3. Source selection, protection and monitoring

3.1 Introduction

Water which flows in streams and rivers or which is contained in lakes is called surface water whilst water which percolates into the ground and reaches the water table is called groundwater. The general features of geological formations associated with surface water and groundwater sources are shown in Figure 1.

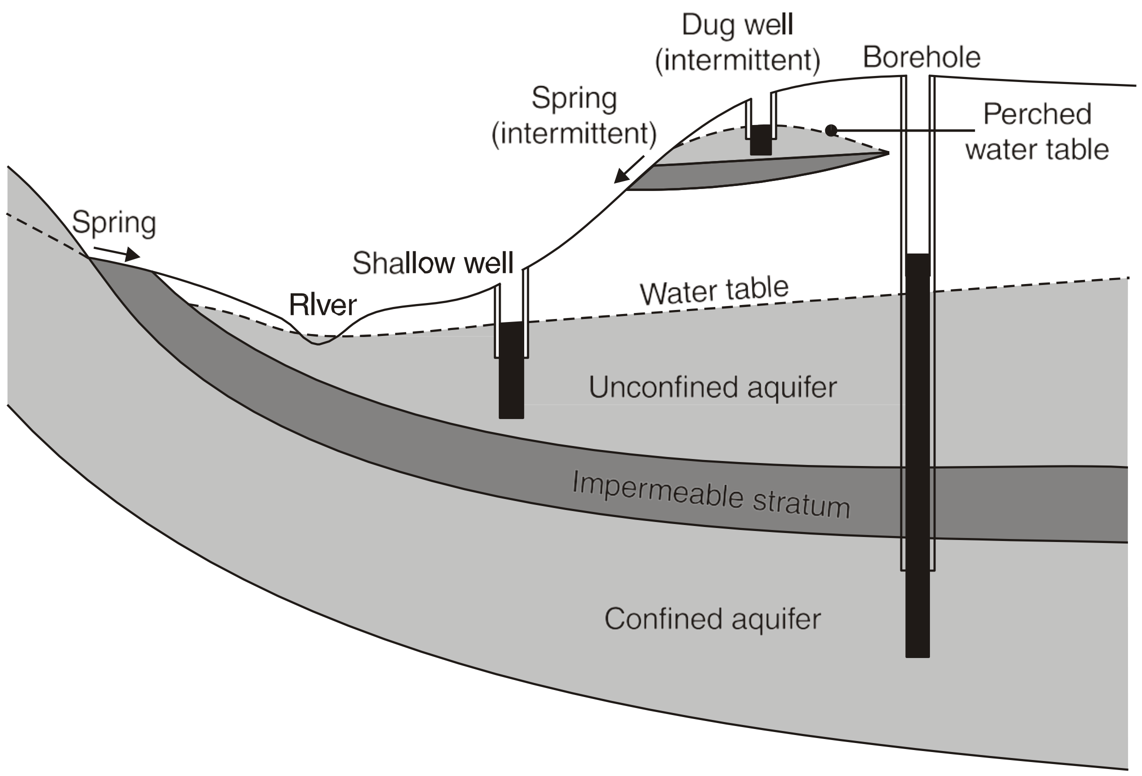


Figure 1: Groundwater and surface water sources

3.2 The hydrological cycle

Precipitation introduces water into the terrestrial environment where it may percolate into the ground, run-off as rivers and streams, or be returned to the atmosphere through evapotranspiration. Precipitation falling on to a soil will wet the soil surface and then infiltrate below ground level where it adheres to the soil particles by a combination of surface tension and molecular attraction to form pellicular water. Such pellicular water escapes the forces of gravity as the attractive forces of surface tension and molecular attraction are such that only evapotranspiration can remove this bound water. Thus precipitation will only penetrate deeper once the soil reaches its field capacity, at which the force of gravity exceeds the attractive forces binding water to soil particles and allows the water to drain downwards. In this region of the soil the voids present are not completely filled with water and so this region of the subsurface is known as the unsaturated zone. As gravity pulls the water down to greater depths the voids become completely filled with liquid and this is termed the saturated zone. Water in this saturated zone is termed groundwater and the boundary between the unsaturated and saturated zone is termed the water table. This separation is not clear-cut and the transition phase between the unsaturated and saturated zone is called the capillary zone or capillary fringe.

If these zones are viewed in terms of pressure then it is found that the unsaturated and saturated zones have different characteristics. The pressure gradient in the unsaturated zone is less than atmospheric pressure, i.e. atmospheric minus capillary pressure, whereas in the saturated zone the voids are completely filled with water at a pressure above atmospheric pressure. Thus the water table may be defined in terms of pressure as the level in the subsurface where atmospheric pressure occurs. These pressure differentials mean that if a well or borehole is excavated into the saturated zone, water will flow from the ground into the well. Water will then rise to a level in the well where the pressures equilibrate. Groundwater can be broadly defined as that water located below the water table, i.e. in the geomatrix (soil, rock or other geological material) where the void area, the space between the constituents of the geomatrix, is approximately 100% occupied by water. These voids or pores can be used to classify groundwater- bearing rocks into two broadly exclusive groups

- reservoirs: geomatrix containing voids that allows liquid to penetrate into the main body of the material;
- non-reservoirs: geomatrix lacking any void space and therefore unable to harbour any liquid.

Reservoirs vary in the degree to which stored water will be released as some may not easily release their stored water e.g. clays are reservoirs but do not release their stored water. This feature of reservoirs requires a further division into permeable and impermeable reservoirs.

Another feature is that groundwater is dynamic, being constantly in motion through the geomatrix. The ease with which water can pass through particular rock strata depends on a combination of the size of the pores and the degree to which they are interconnected resulting from the degree to which the rock is permeable. An aquifer is any rock which contains interconnected pores or fissures which can hold and transfer water and may be defined as a water-bearing rock formation that contains water in sufficient amount to be exploited and brought to the surface by wells.

Geomatrix materials that can serve as aquifers include gravel, sand and sandstone, alluvium, cavernous limestone, vesicular basalt and jointed slate. The different components that combine to produce an aquifer system are shown in Figure 2. It is apparent that there are two distinct types of aquifers: confined or unconfined. In an unconfined aquifer the water table is unrestricted and can thus move up or down through the geomatrix. By contrast a confined aquifer is restrained by an upper layer of impermeable rock, termed an aquiclude, which prevents water moving upwards. As discussed above, the pressure in a confined aquifer will be above atmospheric pressure and this pressure difference will cause water to rise in a well shaft that penetrates the aquiclude. Such wells are termed artesian wells.

To complete the hydrological cycle within the groundwater area, all freshwater found underground must have a source of recharge such as rainfall or leakage from surface drainage such as rivers, lakes or canals. It should be borne in mind that groundwater systems are dynamic with water continuously moving from areas of recharge to areas of discharge with transit times of many years.

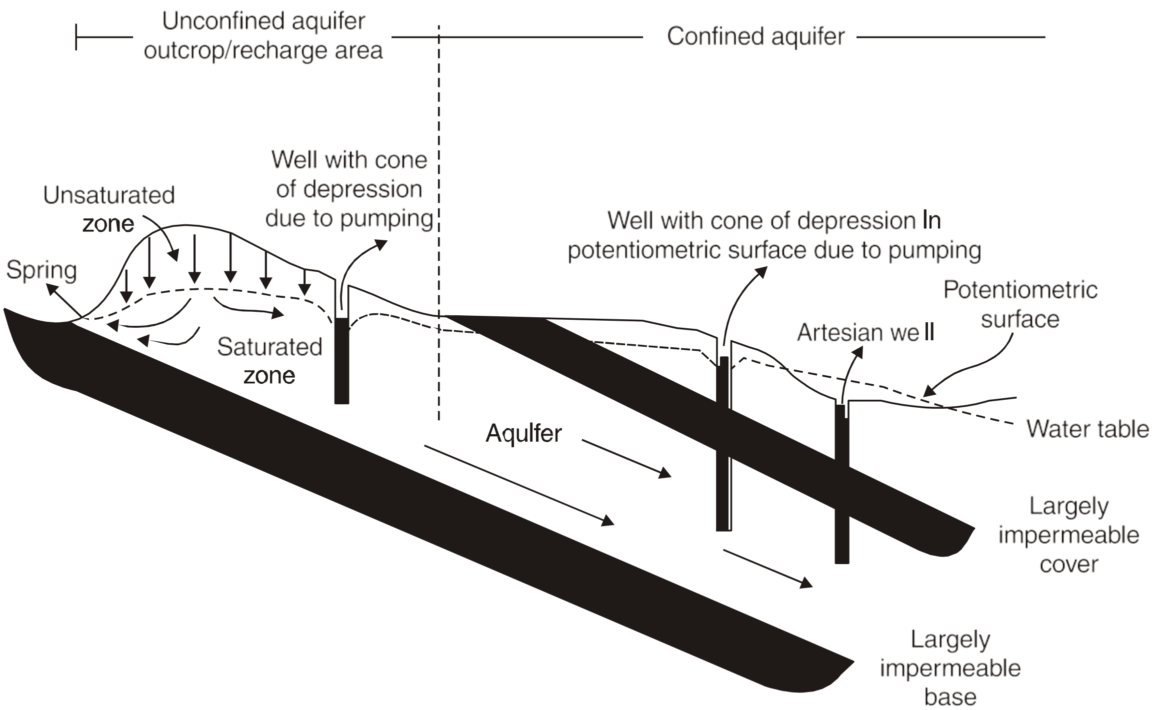


Figure 2: Confined and unconfined aquifers

3.3 Source selection

The principal sources of private supplies are springs, wells and boreholes. Streams and rivers are also used but to a lesser extent because of the reduced spatial accessibility of surface water compared to groundwater as well as the more variable quality of surface water. Other, sources of water used in the domestic setting may include rain water (which should be treated as surface water) and sea water (from desalination). Whatever the source, it must consistently yield a quantity of water sufficient to satisfy the requirements of the user.

3.3.1 Streams and rivers

Streams and rivers may be susceptible to pollution and may exhibit variable quality. The risk and extent of pollution depends on the catchment and the activities being undertaken on it. Water derived from upland catchments that are not unduly peaty and not used for agricultural purposes are usually of good chemical quality. However, soft acidic upland waters derived from peaty moorland catchments may be corrosive (to plumbing fittings) and contain relatively high concentrations of dissolved metals. Small streams often exhibit variable quality because of the activities of man and animals within the catchment.

Lowland surface waters are likely to be of poorer quality. The quality of surface waters may show a strong seasonal variability. Colour may be highest in late autumn and winter. Turbidity may be highest following periods of heavy rainfall.

Because of these potential problems, a surface water source is normally only considered for use as a drinking water supply where a groundwater source is unavailable. Water treatment will require a minimum of filtration and disinfection and should be designed for the worst expected raw water quality. A small reservoir or tank installed at the source can provide a period of settlement and reduce the variability in water quality. This tank will require regular inspection and cleaning. Figure 3 shows the construction of brick or concrete reservoirs; pre-cast concrete reservoirs can also be used.

3.3.2 Springs

The quantity of water available from a spring depends on its source. Most reliable are springs issuing from deep aquifers whereas those from perched water tables or supported by flow from fissured limestone or granite aquifers may dry up after a short period without rain. Spring sources can be of good chemical and microbiological quality although springs from shallow or fractured strata may be of variable quality because of surface contamination. The treatment of spring waters is usually simpler than for surface waters because spring water is likely to contain less suspended matter.

Some “spring sources” used for small water supplies are in fact artificial land drains. If the whole drainage system is properly maintained, the quantity and quality of water may be acceptable for a drinking water supply but for assessing treatment needs, a land drain should be regarded effectively as a surface water source. If maintenance is poor, the water quality and flow may decrease. The probability of agricultural pollution must be considered carefully.

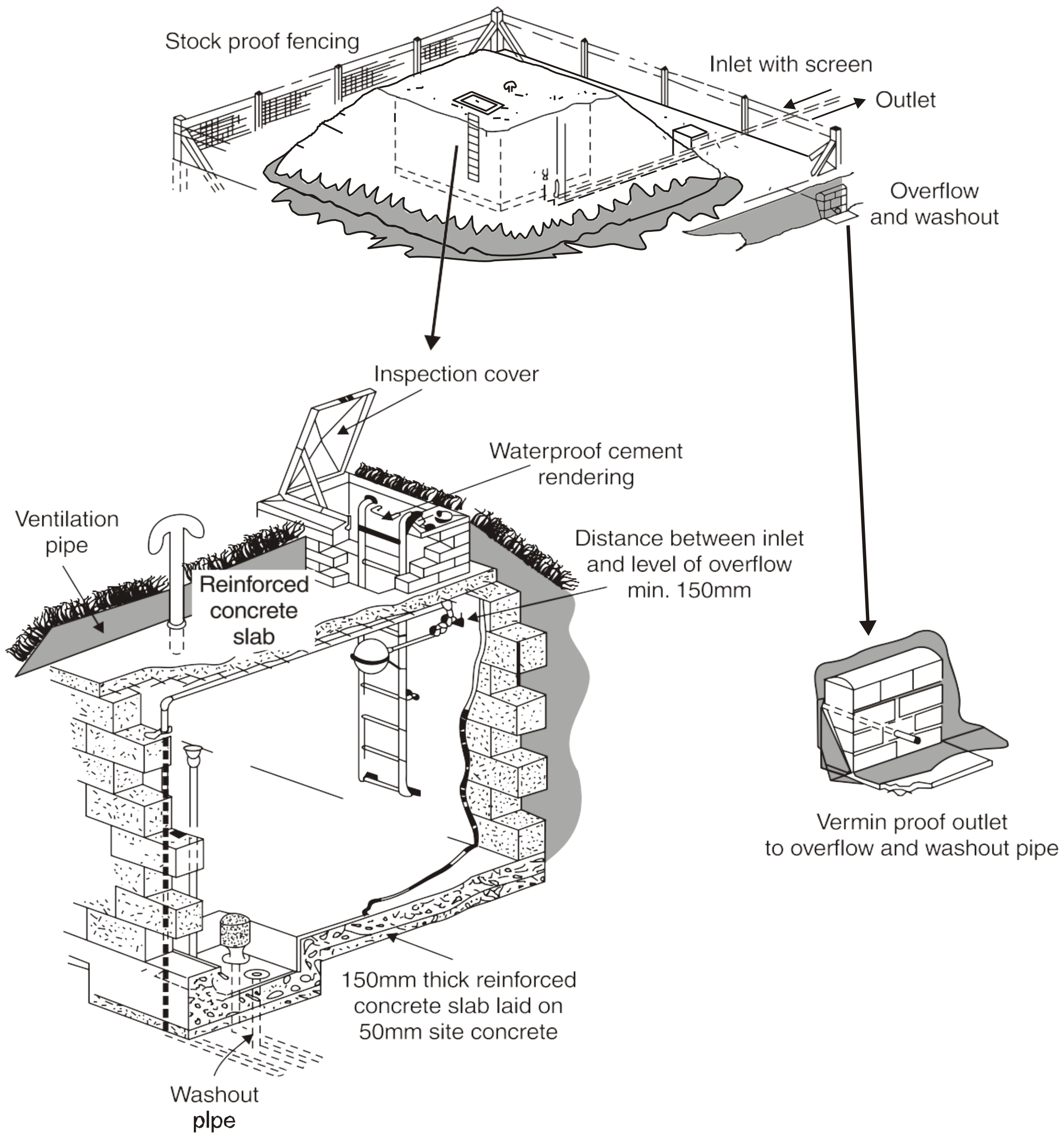


Figure 3: Brick or concrete reservoirs

3.3.3 Wells and boreholes

Many small drinking water supplies are derived from wells and boreholes. Wells are usually of large diameter and dug by hand or, more rarely, by a mechanical excavator. Boreholes are of smaller diameter, variable depth and are drilled by a specialist contractor using a mechanical drilling rig.

The quantity of water available will depend on the characteristics of the aquifer and the well or borehole drilled into it, and can be determined by test pumping after construction. A well or borehole that penetrates an extensive aquifer will be the most reliable, where as a well or borehole sunk into a perched aquifer may dry up after a short period without rain.

Water abstracted from deep wells and boreholes may have originated from catchments several miles away. If the aquifer is a porous stratum, such as sand or gravel, the water will have undergone thorough filtration. Such water will usually be of very good quality. Some aquifers, such as limestone or granite strata, may be fissured and the filtration of the water will not have been so thorough. Groundwater abstracted from shallow wells and boreholes may be prone to local pollution unless adequate precautions are taken. However, groundwater is usually of good quality and treatment may consist of disinfection only. However, some groundwater contains high concentrations of iron and manganese, which are usually removed by oxidation and filtration. Others may be polluted by nitrate or pesticides derived from agricultural or other activities or by chemicals from industrial sites.

3.4 Source protection

3.4.1 Streams and rivers

Pollution and natural variations in water quality are the main problems associated with stream and river sources that need to be considered when siting and constructing an intake. Water may be pumped directly from the stream or river or it may be collected from the ground in the immediate vicinity of the stream or riverbank. The advantage of the latter is that where the strata have suitable transmissive properties, supplies taken in this way are naturally filtered and of better quality than the river water itself.

The intake should be located away from any features that might create turbulence during periods of heavy rainfall and increase the turbidity of the water. This means that intakes should not be situated on bends in the stream or river or at places where sudden changes in level occur. Most commonly, intake pipes are situated in the stream or river protected by a strainer to prevent the ingress of debris, fish and vermin. The inlet pipe feeds a settlement tank that allows particulate material to settle. The outlet of the tank, fitted with a strainer, should be situated above the floor of the tank to prevent contamination by sediment. The tank must be built of a material that will not impair water quality and designed to prevent entry of vermin and debris. An example of a slightly more sophisticated intake is shown in Figure 4. The inlet pipe is situated in a small gravel filled tank buried upside down in the stream or riverbank (alternatively, the tank may be buried in the stream or river bed). The water enters the tank through a substantial thickness of riverbank material. This type of infiltration gallery will only be appropriate where the riverbank is sufficiently permeable to allow water to enter the tank at an adequate rate. The intake may suffer a gradual loss of capacity through siltation.

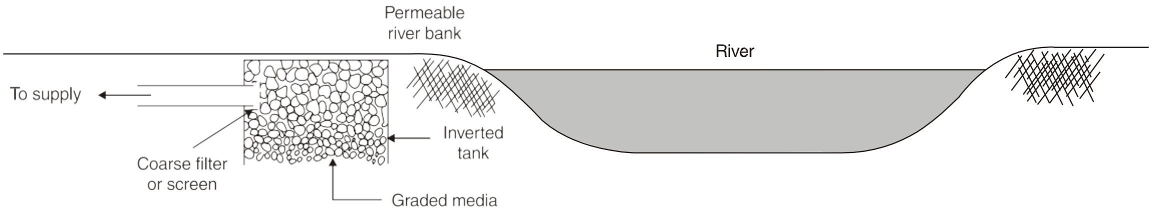


Figure 4: River Source

3.4.2 Springs

Spring water can be of good quality but it must be protected from possible contamination once it has reached ground level. In particular, it is necessary to consider the possibility of pollution from septic tanks or from agricultural activities. A small chamber built over the spring, for example as shown in Figures 5 and 6, will protect it from pollution, provide storage for periods of high demand and serve as a header tank. The collection chamber should be built so that the water enters through the base or the side. The top of the chamber must be above ground level and it should be fitted with a lockable watertight access cover. An overflow must be provided and be appropriately sized to take the maximum flow of water from the spring. The outlet pipe should be fitted with a strainer and be situated above the floor of the chamber. The chamber should be built of a material that will not impair water quality and be designed to prevent the entry of vermin and debris. The area of land in the immediate vicinity of the chamber should be fenced off and a small ditch dug upslope of the chamber to intercept surface run-off.

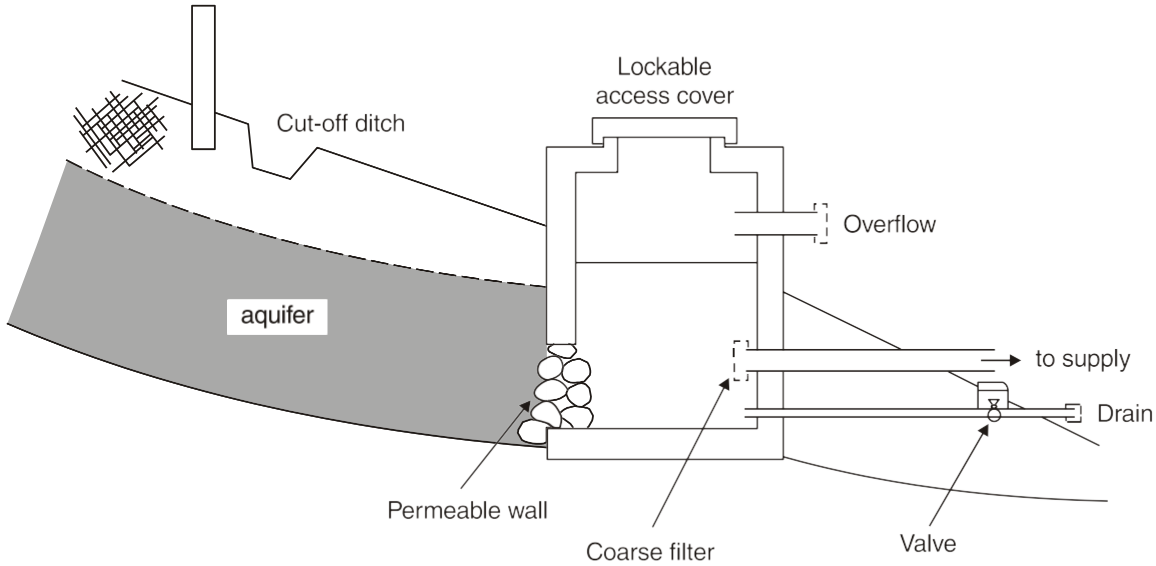


Figure 5: Spring source schematic

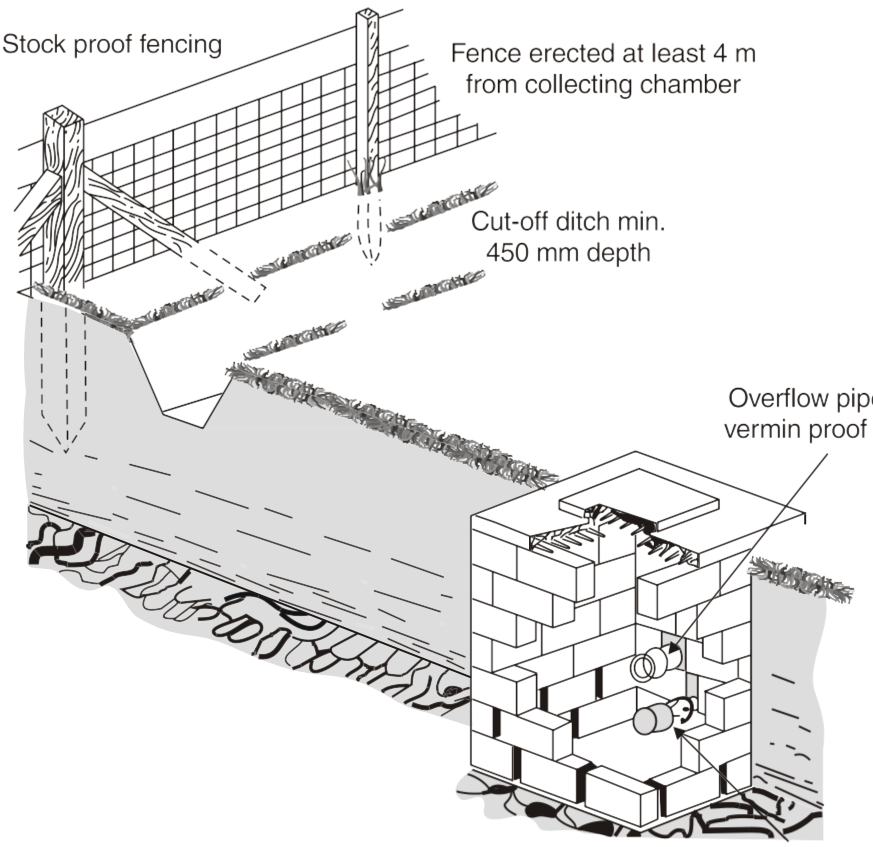


Figure 6: Spring collection chamber

3.4.3 Wells and boreholes

Shallow wells and boreholes are more at risk from contamination than deep wells and boreholes but if built and sited correctly, both may provide good quality water. Similar measures may be taken to protect both sources and an example is shown in Figure 7.

The upper section of the shaft must be lined and sealed against the surrounding material to exclude surface water ingress and, in the case of shallow wells and boreholes, water from the upper layer of the aquifer. Such sanitary seals range in depth depending on the aquifer but all must extend above ground level. Wells are often lined with masonry or concrete pipes and boreholes with steel, plastic or glass-reinforced plastic casings and sealed into the ground by a cement grout injected into the annular space between the casing and the surrounding ground. The shaft lining material should not affect water quality.

Where boreholes are drilled through a perched aquifer into lower water bearing strata or several different aquifers, highly variable water quality may be obtained. Use of such boreholes as sources of potable water should be avoided unless the area through the perched aquifer is sealed.

Slotted or perforated borehole linings lining may extend some depth into the aquifer if the bottom section requires support. A gravel packing may be necessary if the borehole penetrates unconsolidated aquifer material to prevent fines from being drawn into the borehole during pumping. At ground level, the well or borehole should be covered by a watertight chamber with a lockable cover. A concrete apron should slope away from the chamber to drain surface water. The well or borehole should preferentially be sited up-hill of, and at least 50m away from, potential sources of pollution which include septic tanks, sewer pipes, cess pools and manure heaps. Typical arrangements for wells and boreholes are shown in Figures 8 to 10.

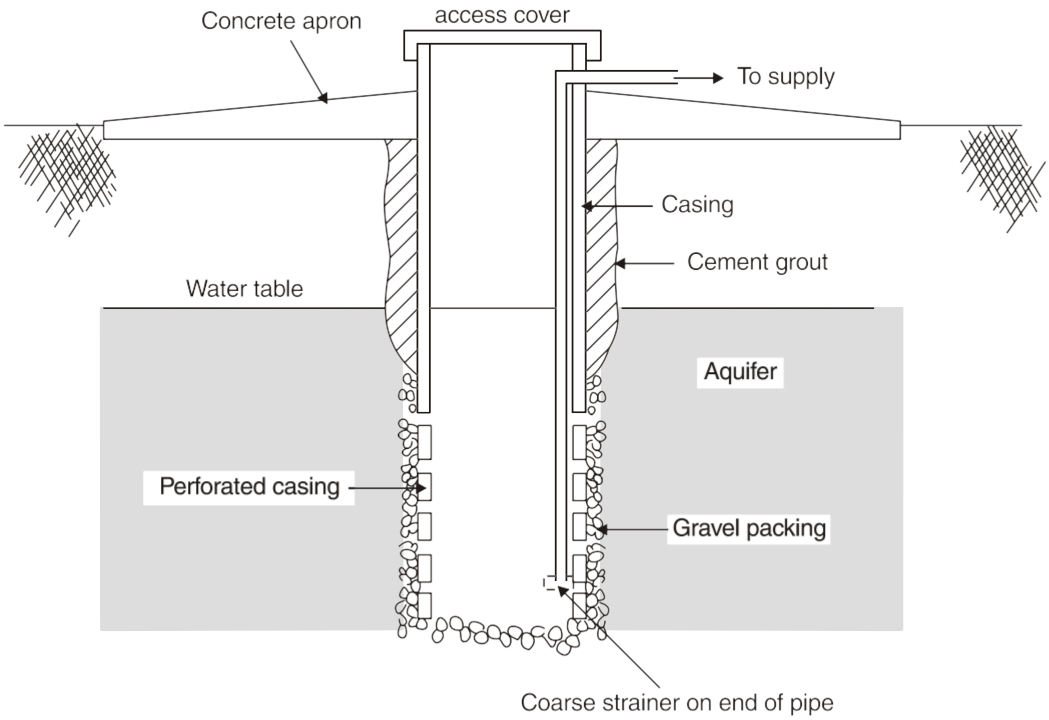


Figure 7: Well or borehole source schematic

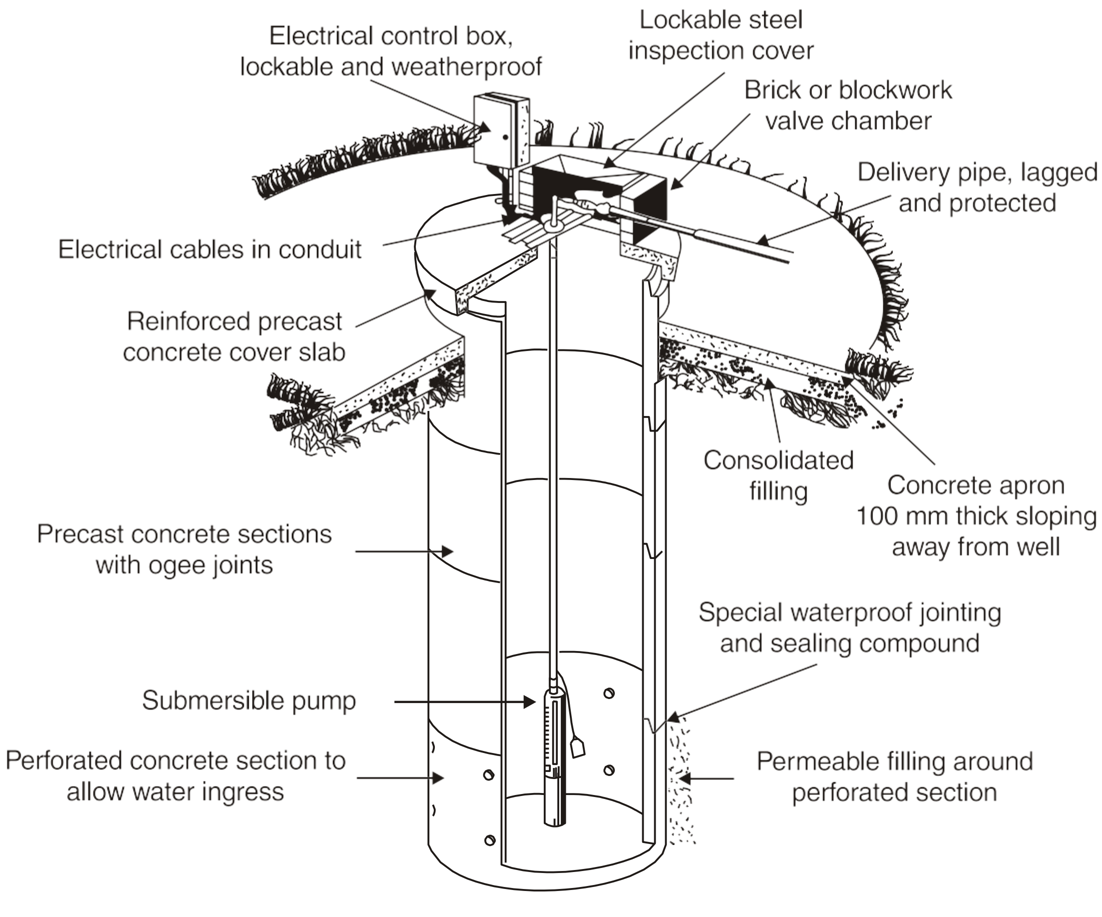


Figure 8: Typical well and submersible pump installation

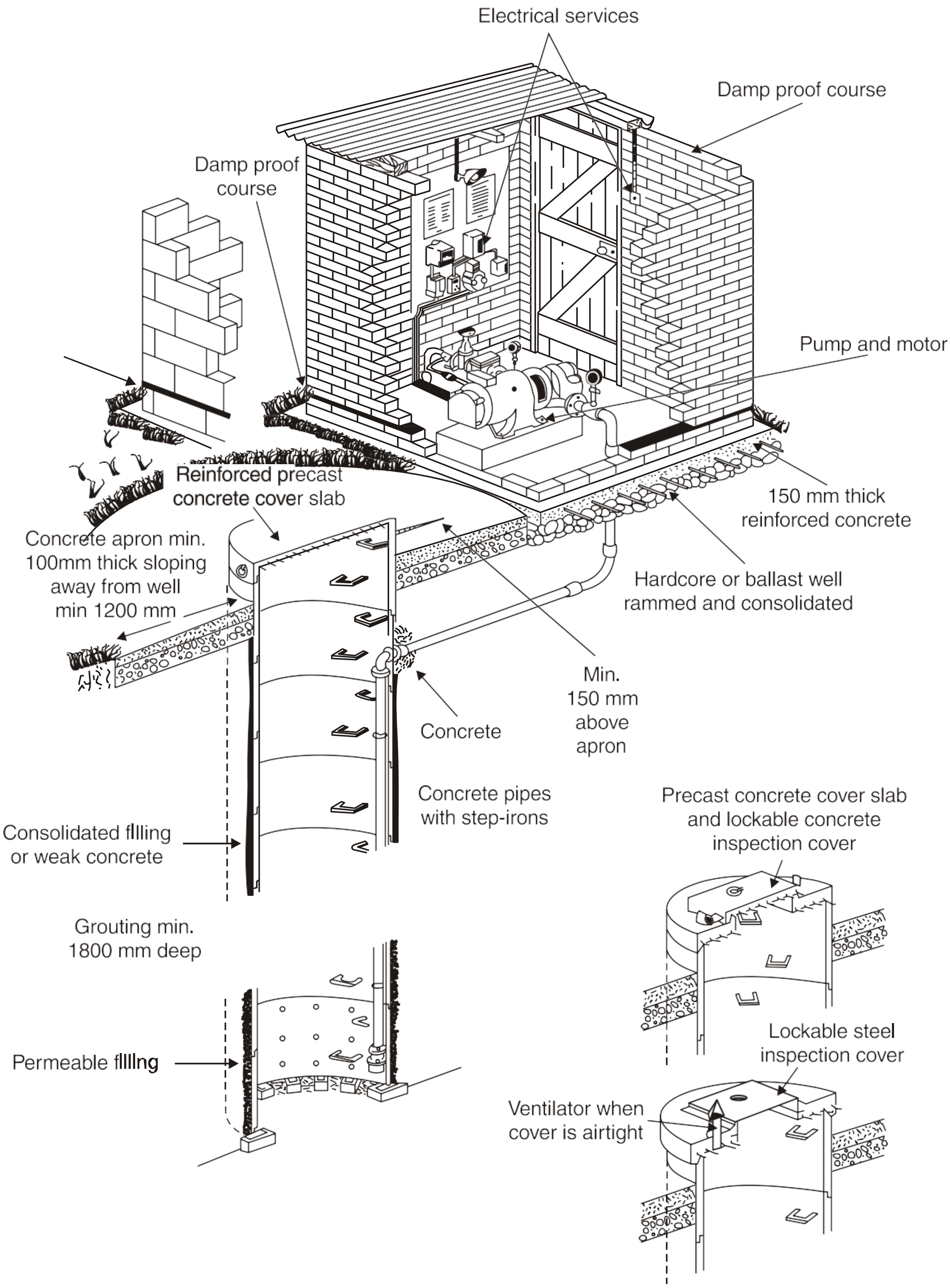
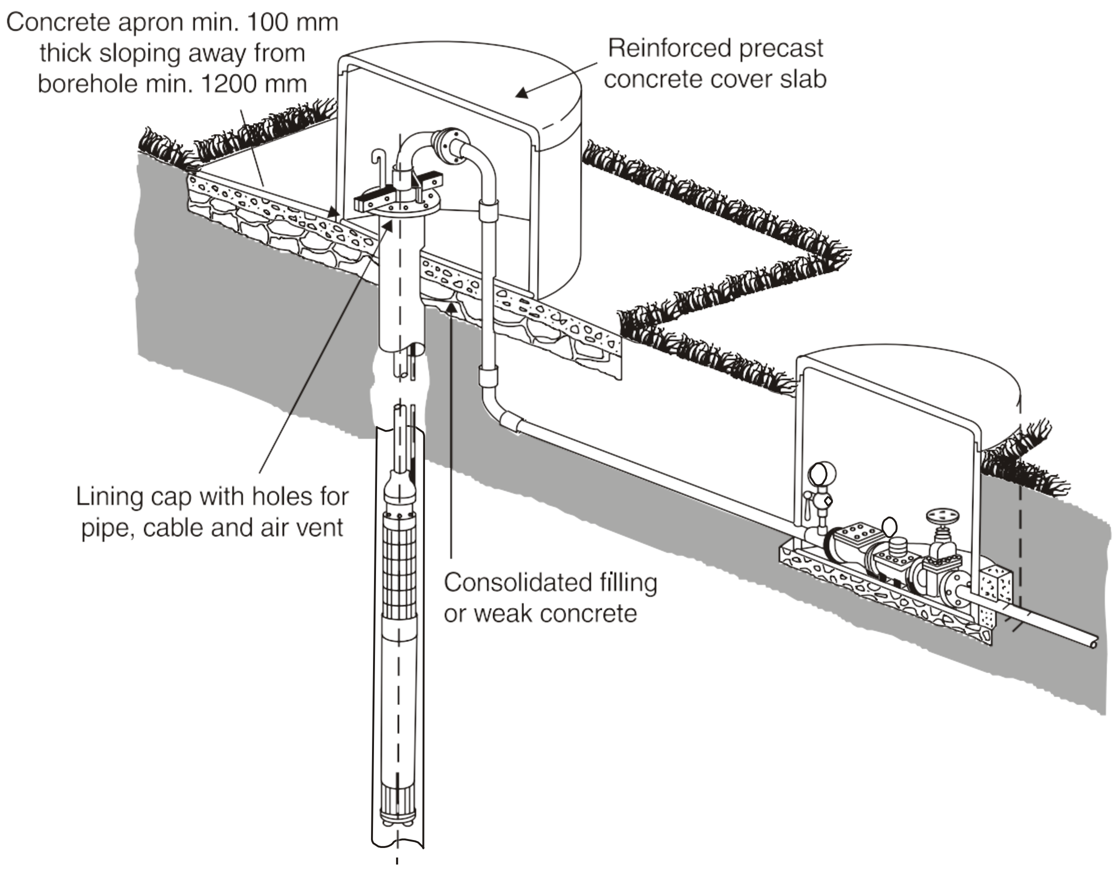


Figure 9: Typical well and surface pump installation



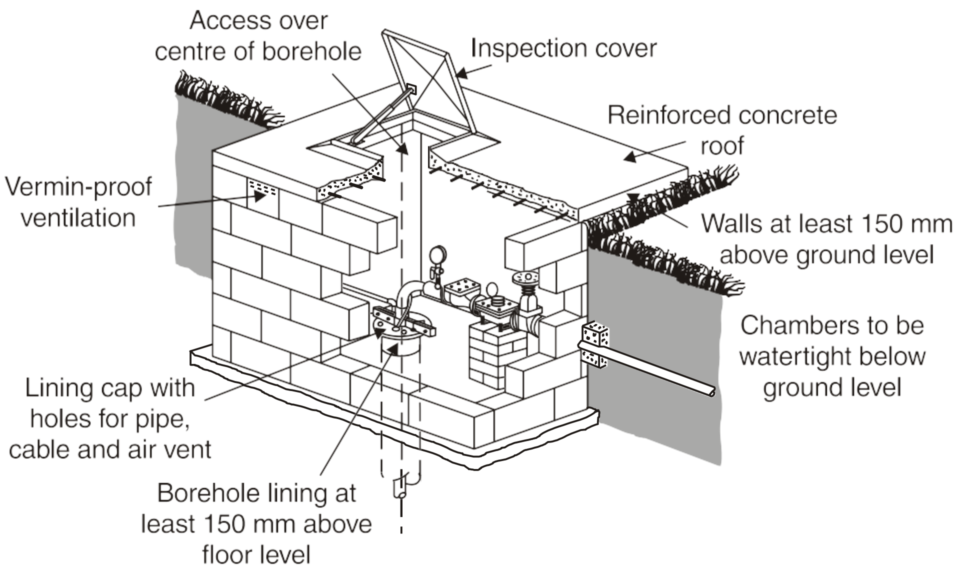


Figure 10: Borehole headworks