collapsing, to provide an impermeable barrier to store ground water in, and to keep polluted surface water out. For dug wells, the casing supports the wellhead. Casings are usually made from concrete or metal. For dug wells, they may be brick or masonry. Casings are installed either after the shaft is sunk, or as it is sunk.

The intake is either the lower portion of the casing which is perforated or made from porous material or the open bottom end of the casing. In either case, the intake is within the aquifer, and its purpose is to allow ground water to flow into the casing.

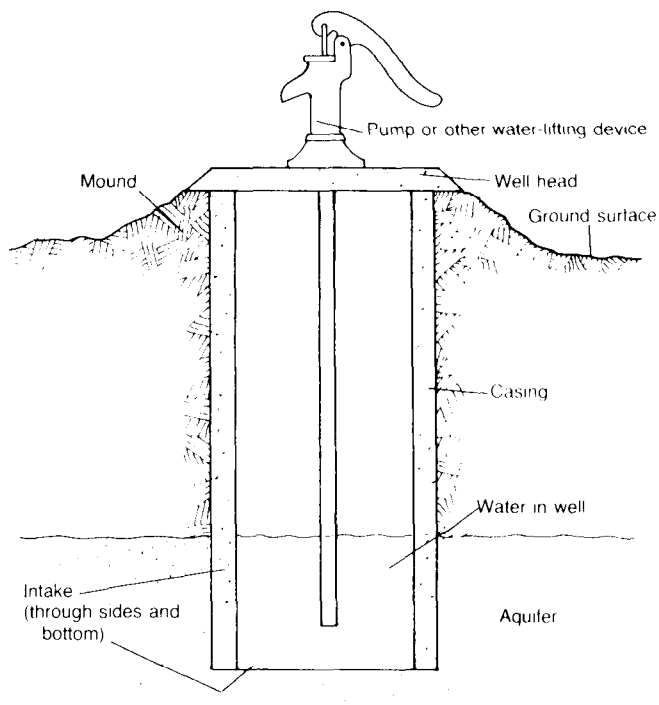

Figure 1. Parts of a Well

The wellhead is a structure built on and around the casing at ground level. It is usually made of concrete. The purpose of the wellhead is to provide a base for a water-lifting device, to prevent contaminants from entering, to keep people and animals from falling in the well, and to drain away surface water. The wellhead should be built on an earthen mound 15-20cm above the original surface so water will drain away from the well.

The water-lifting device can be a pump (see "Selecting Pumps," RWS.4.P.5), windlass, windmill or other method of extraction. The purpose of the device is to get water out of the well.

Hand-Dug Wells

Hand-dug wells are usually 1.0-1.3m in diameter and rarely more than 10m deep. They are dug with pick and shovel by one or two men working in the bottom of the shaft. Excavated soil can be lifted out with a bucket and rope as shown in Figure 2.

The casing or lining of a hand-dug well should be concrete. The casing can be installed in two ways. The shaft may be sunk and the casing built in place or sections of casing may be pre-formed above ground, soil excavated from within one section and, as the casing moves down, more sections added on top. Often, both methods are used to line a well. The first method is used until the water table is reached; then the second method, called caissoning, is used to sink the well into the aquifer. Masonry lining can be used but it is hard to make joints watertight with masonry.

The intake of a hand-dug well is designed to fit the nature of the aquifer. Usually the lower sections of casing that are within the aquifer are made of porous concrete to allow ground water to seep through. However, if the aquifer is made of fine sand, which would clog the porous concrete, the lower sections should be standard concrete and the bottom of the shaft should be left open and lined with layers of carefully selected gravel. Ground water then seeps up through the gravel.

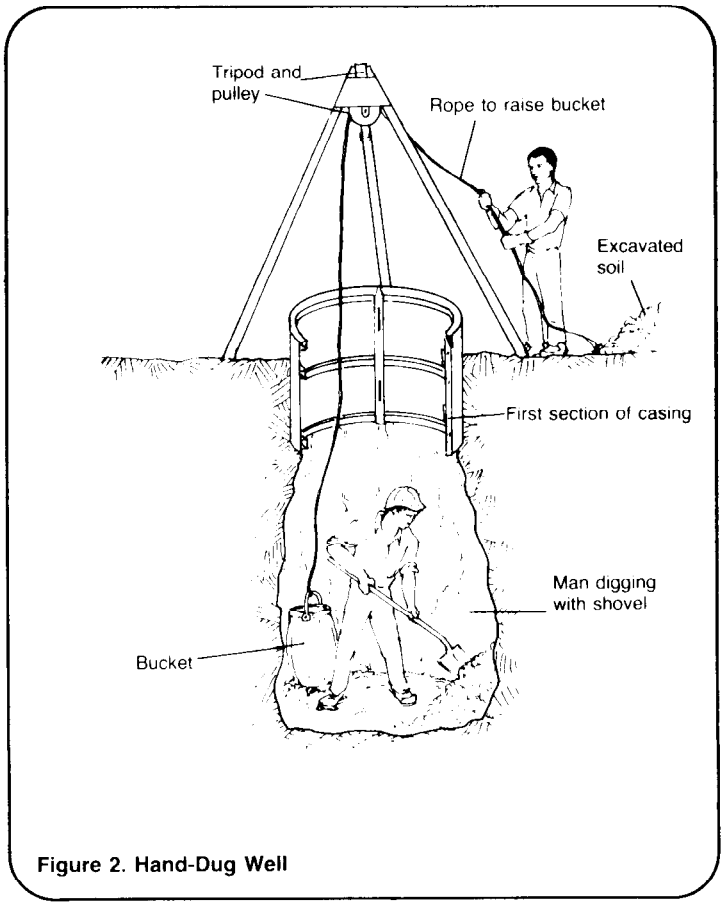

Figure 2. Hand-Dug Well

After the casing is in place, the wellhead is constructed on the mound around the top of the well. It usually has a concrete apron to drain away surface water. If the well is to be equipped with a pump, the wellhead is fitted with a concrete cover that has an opening for the pump and an inspection port or manhole.

Because of the simple tools and materials needed, and the common construction method, hand-dug wells are the most common type.

Driven Wells

These wells are the simplest to construct. A pointed strainer, called a well point, is connected to sections of pipe and driven into the ground until the aquifer is reached as shown in Figure 3. The well point and pipes are 30-50mm in diameter, and the well is generally driven no more than about 8m deep. The well point serves as the intake for the well and the pipe is the casing.

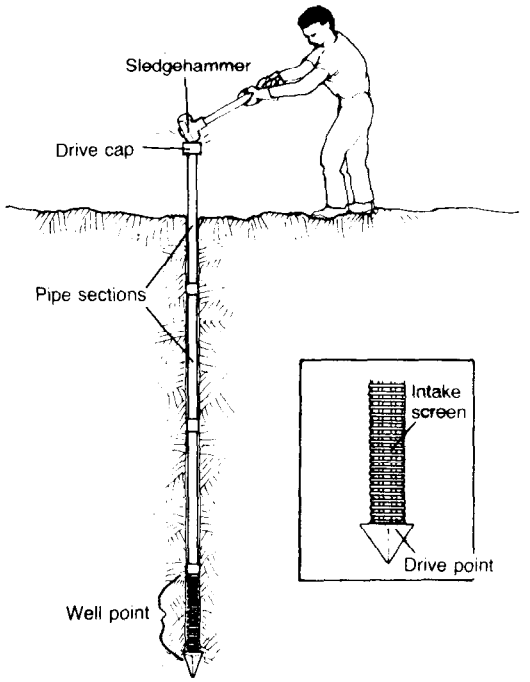

Figure 3. Driven Well

There are a number of ways to drive the well: a drive cap is threaded on top of the pipe, and then is struck repeatedly with a sledgehammer or a drive pipe that fits over the well pipe; a driving bar that fits inside the well pipe is raised and dropped to strike the well point itself; a drive head and guide rod are coupled to the top of the well pipe and a weight is raised on the rod and allowed to drop on the drive head.

The most common types of well points are either a pipe with holes covered by a screen and a brass jacket with holes, or a slotted steel pipe with no covering. Both types have a hard steel point.

After the well point is driven into the aquifer, earth is removed from around the pipe to a depth of at least 2.5m. Grout is tamped into the space around the pipe. When this hardens, it seals out surface contamination and holds the pipe firmly in place. A mound and concrete platform are then built and a pump is attached to the top of the pipe.

Jetted Wells

Jetted wells are built by pumping water through a boring pipe equipped with a special cutting bit. The boring pipe is held upright by a tower or tripod, and it is attached by a hose to a pump and a supply of water. The pipe is manually rotated. This chopping action, coupled with the jetting action of the water, causes the pipe to sink into the ground. When the first section of 6m pipe is nearly sunk, another section is attached to the top and the pumping and rotating continue. This goes on until the aquifer is reached. See Figure 4.

A 38mm diameter boring pipe can be sunk 60m deep. Larger diameter casings (250-380mm) can be sunk as deep as 100m. However, these larger pipes require pumps of much greater size and a large source of available water, such as a nearby river or lake.

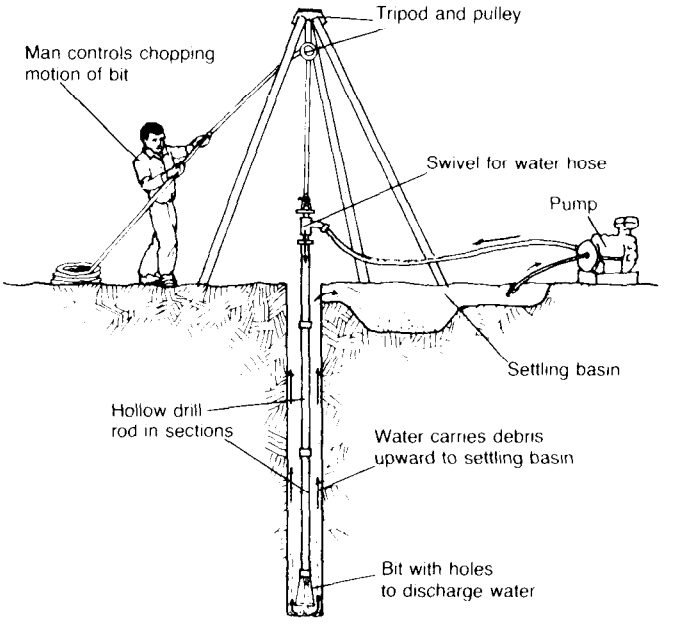

Figure 4. Jetted Well

When the aquifer is reached, the boring pipe is lifted from the hole. If the boring pipe is to be used as the casing, the cutting bit is removed from the first section of pipe and replaced with a well screen. If a different pipe is to be used for casing, the well screen is attached to the first section of casing. See Figure 3. The well screen and the first section of pipe are lowered into the hole. Pumping continues, but now through the screen. When the screen has been lowered to the position desired, a pre-seated plug is dropped into the pipe to seal the bottom of the well.

To finish the well, the space between the well pipe and the earth shaft is compacted with clay or concrete. A mound is built with a concrete platform or apron for drainage. Then a pump is installed.

Jetting can be used in loose soils that can be brought into suspension and moved with a stream of water. Jetting is not suitable for hard rock or tight clays.

Bored Wells

Bored wells are also called augered or tube wells. They are dug by manually rotating an earth auger which penetrates the ground and fills with soil. The full auger is pulled out of the ground and emptied. As the hole gets deeper, additional sections of drilling line are added. To facilitate operating and emptying the auger, an elevated platform or tripod is constructed over the well site. See Figure 5.

When the shaft has sufficiently penetrated the aquifer, the auger is removed and the casing and well screen are lowered into the shaft. If the soil is so soft that it frequently caves in, the casing is lowered as the shaft is dug. To do that, a special borer is used that fits through the casing and has a moveable extension cutter. If a water-bearing sand layer is to be penetrated, a special auger or "sand bucket" is used to dig the shaft from inside the casing, allowing the casing to sink with the shaft.

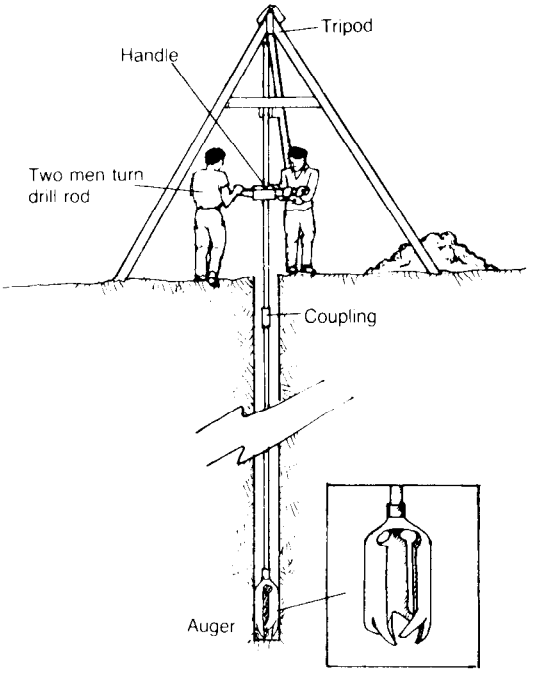

Figure 5. Bored Well

To finish the well, the space between the casing and the earth shaft is filled with concrete grout to a depth of about 3m. An earthen mound and a concrete wellhead or apron are built for drainage. Then a pump is installed.

In general, bored wells are 50-200mm in diameter and no deeper than about 15m. Larger and deeper wells have been bored using a power source and specialized augering equipment.

Cable Tool Wells

The equipment needed for cable tool wells, also called percussion drilled wells, is usually sophisticated and expensive. A simpler version of this method consists of a tripod, pulleys, strong rope, motorized vehicle, heavy drill bits, suction pump, and a 3-6m long pipe called a bailer.

The vehicle is parked at the well site, the rear end is jacked up, and the rear wheel is removed and replaced

with a small drum as shown in Figure 6. A rope is wrapped loosely around the drum, threaded through the pulleys, and attached to the drill bit. By setting the drum in motion, and alternately pulling the rope taut and letting it go slack, the drill bit is raised and allowed to fall. The impact of the bit breaks up pieces of ground. The debris is mixed with water and is periodically brought to the surface with either the suction pump or the bailer. When the aquifer is reached, it is generally drilled completely through before the casing and well screen are installed. In sandy soil, the shaft is sunk from the inside of the casing and the shaft and casing descend together.

To finish the well, an earthen mound and a concrete wellhead or apron are built for drainage. Then a pump is installed.

These wells can be 50-100mm in diameter and as deep as 75m.

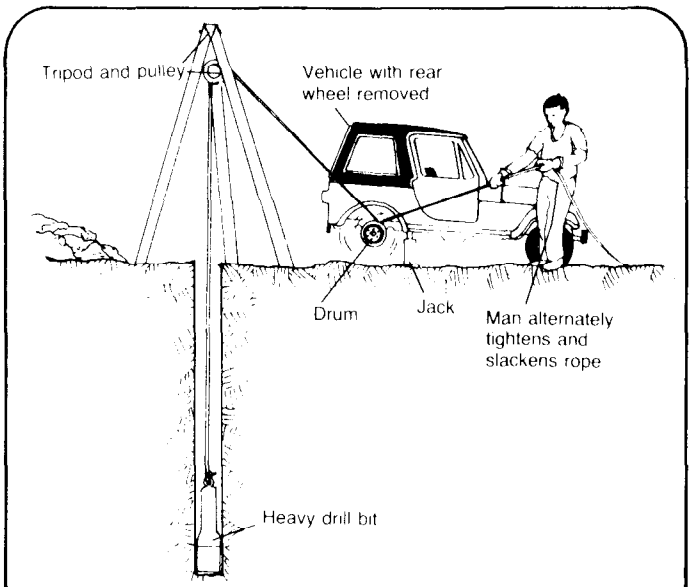

Figure 6. Cable Tool Well

Table 1 summarizes the five types of wells. This table can be used as an aid in selecting a method of well construction. Also see "Selecting a Method of Well Construction," RWS.2.P.2.

Table 1. Comparison of Types of Wells

FACTOR	WELL TYPE				
	Hand-Dug	Driven	Jetted	Bored	Cable Tool
Method of sinking shaft	Soil excavated by pick and shovel and lifted out by rope and bucket	Well point or steel pipe driven into ground	Jet of water and rotating section of bit force pipe into ground	Auger is rotated and fills with soil; lifted out of hole and emptied	Bit raised and dropped to pulverize soil and rocks; debris is mixed with water and lifted out with a bailing bucket or pump
Average diameter	1.0-1.3m	30-50mm	40mm	50-200mm	50-100mm
Maximum practical depth	10m	8.0m	60m	15m	75m
Principal tools and equipment	Pick, shovel, rope and bucket; steel forms for concrete; hoist for lowering casing	Sledge, drive pipe, or drive weight; raised platform	Boring pipe; raised platform or tripod; pump and hoses; jetting bits	Augers; drill line; raised platform	Motorized vehicle; tripod, pulleys, rope; heavy drill bits; suction pump; bailer
Casing materials	Cement, sand, gravel, and water (for concrete)	Steel pipe	Steel pipe	Steel or concrete pipe	Steel pipe
Intake	Porous concrete sections, or gravel-lined bottom	Specially-made well point	Well screen	Well screen or perforated pipe	Well screen
Skill of workers	Minimal	Minimal	Moderate	Moderate	Experienced
Outside water needed for construction	No	No	Yes	No	Yes