5

Installation technology

IN THIS CHAPTER:

- Choice of abstraction technology — considerations, what works and under which conditions it will work
- Methods of abstraction equipment installation; equipment and skills required
  - — Digging-in
  - — Driving
  - — Jetting
- The advantages and disadvantages of each system

Selection of an appropriate abstraction system

A water/sediment separation and water abstraction system must be suited to the hydrogeological conditions of the river channel and riverbank. The nature and depth of the river alluvium is a particular consideration. To aid the selection process, the appropriateness and advantages and disadvantages of each system are discussed here. For a complete description of various methods of sand-abstraction see Chapter 4.

Well-point and suction pump

This is a suitable abstraction technology for areas where the river alluvium is deep, relatively stable and is ideally predominantly comprised of coarse sediment grains. The main criterion is an adequate depth of sediment. Well-points typically offer an effective and versatile option for most sand-abstraction situations.

Advantages

- Low-cost — a straightforward level of technology with only a few basic materials required for fabrication and installation.

- Low maintenance system – materials required for maintenance and repair are usually readily available, no expensive parts or specialist repair tools or equipment is required.
- Satisfactory depth of installation easily achievable – system uses simple installation techniques to ensure a year round supply of water in the right conditions.
- Can be used in all seasons – whether or not the river is in flood.
- Multiple well-points can be joined for high volume schemes and/or where permeability is low where the alluvium is fine grained.
- Safe – no unstable well sides liable to collapse on users, unlike traditional open wells.
- Easy on the environment – installation is sub-surface and system requires little infrastructure and no brushwood fences to protect it.
- The system typically yields safe water suitable for household use.

Disadvantages
- Requires fabrication or purchase of abstraction or fabrication equipment.
- Requires a sealed system between the well-point and the pump – air leaks in the connecting pipes or leaking pump seals render well-point systems inefficient or even inoperative.
- Equipment can be vulnerable to flood damage – although the security of systems can be improved by anchoring the well-points to stakes, steel pipes or fence posts driven into the riverbed.
- Water may contain significant traces of silt when river is in flood.
- During effluent river flow or where there are high rates of abstraction, water in the river alluvium may become contaminated by the intrusion of saline salts from the riverbank. Mineral salts will affect the palatability of water and will contribute to encrustation around the well-point slots.
- In some situations, more often in perennial rivers, biofouling may occur within a well-point.

Infiltration gallery and collector well *(sometimes known as a false well)*
The system draws water from a large area making it most suited for abstraction in river channels with shallow beds of alluvium, or where the alluvium is comprised of fine grained sediment.

The layout of an infiltration gallery can be adjusted to the nature of the river. A single large diameter gallery across the river may be quite sufficient in wide slow-moving rivers whereas a river which is fast flowing with a high rate of sediment transport or a site on the outside of a river bend will require a number of short galleries, that might require anchoring to the riverbed with steel stakes.

Advantages

- No fabrication or complex installation equipment is required. There are proficient well diggers in many rural communities.
- Year round use — whether or not the river is in flood.
- Very basic abstraction technology — water can be drawn from a collector well by a simple handpump or a by bucket on a rope.
- Provides clean water that may be easily drawn from a protected well.

Disadvantages

- Infiltration gallery screening requires purchase or fabrication.
- Difficult to install to a sufficient depth to ensure satisfactory year round water abstraction.
- Requires a significant amount of work — digging and lining a collector well on the riverbank and excavating a connecting trench for the galleries in the river alluvium.
- Equipment can be vulnerable to flood damage — although this can be improved by anchoring the infiltration pipes to stakes, steel pipes or fence posts driven into the riverbed.
- Difficult and costly to construct in riverbanks that are not alluvial where rock breaking techniques or compressors may be required.

Caisson

A useful option in shallow, fine sediment where a pit can be excavated to the riverbed and a stable foundation secured for the installation. Ideally used in fine, stable river alluvium on a clay base or on bedrock where there is little transport of sediment through the channel.

Advantages

- Simple to construct — uses basic well construction technology, a skill many people in rural areas are conversant with.
- Suited to conditions of fine alluvium — due to a large screen area available for infiltration.
- Particularly suited to low-yielding small sand rivers where installation can be effected to a satisfactory depth — into or even through the riverbed.

Disadvantages
- May be difficult to install to a satisfactory depth, particularly in fluidized sediment.
- Installation requires a solid foundation.
- Where a caisson is submerged in sediment the top surface requires a cover to prevent infill and clogging with silt.
- As the screen is typically formed by no-fines concrete well-rings or courses of mortar free bricks, fine sediment is liable to penetrate a caisson that may then require de-silting.

Sand well
A larger structure than a caisson that extends from the base of the river channel to a height above the surface of the river sediment. Can be used as an offset sand well in an alluvial riverbank that has a high permeability and a good recharge to the well but may be used within river alluvium where suitable precautions are in place to prevent subsidence or in-filling with silt.

Advantages
- Simple to construct — uses shallow well construction technology, a skill with which many people in rural areas are conversant.
- Very basic abstraction technology — water can be drawn by a simple handpump or a bucket on a rope.
- A protected well can be used which will yield clean water.
- Suited to low-yielding small sand rivers where installation can be effected to a satisfactory depth — into or even through the riverbed.

Disadvantages
- Excavation in the riverbank or riverbed may be difficult to achieve to an adequate depth. Particularly in fluidized sediment, de-watering or well sinking techniques appropriate to unstable conditions may be required.
- Installation requires a solid foundation.
- Within river channel alluvium a well shaft can be vulnerable to physical flood damage and if not adequately sealed, to siltation.
- When installed within a river channel, system cannot be used when the river is in flood.

Figure 5.1 indicates the process of sand-abstraction site and equipment selection.

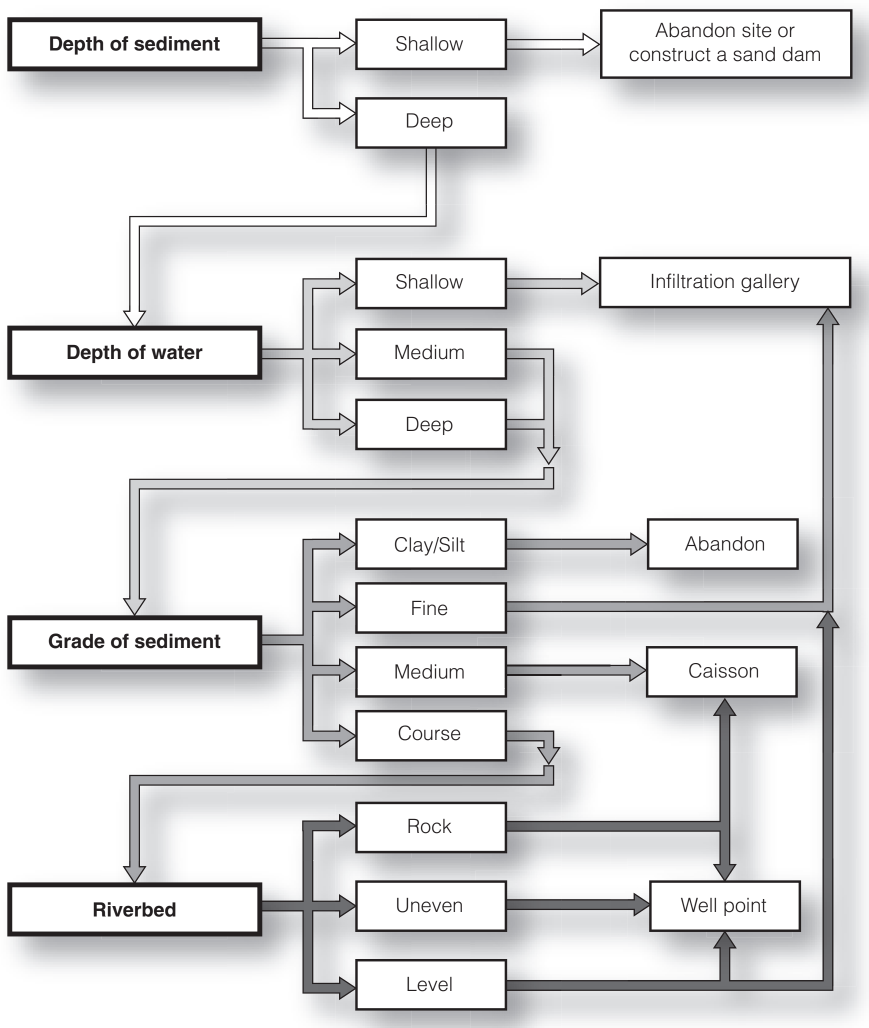

Figure 5.1. Site and equipment selection chart

Installation selection procedure

The following is a step by step selection procedure that can be used to identify a suitable abstraction technology with the correct equipment design criteria and dimensions.

1. Select the abstraction technology

   1.1. Appraise the site in the following way:

   - Determine the depth of sediment.
   - Analyse sediment particle size — assess from fine to coarse.

- Approximate the gradient of the river channel sediment surface.
- Determine the extent of the aquifer and calculate the volume.
- Observe the number of traditional open sand wells and seek the advice of local people with regard to permanence of water.

1.2. Determine the system best suited to the site conditions (refer to foregoing information).

2. **Select an appropriate screen** (refer to Chapter 3, sediment classification). This will invariably be determined by the abstraction technology 1.2 above, but the following should be borne in mind:

2.1. Optimum style

- An efficient screen will not become blocked with fine sediment grains – in effect the apertures should be self-cleaning, allowing every particle that enters the screen to pass through and not become wedged. A slot tapering in the opposite direction to water flow is generally better than a parallel sided slot (see Figure 4.8, Chapter 4). Unfortunately it is virtually impossible to construct taper-sided slots or holes in homemade screens with apertures of less than approximately 5mm. Probably the best that can be achieved in homemade screens is to ensure that apertures are as clean as possible with little or no swarf to block the movement of particles.
- In the construction of homemade screens longitudinal slots are difficult to fabricate in a pipe. Transverse slots are easier to cut but significantly weaken the pipe, which is likely to fracture between slot ends. Holes are easily drilled but particularly with smaller diameter holes it may be difficult to ensure a sufficiently large open surface area. Photograph 5.1 shows a range of well-points and screens. Photograph 5.2 shows a fracture that occurred in a homemade transverse slotted well-point screen.
- The screens of caissons and lined wells will typically be formed from no-fines concrete and will thus be random with no consistent aperture size and, depending on the materials and consistency of mixtures may include large orifices or conversely may not have a sufficiently large screen area. Photograph 5.3 shows no fines concrete well-rings of a type suitable for the construction of a collector well, caisson or sand well.
- The aperture dimensions of mortar free brickwork may not be sufficiently narrow to preclude fine sediment.

Photograph 5.1. Selection of well-points

Commercial Homemade

Photograph 5.2. Well-point fracture between transverse slots

Photograph 5.3. No fines concrete well-screen

2.2. Optimum aperture size

- A standard recommendation based on traditional water supply borehole design principles is that a screen slot size should be large enough to allow 40 to 70% (nominally 60%) of sediment particles to pass through. In situations where the sediment is of a uniform grade (mostly single size particles) the lower percentage rates should be observed. Narrow slots tend to block more easily and satisfactory screens with small diameter holes are difficult to construct. In reality an acceptable screen can usually be developed even when a larger percentage of sediment grains pass through the apertures. Provided the sediment is not uniformly fine an effective screen will be formed but will take longer to develop as more fines will require extraction and consequently there may be greater wear to the pump. Ideally a natural filter should be developed in the sediment surrounding a well-point within 30 minutes of pumping. However, in exceptional cases, pumping in excess of this may be needed.

- Where sediment is homogenously fine a screen with small apertures must be fabricated. Depending on the sediment grading this can be undertaken with a 1.00, 0.75 or 0.5mm slotting saw or by drilling a pipe with 6mm holes and then wrapping the entire pipe in synthetic, non rotting geo-textile.

2.3. Optimum open surface area

- Depending on aperture size an efficient screen should ideally comprise 60% of pipe material and 40% of open surface area. However it is unlikely that a percentage higher than 25% open surface area will be achievable in a homemade screen and 10% could be the norm. Figure 5.2 shows a commercial continuous slot well-point screen.

3. Select suitable connecting piping

3.1. Class of pipe

- Piping is required with an adequate tensile strength, flexibility and a wall thickness that will not be damaged by the flow of river water and debris within the environment of river alluvium. Where suction pumps are used the pump and connecting pipes must adequately withstand the differential pressures that will be exerted.

3.2. Optimum velocity

- A well designed system has a screen with apertures that in conjunction with a further natural screen system developed within the alluvium will prevent the passage of all but the finest particles

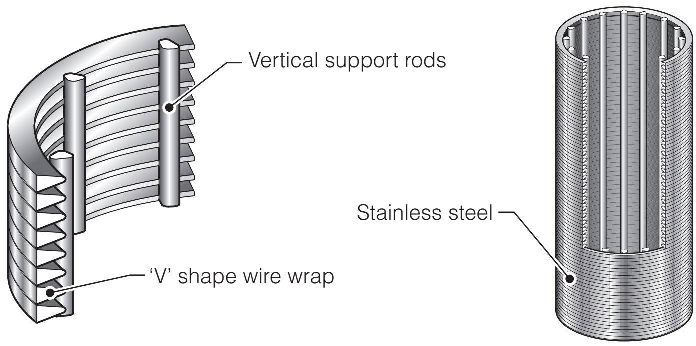

Figure 5.2. Continuous slot well-point

Although screen open surface areas are likely to vary from a low 1% in perforated pipe to more than 40% of continuous slot screens, the aperture size and open surface area of a screen is important. A high open surface area and a suitable aperture size and configuration is required to permit fine material to be removed quickly from the alluvium surrounding a screen in order that a zone of graded material can be effectively developed around a screen to increase permeability and recharge to the point of abstraction.

of sediment. In order to optimize such a filtration system and to prevent the further passage of sediment grains that do enter the system when it is developing or following disturbance of the alluvium during sediment transport, there is an optimum velocity of water flow in each section of the abstraction system.

Field experience indicates appropriate flow rates through a developed well-point screen system to be:

- At the point of abstraction 0.03 to 0.07m/sec — this is the velocity of the flow of water through the aperture area of a well-point. Entrance velocities into a well-point during the development stage of the natural filter when sediment particles are being displaced and repositioned are likely to be higher. Low entrance velocities are preferable, ideally slow enough to achieve laminar flow in the sediment. A low abstraction velocity also reduces the degree of incrustation that accumulates around screen apertures in groundwater that is high in mineral salts.
- Through a well-point and connecting pipe, 0.6 to 0.9m/sec — a relatively low velocity in this section prevents any further movement of particles that have been drawn into the pipework. In multiple well-point systems a large diameter manifold to reduce the velocity of flow to 0.3m/sec will further ensure this. The layout of a multiple well-point system showing a central manifold with multiple off shoots is shown in Photograph 5.4.
- Through the pump, 1.25 to 1.5m/sec — this is the generally recommended maximum delivery velocity of a well-point system.

The entrance velocity of water into an infiltration gallery and ideally a sand well-screen should be 0.006m/sec. This slow rate of flow ensures that in the creation of the filter in the sediment surrounding the gallery a minimum of fine sediment is drawn through the screen, which might create a blockage in the gallery pipe or in the well shaft.

An example of the calculations of the aperture size and pipe diameters required in the correct design of a well-point system is detailed in Appendix 1.

3.3 Drawdown

- By ensuring that as much as possible flow through sediment to a screen is laminar with abstraction rates not exceeding 1 to 1.5m^3/hr per well-point drawdown in coarse saturated sediment in practical terms is not a significant factor. Due to the difficulty of installing infiltration galleries by hand to an adequate depth, drawdown is more significant with this system. Standard data collection procedures and formulae are available for calculating drawdown but again in practical terms, if the correct withdrawal velocities are observed problems seldom arise unless the water-level drops to the level of the upper apertures of the well-point or infiltration gallery.

Photograph 5.4. Installation of a multiple well-point system

In order to develop an efficient graded zone in the alluvium surrounding a screen, apertures that will permit the removal of 60 to 75% of sediment particles are required and in fine sediment up to 90%. The resulting natural screen should extend for as much as 300 to 600mm beyond the screen surface. The increased porosity and hydraulic conductivity of the graded material assist in the recharge at the point of abstraction, which reduces the drawdown and the possibility of an ingress of air during pumping.

Insufficient removal of fine sediment will prevent an adequate development of a natural screen in the alluvium.

Excessive removal of coarse sediment grains will lead to large amounts of sediment drawn into the delivery system.

Methods of installation

This section examines the methods of equipment installation, equipment and skills required, and the pros and cons of each system.

- Digging-in
- Driving
- Jetting

Digging-in

By excavating, either by hand or mechanically, each system can be physically dug into water yielding sediment.

- **Well-points:** a team equipped only with shovels is able to install a well-point into saturated sediment, however as with any digging, once fluidized sediment is reached it is difficult to dig any deeper and unless dug-in late in the dry season the water-level in the sediment is likely to drop so that the screen will be exposed before the river flows again. A slight advantage can be gained by forcing a shovel as deep as possible into fluidized sediment, then rocking the shovel backwards and forwards and working in the well-point behind the shovel blade.

  However, a largely untrained installation team with no sophisticated equipment can undertake digging-in. Photograph 5.5 shows a team of installation technicians digging-in a well-point.

Photograph 5.5. Digging in a well-point

E. M. Nyoni

- **Infiltration-galleries and collector wells:** as far as small-scale operators are concerned, digging-in is the most common solution to installing infiltration-galleries. In order to gain sufficient depth without the use of de-watering pumps, mechanical excavators or shuttering, the manual installation of infiltration-galleries can only be carried out at the end of a dry-season, before the onset of rains.
- **Caissons and sand wells:** Digging-in is the only way in which caissons and lined sand wells can be installed into river channel alluvium. When digging-in into unconsolidated alluvium it is a simple matter to place a well-ring at an appropriate point and to remove the material from inside the ring. By removing sediment evenly, starting in the centre and moving out until material is removed from under the well-ring the ring will be lowered evenly into the alluvium, securing the sides of the well as it drops. By placing a further ring on the top of the original ring the well lining is automatically placed and digging-in can continue safely in unstable material until water is reached. To assist the lowering of the lining the leading edge of the first ring can be bevelled to create a 'cutting' edge.

  Digging-in is also the only option for brick constructed caissons and sand well shafts located in a river channel. A frustum shaped excavation is required to a depth sufficient to ensure a satisfactory, stable foundation. The diameter of the base will need to be significantly wider than the outer diameter of the shaft and depending on the amount of fines and compaction of the sediment, the slope of the sides should be approximately 45° (the natural reclining angle of uncompacted sediment).

  Once again, as it is not possible to effectively excavate by hand into water saturated sand due to fluidized sediment welling up within the well lining or caisson, digging-in should be carried out late in the dry season to ensure that a firm base is obtained and to prevent the well running dry as the season progresses. As a caisson does not extend to the surface of the alluvium the sides of a caisson excavation must be cleared away, at least to the natural reclining angle of the material, as the digging progresses.

Driving and jacking

- **Well-points —** Where steel well-points are used these can be easily and quickly driven by a strong person with a steel sledge hammer.

Photograph 5.6. Driving in a well-point to 3 metres

They can be either vertical or inclined to the full depth of the riverbed sediment. Even where uPVC, ABS or plastic well-points are used, these can also be driven to satisfactory depths of 3.00 to 5.00 metres if equipped with a sacrificial steel point and a steel driving tube.

To achieve depths in excess of 2.00m a driving tube in lengths of approximately 1.50m is required; alternatively a temporary platform or stepladder will enable 3.00m lengths to be installed. To reduce damage to the steel by hammering, a length of timber is best held or fitted to the top of the pipe. However, even with a wooden block there is likely to be significant damage to the tube, particularly where there are threads. The driving tube is removed from the sediment when the well-point has reached a satisfactory depth, leaving the well-point in place. Photograph 5.6 shows a well-point being driven to a depth of 3.00m, with driving commencing from a step-ladder. Figure 5.3 indicates the protection that a block of wood can provide to a well-point driven with a steel hammer.

- Experience has shown that sediment can become compacted between the well-point tip and the driving tube making a fit so tight that when the driving tube is removed the well-point is also withdrawn! Two short wings attached to the well-point tip will

Reports from the mid-west of the USA indicate that well-points for tube-well water supplies can be driven into gravel beds to depths of 20 metres.

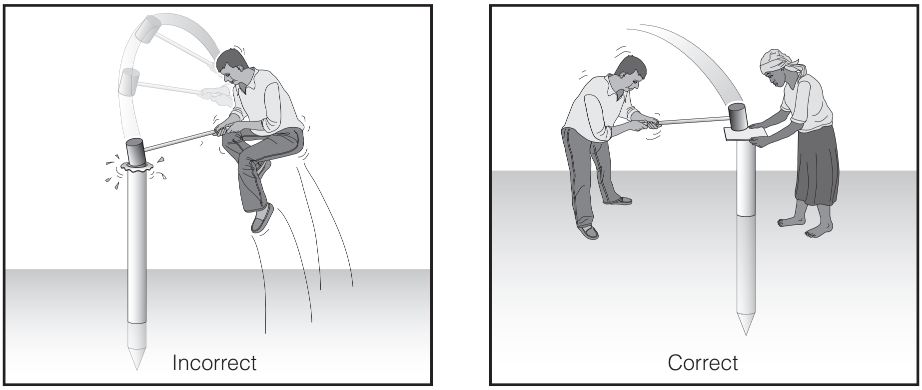

Figure 5.3. Driving in a well-point showing incorrect and correct methods

Photograph 5.7. Infiltration gallery and collector well on Blood River, South Africa

prevent this. A drawing of a uPVC well-point with sacrificial tip and anchoring wings is shown in Chapter 4, Figure 4.07.

- **Infiltration galleries —** Although beyond the scope of small-scale operators the British Geological Survey (BGS) has experimented with the horizontal jacking of infiltration pipes from collector wells below the bed of river channels. The system used was similar to the method above with a sacrificial tip and a jacking tube to push the tip horizontally through the formation. In order to undertake this it is necessary to construct a collector well of a diameter not less than the combined length of the jacking pipes and the hydraulic jack, (some 3.00m). Although there is a distinct advantage in placing infiltration pipes below the riverbed to increase the functional time of a well in seasons of low rainfall, the level of technology and the size of the well required constitute a considerable drawback. Photograph 5.7 shows the top of a collector well shaft, from which infiltration pipes radiate out under the riverbed.

Jetting

- **Well-points —** jetting requires an independent source of water. A motorized centrifugal pump is required to discharge water either directly through a self-jetting well-point or from an open-ended pipe attached to a regular well-point. Well-screens can then be pushed (jetted) through fluidized sediment into the lower levels of sediment whilst it is in an induced quicksand condition. The system operates more effectively in saturated sediment than in dry material where the water is likely to be dissipated laterally. Thus jetting is best carried out when the river sediment is fully saturated, or in situations where overlying dry sediment has been removed to expose water saturated sediment.

  Figure 5.4 shows a self-jetting well-point and Photograph 5.8 the installation of a well-point by jetting. Finally Figure 5.5 indicates how the jetting process is effected as water is ejected from the open end of a pipe or a self-jetting well-point to flow back to the surface. It is important to maintain flow around the outside of the pipe or the water ejected will simply be forced into the underlying sediment and the jetting pipe will cease to move. A simple well-point can be attached to a jetting pipe with a piece of low strength string. When a satisfactory depth has been reached the jetting process is stopped and material will collapse around the jetting pipe and well-point. The jetting pipe can then be withdrawn by breaking the string leaving the well-point in place.

This system of installation is more technically complex and is dependent on a portable centrifugal pump, source of water, materials and equipment that are often not readily available in disadvantaged areas. By jetting when the alluvium is saturated to full depth there is an associated problem with not being able to sufficiently bury the well-point connecting pipe. In such a situation the pipe could be damaged during subsequent river flow.

- **Infiltration-galleries —** Some installation technicians report installing infiltration pipes by jetting. By moving a jetting pipe slowly sideways through sediment rather than downward, the surface becomes fluidized to enable an infiltration pipe to be inserted. The practice is not as straight forward as downward jetting and requires experience and a greater degree of skill.

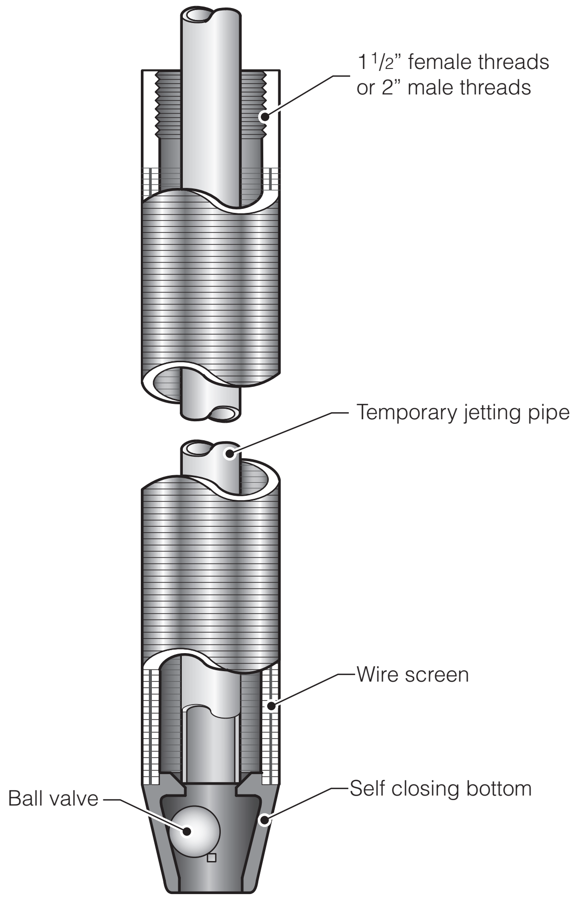

Figure 5.4. Self-jetting well-point

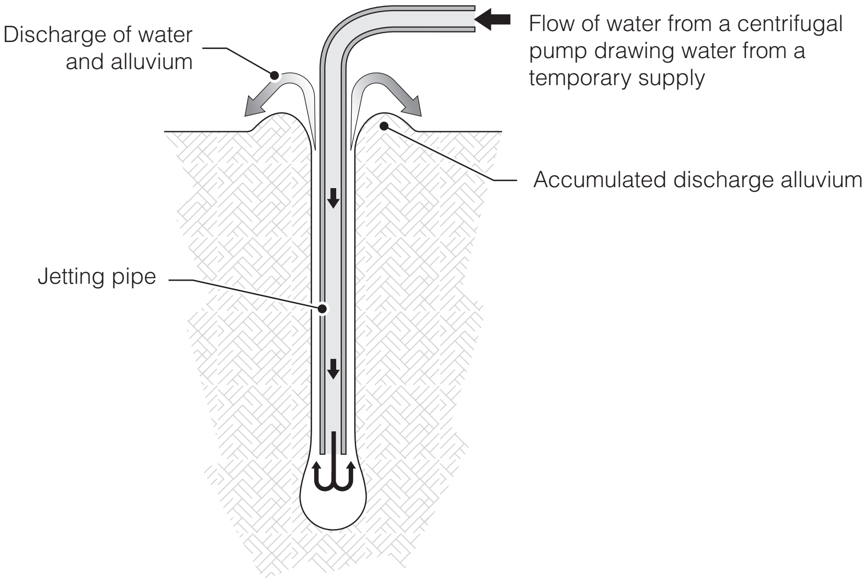

Figure 5.5. The jetting process

Photograph 5.8. Installing a self-jetting well-point

Chapter summary

There is a range of screens and abstraction methods that are suitable for use in a number of differing situations. The correct system will depend on the nature of the river channel, the type and volume of the sediment, the site conditions and the requirements of the end users.

A well-point and suction pump scheme is a basic system that is easily installed and often provides a straightforward effective solution in conditions where there is deep coarse sediment. Either an infiltration gallery and collector well system or a sand well are appropriate where sediment is fine or shallow. Other abstraction systems such as caissons and sand wells are best used where there is fine sediment and particularly in smaller river channels where it is possible to excavate deep into the riverbed.

The installation of well-points can be easily achieved by either digging, driving or jetting them into deep sediment. The installation of horizontal infiltration-galleries is more difficult due to the difficulty of digging sufficiently deep in fluidized sediment. This difficulty may also occur when attempting to install collector wells, caissons or sand wells to an adequate depth.

In order to determine the most appropriate water abstraction system and installation method each system must be assessed against the river and sediment conditions, the materials available and the resources of the beneficiary community.

When the most suitable abstraction system has been decided an appropriate method of drawing water to the surface will be required. There are many methods of water lifting, of which not all are suitable for every system of sand-abstraction.