SESSION 23

WELL CONSTRUCTION AND COMPLETION

Materials were prepared by House of Water and Environment (HWE)

Lecturers

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1 Introduction

Well construction consists of three main components:

- ✓ Setting (and pulling) of the well screen
- ✓ Placement of a gravel pack of formation stabilizer
- ✓ Sealing of the borehole annulus

The factors that determine the methods of well construction include the nature and hydraulic properties of the aquifer materials, drilling method, borehole dimensions, and type of casing and screen.

2. Materials

2.1 Casing Strength

I. Tensile Strength (axial)

- ✓ This is needed withstand installation processes when the casing string is suspended from the top of the borehole. The tensile stress is partly reduced by uplift from the water in the borehole.

- ✓ Will also be required if the casing is to be removed at a later date (tensile load increased in this situation by the “skin friction” of the formation).

2. Materials

II. Compressive Strength (axial)

- ✓ This is required if the ground in which the casing is installed settles.
- ✓ This casing string can in effect be standing on its base while supporting the well head fixtures and fittings (pump and pump-house included) and to some extend the adjacent formation because of friction.

2. Materials

III. Compressive Strength (Radial)

- ✓ Required to withstand differential hydraulic and “active” earth pressures. Differential hydraulic pressures most notable in upper well casing. Earth pressures are approximately equal to (700 x H) kg/m where H is the depth below ground level in sands, but can be computed (see soil mechanics text books).

- ✓ Axial strength given by:

$$\sigma \, x \, \pi \, x \, t \, x \, (D - t)$$

Where; σ is the unit strength of the material

t is the wall thickness of the pipe

D is the outer diameter of the pipe

2. Materials

- ✓ Radial strength approximately given by:

$$\frac{2.2\,E\,t^{3}}{D^{3}}$$

Where E is the modulus of elasticity

2. Materials

2.2 Material Selection

- ✓Material selection is a function of
- ✓Water quality;
- ✓Well depth and borehole diameter, which affect strength requirements;
- ✓Cost (capital expenditure; required longevity of well)
- ✓Drilling procedures and method of well installation;
- ✓Purpose of well (water supply; industrial; excavation dewatering; monitoring)
- ✓Regulations (national, Local)

2. Materials

Water Quality

- General indicators of corrosive waters include:
  - low pH;
  - Dissolved oxygen content > 2 mg/l (shallow unconfined aquifers)
  - Chloride concentrations > 500 mg/l
- General indicators of encrusting water include:
  - pH greater than 7.5;
  - Carbonate hardness > 300 mg/l
  - Dissolved iron concentration > 2 mg/l

2. Materials

2.3 Casing Materials

I. Steel

a. Strong

b. Ductile

c. Easy to handle

d. Relatively cheap

e. Subject to corrosive and encrustation

2. Materials

II. Special Steels

1. Coated (Galvanized) Steel

Coatings inhabit corrosion. Not very effective as coatings are inevitably scratched during installation and corrosive attack then concentrates in damaged area.

2. Low Carbon Steel

Slightly better corrosive resistance than mild steel, but more costly.

3. Stainless steel

Much better corrosion resistance than mild steel (depending on the actual chemical composition) but are much more expensive. Still a problem in some aggressive environments.

2. Materials

III.Other metals

Special alloys sometimes used especially for screens eg. Brass, nickel/copper, nickel/iron. Characteristics dependent upon composition (see Table 2.1).

✓**Glass Reinforced Plastic (GRP or Fiberglass)**

- Relatively Strong (similar to steel)
- Relatively brittle
- Relatively expensive (similar to stainless steel)
- Chemically inert

2. Materials

✓**Thermoplastics**

Various compounds are used, such as

-ABS (acrylonitrile butadiene styrene)

-PVC (polyvinyl chloride)

-SR (tuber-modified polystyrene)

-Polyolefin

-Polypropylene (including HDPE)

2. Materials

The properties of these vary according to the different chemistry, but are generally:

- Relatively weak and/or brittle. Can suffer from creep under sustained loading
- May be susceptible to ultra-violet light, making them brittle
- Susceptible to heat deformation, therefore not suitable for deep wells
- Chemically inert, therefore not susceptible to corrosion
- Relatively cheap for simpler compounds

2. Materials

Table 2.1: Basic Composition and uses of various metals for water-well casing and screens

Metal	Composition		Uses
Steel, low-	Carbon	0.8% max	Used where waters are non-
carbon	Iron	Balance	corrosive and non-encrusting
Stainless steel,	Chromium	18% min	Used for wells in corrosive
type 304	Nickel	8% min	environments; most
Stainless steel,	Manganese	2% max	commonly used stainless
type 316L	Carbon	0.08% max	steel screen materials
Stainless steel	Iron	Balance	Used in ground waters of
	Chromium	16% min	moderate salt content
	Nickel	10% min	Used for potable waters of
	Molybdenum	2% min	low to medium corrosivity
	Carbon	0.03% max	
	Iron	Balance	
	Chromium	11.5% min	
	Aluminum	0.3% max	
	Iron	Balance	

2. Materials

2.4 Methods of Joining

The joints are in general the weakest link in the casing string, but are generally designed to carry the tensile and compressive loads that the casing material has to withstand.

- Threaded coupling (can be used in any casing materials)
- Mechanical key locks (mainly used for thermoplastics and GRP)
- Welding (used for steel based casing)
- Solvent welding (used for thermoplastics “otherwise known as glueing!”)

3. Installation and Removal of Screens

Methods commonly used to install well screen include Pull-pack method, open-hole method, bail- down method, wash-down method, and jetting method.

3.1 Pull-Back Method

The pull-back method (**Figure 3.1**) entails three main steps:

- ✓Lower a drive or bail casing to the full depth of the well.
- ✓Lower (telescope) screen inside the casing.
- ✓Pull back the casing to enable allow direction contact between the screen and the aquifer.

3. Installation and Removal of Screens

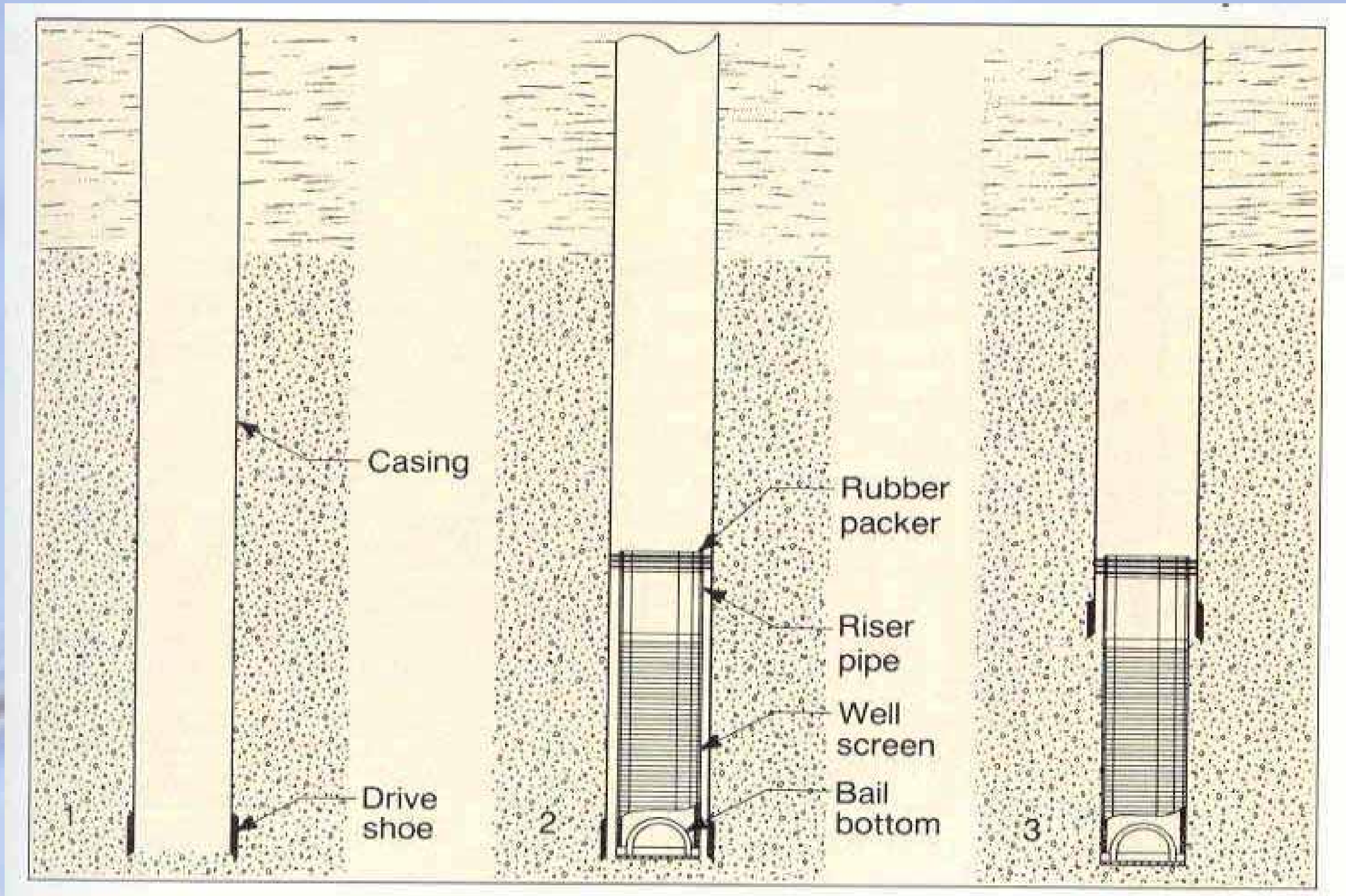


Figure 3.1 Pull-back method of setting well casing and screen

3. Installation and Removal of Screens

A riser pipe may be attached to the top of the screen; this pipe prevents the loss of the screen through casing bottom and prevents settling during well development in loose or unconsolidated formations. After the casing has been pulled back to expose the screen, a rubber packer is emplaced to provide a sand-tight seal between the top of the telescoped screen and the casing (Figure 3.1). If the casing is filled initially by cuttings or other loose material, these materials need to be removed before the screen is lowered and the casing pulled back. The pull-back method of installing well screen is analogous to the use of a hollow-stem auger in which the well is installed inside of the auger.

3. Installation and Removal of Screens

3.2 The open-hole method

The open-hole method is commonly used in rotary-drilled wells for installing screen. The following steps are completed:

- ✓ An open hole is drilled to the top of the aquifer and the casing is set (**Figure 3.2**). a grout shoe (plug) is set, and the casing is grouted in place. All grout-contaminated fluids then are removed.

- ✓ The aquifer is drilled by using a smaller diameter bit.

3. Installation and Removal of Screens

- ✓ The screen (that has a riser pipe) is lowered into the formation below the casing; a packer is used to seal the connection between the riser pipe (or screen) and the casing (Figure 3.2).

- ✓ The well may be naturally developed or gravel packed. If the well is gravel packed, the use of a cross-over tool (**Figure 3.3**) for deep wells or the inner-casing method (**Figure 3.4**) may be used.

3. Installation and Removal of Screens

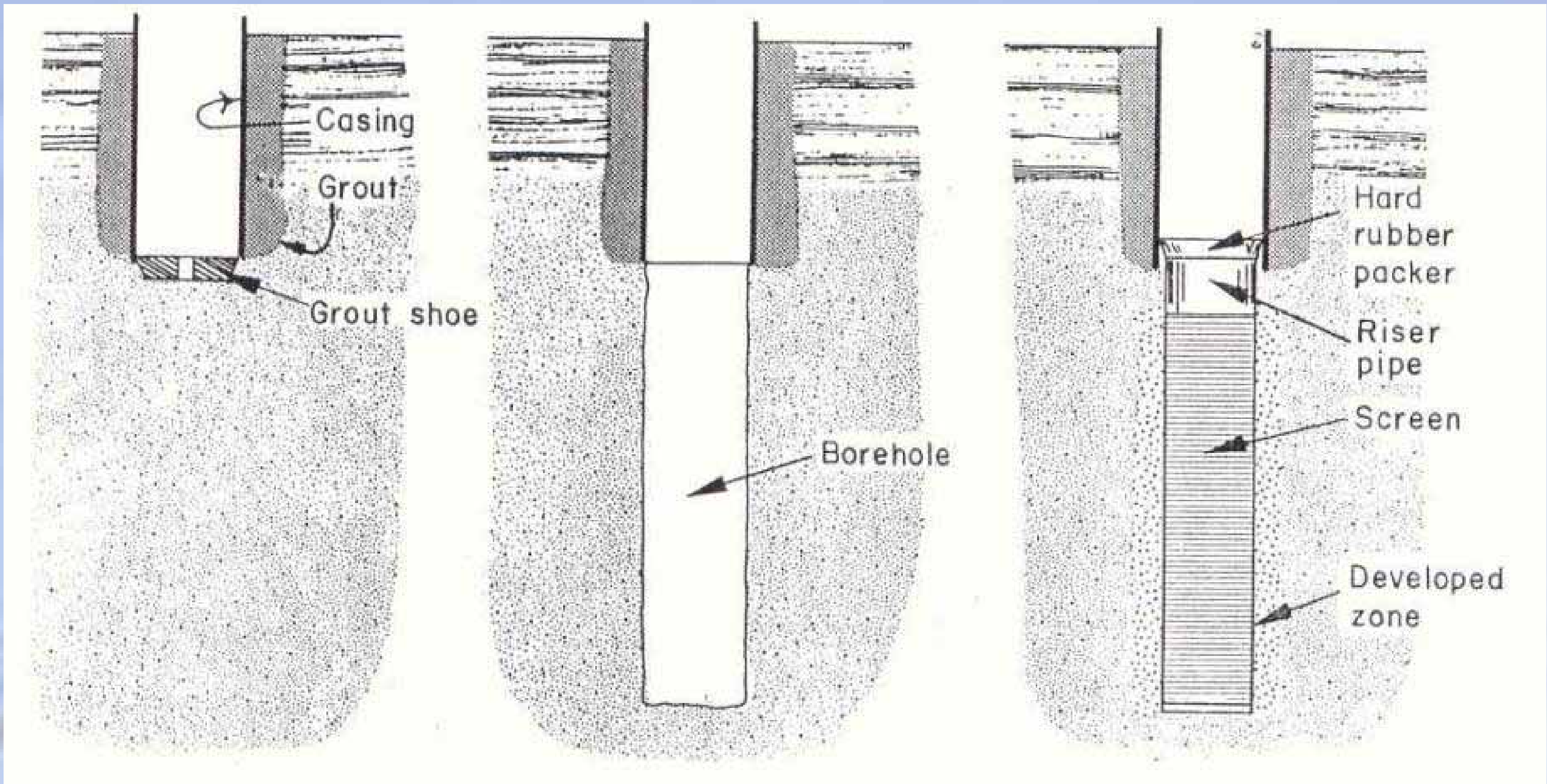
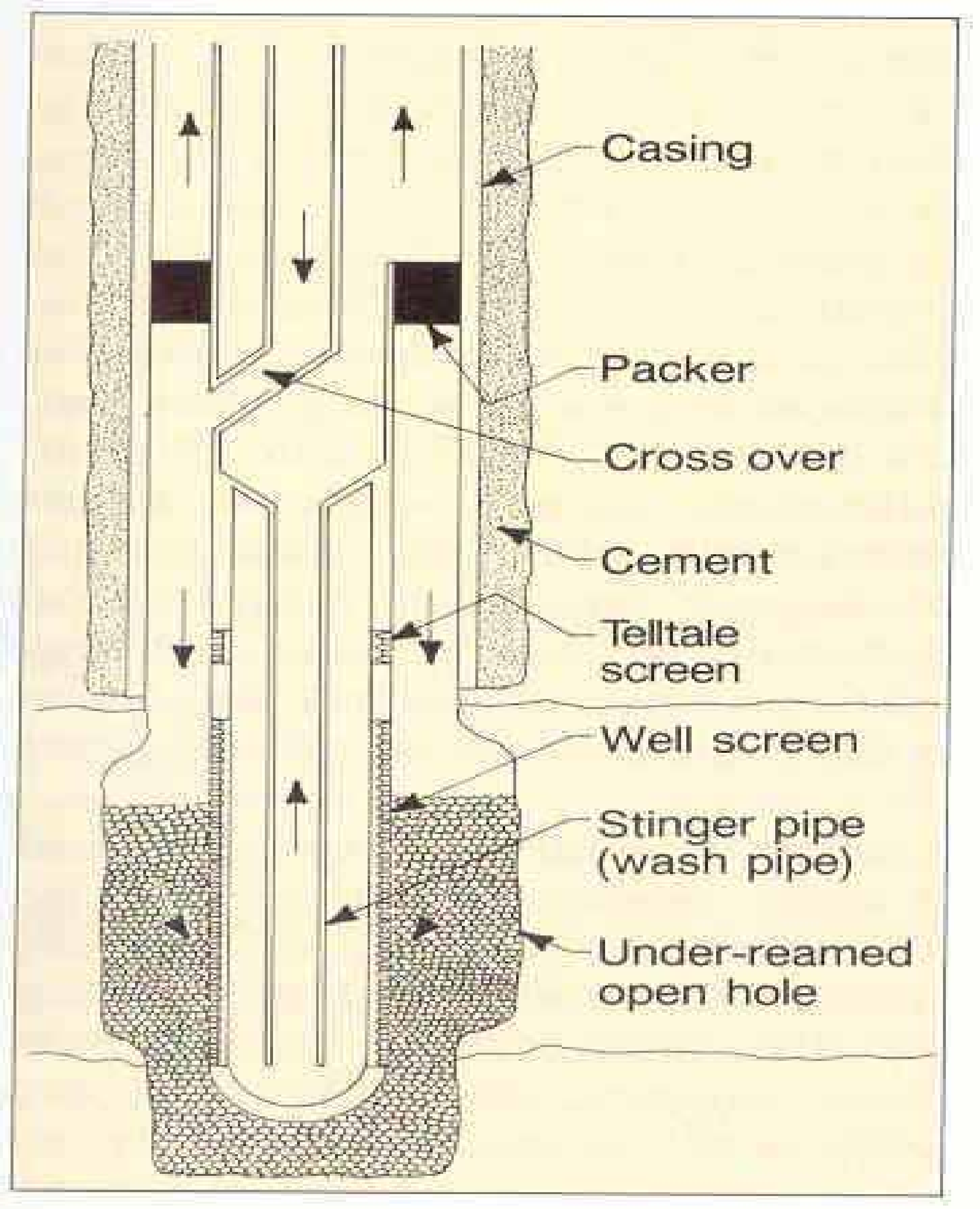


Figure 3.2 Open-hole method of setting well screen

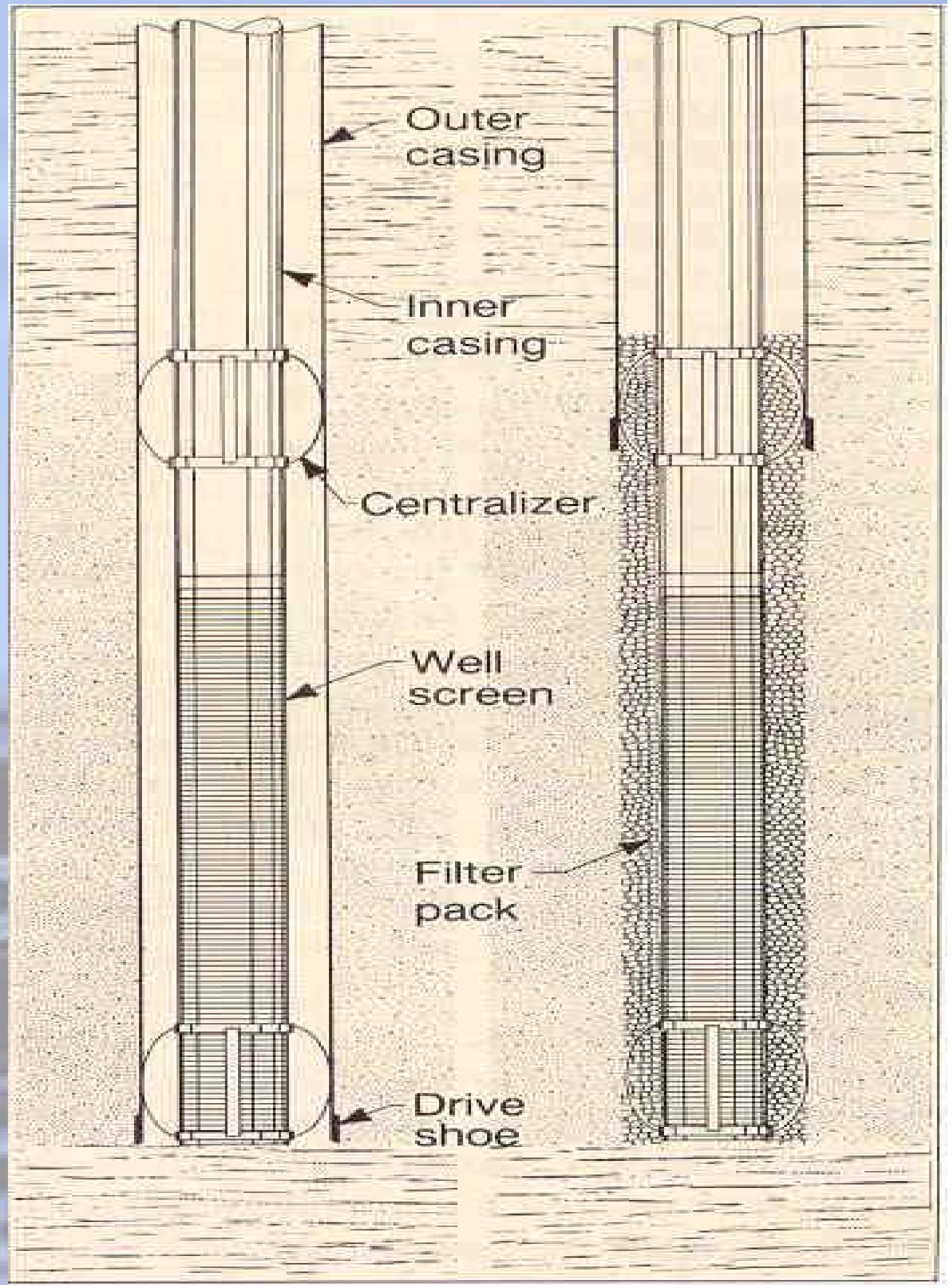
3. Installation and Removal of Screens

Figure 3.3 Cross-over tool used for setting well screen and for placing filter pack



3. Installation and Removal of Screens

Figure 3.4 Inner-casing method for placing filter pack.



3. Installation and Removal of Screens

In small-diameter, rotary-drilled wells that are completed in unconsolidated sediments, the screen and casings are attached and installed directly as a single string. If natural development is used, a formation stabilizer may be emplaced to prevent fine material above the aquifer from settling next to the screen. Methods for installation of plastic screen are similar to those for steel screen; however, greater care is needed during installation because of the lesser material strength.

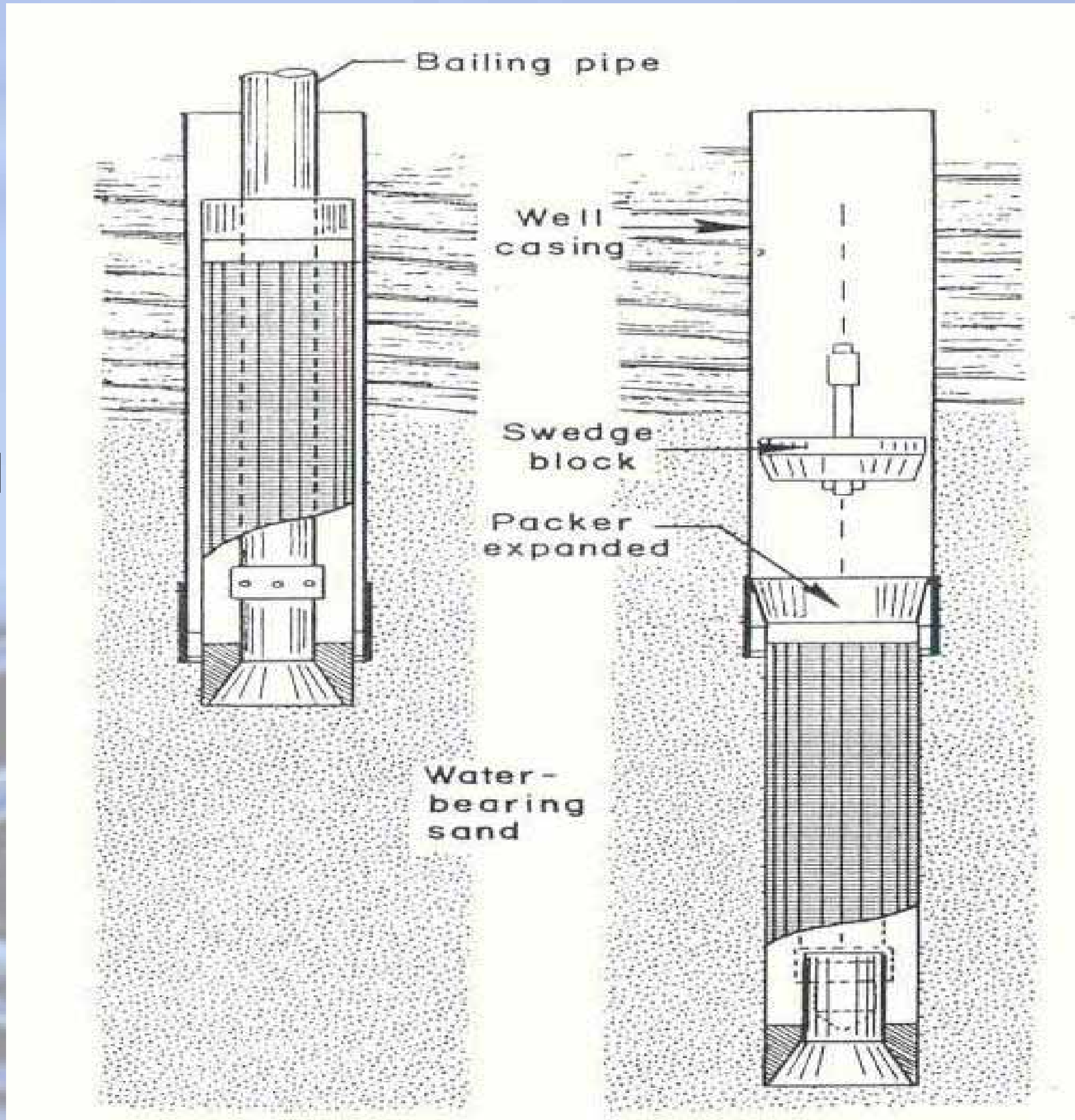
3. Installation and Removal of Screens

3.3 Bail-down method

The bail-down method is used in soft formations to remove sediment from below the screen which enables the screen to settle (**Figure 3.5**). The wash-down and jetting methods are used to flush unconsolidated materials away from the screen and up the borehole and to enable the screen to be washed down into place.

3. Installation and Removal of Screens

Figure 3.5 Bail-down method for placing well screen



3. Installation and Removal of Screens

A special fitting called packer is required to provide a sand-tight seal between the top of the telescopic screen assembly and the casing (see **Figure 3.6 and 3.7**)

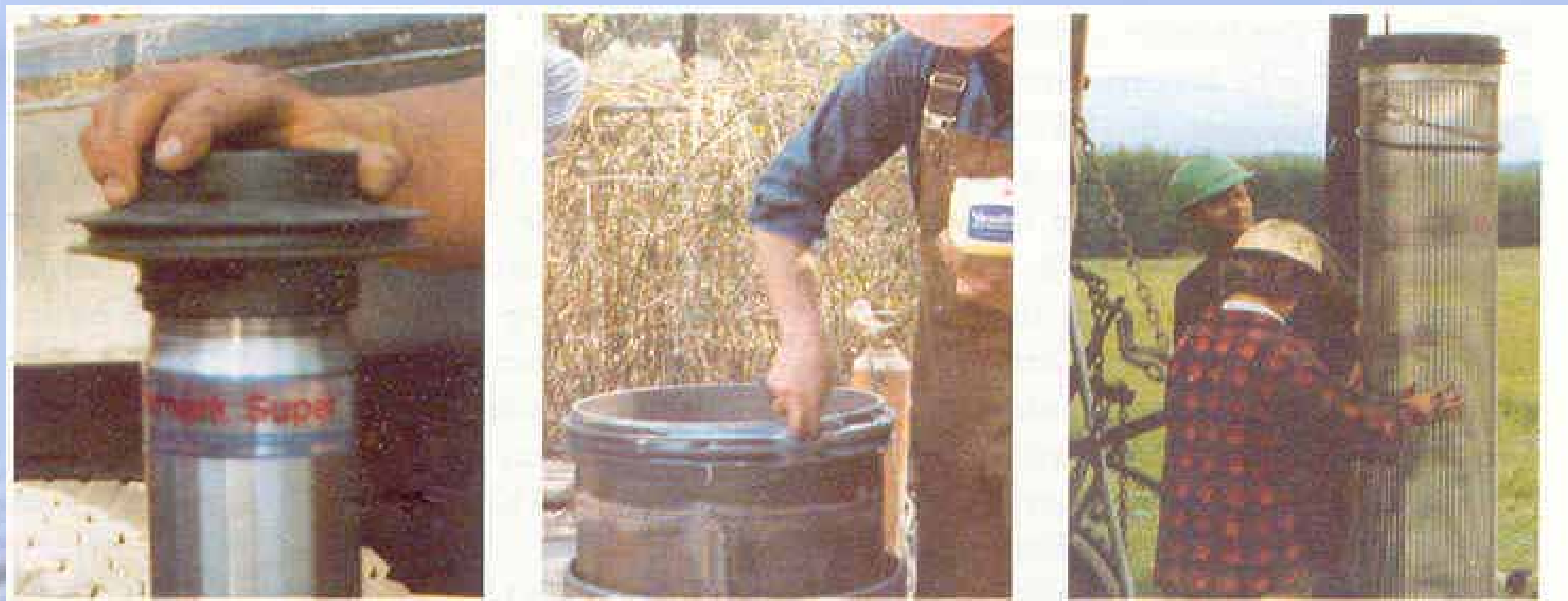
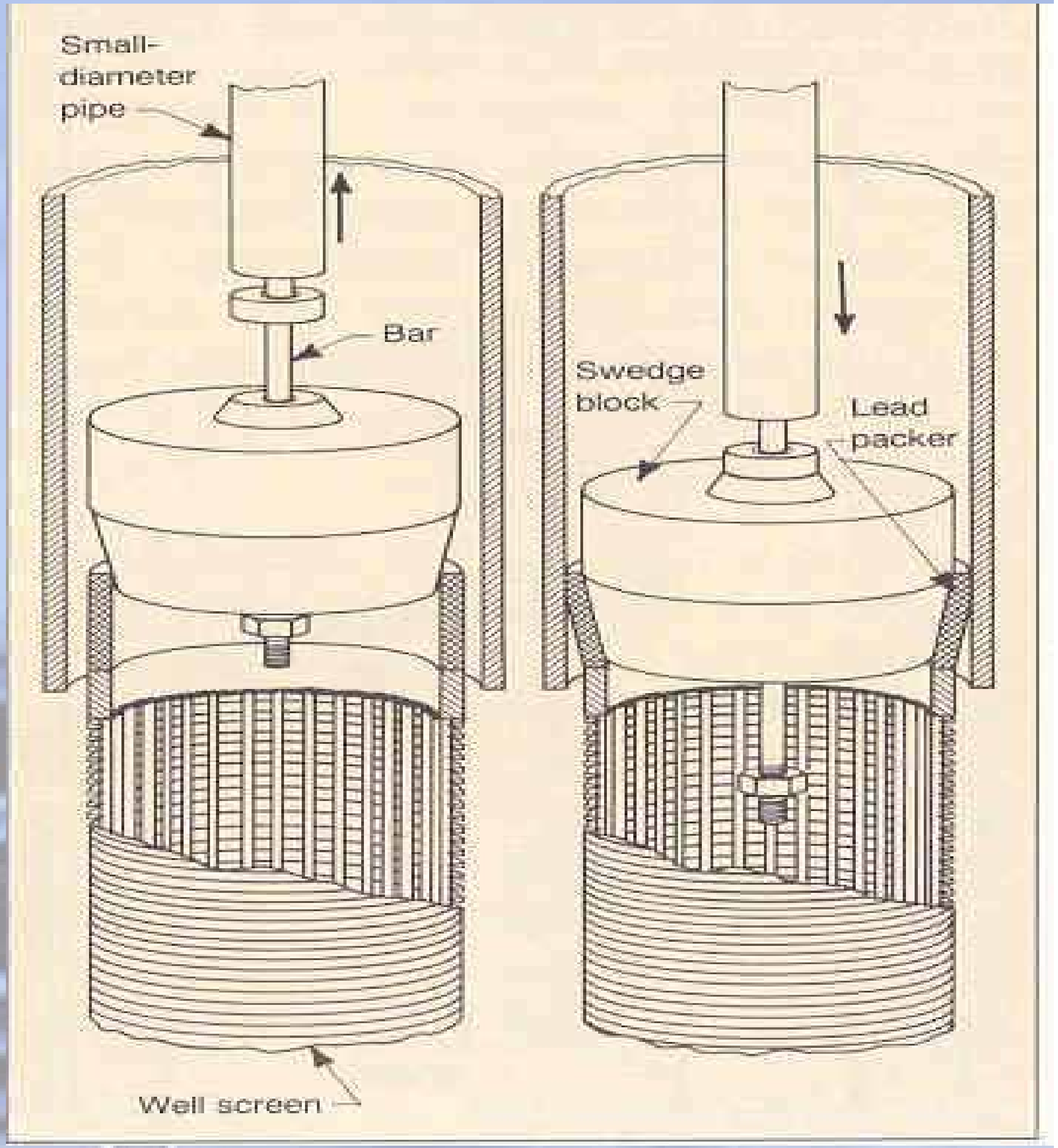


Figure 3.6 Self-sealing neoprene rubber packers from an effective seal between the casing and upper end of the screen or riser pipe (left). Petroleum jelly is often applied to the lips of the packer to minimize damage that may occur as the packer and screen assembly is lowered into the casing (center). The screen is lowered into place by the sand line (right).

3. Installation and Removal of Screens

Figure 3.7 A swedge block is used to expand a lead packer attached to the top of a telescoped screen assembly



4. Placement of Gravel (Filter) Packs

- The placement of the gravel (filter) pack is an integral part of proper well constraution, particularly where a graded mixture is used (see **Figures 4.1** and **4.2**). A gravel-pack material placed directly into the annular space around the casing at the surface may result in the separation of the fine and coarse fractions as the particles settle through the water or mud in the borehole, or brindging or voids may occur.

- The gravel pack should never extend to the surface as it would provide a highly permeable conduit for the passage of pollutants from the surface.

4. Placement of Gravel (Filter) Packs

- A tremie or conductor pipe is used to minimize the potential for segregation of grain sizes and bridging during placement of the gravel pack. The tremie pipe is lowered into the annular space and the gravel-pack material, mixed with water, is fed through a hopper to minimize the potential for bridging. The gravel-pack material also may be pumped through the tremie pipe rather than being fed by gravity. The tremie pipe is raised as the gravel pack in the well bore needs to be measured periodically, to confirm proper placement, using a weight attached to a steel tape.

4. Placement of Gravel (Filter) Packs

- Emplacement is usually via two tremie pipes on opposite sides of the hole. Size of tremie pipe is dependent upon the annular space, but should be a minimum of 50 mm internal diameter. A general rule is :

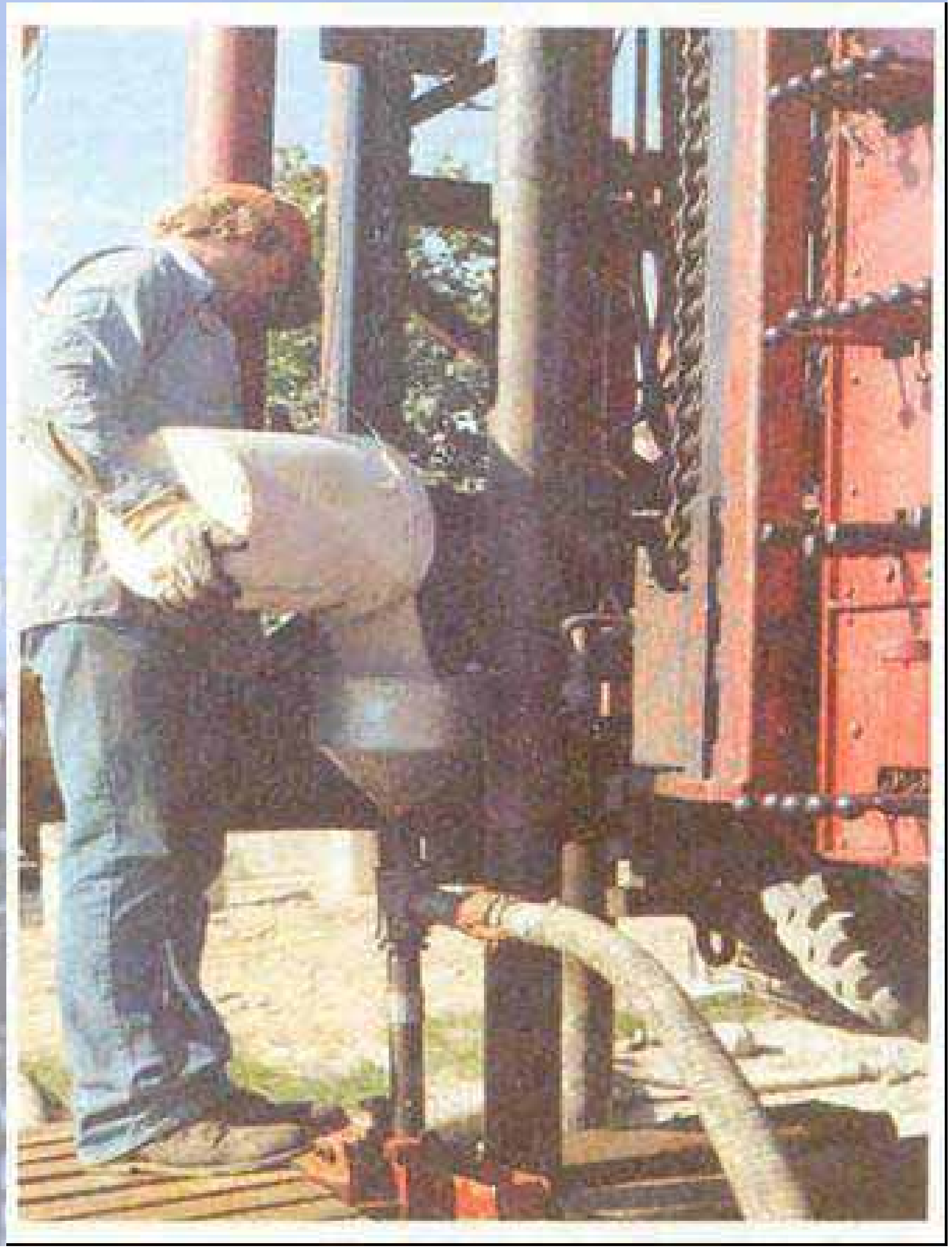
$$ID > 12xD_{100} \text{ gravel pack}$$

- This should be noted when deciding on drilling diameters.

- The tremie pipes are lowered to the base of the hole and gradually withdrawn as gravel is emplaced.

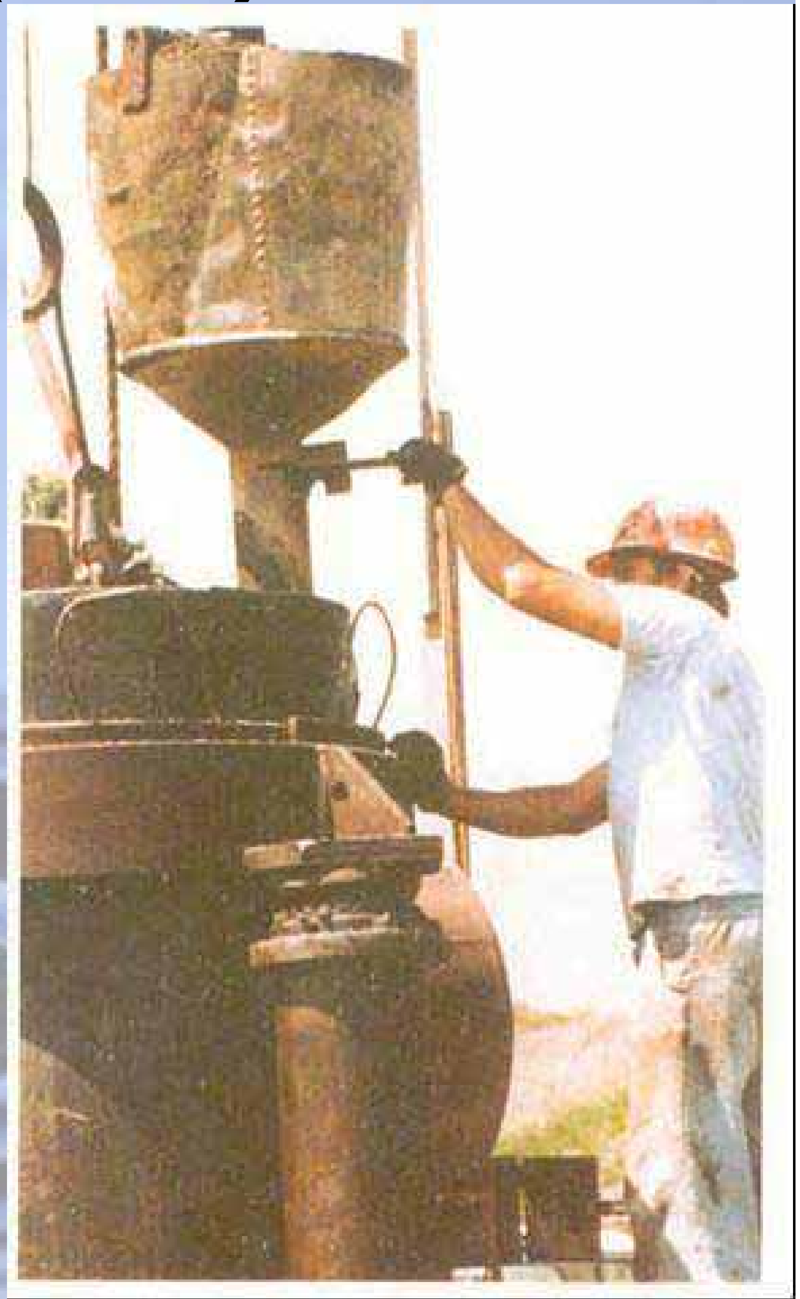
4. Placement of Gravel (Filter) Packs

Figure 4.1 A filter pack can be placed in the annular space between inner and outer casings by using a small hopper attached to the top of a tremie pipe. Water is introduced into the tremie to prevent bridging of the gravel material.



4. Placement of Gravel (Filter) Packs

Figure: 4.2 Continuous-feed hoppers facilitate the installation of large volumes of pack material.



5. Well Base

If the base of the well is in a soft formation such as running sand or clay, the well should be overdrilled and provided with a concrete or gravel base of (1-2) m depth to enhance well stability and reduce the possibility of subsidence.

6. Grouting

In most wells, a seal is needed above the top of the gravel pack to isolate the open section in the well from the overlying formations and the ground surface. The seal usually consists of bentonite or bintonite/cement grout to prevent leakage along the borehole and to minimize surface or interaquifer communication. In loose formations, a grout seal is placed below the top of the water-bearing zone to prevent the piping of overlying materials into the gravel pack. The technique for placement of a seal is similar to that for the gravel pack. The preferred method is to tremie the seal material to ensure placement at the desired depth. If a coarse gravel pack is used, a graded filter may be needed between the gravel pack and the bentonite seal to prevent piping of the bentonite into the gravel pack.

6. Grouting

Bentonite pellets, which are balls of compressed bentonite, can be used as a seal. These pellets tend to settle and then expand to about 10 times the original volume. If properly placed, 150 mm or less of bentonite normally is adequate to obtain an effective seal

The preferred method of sealing the remainder of the borehole is with a cement/bentonite grout mixture. Frequently, 2 to 3 percent of bentonite is added to the cement to promote expansion and, therefore, to provide a greater degree of impermeability.

Native clays also are used to provide a surface seal. However, natural clays that are reintroduced into the borehole need to be compacted properly to achieve the desired degree of impermeability.

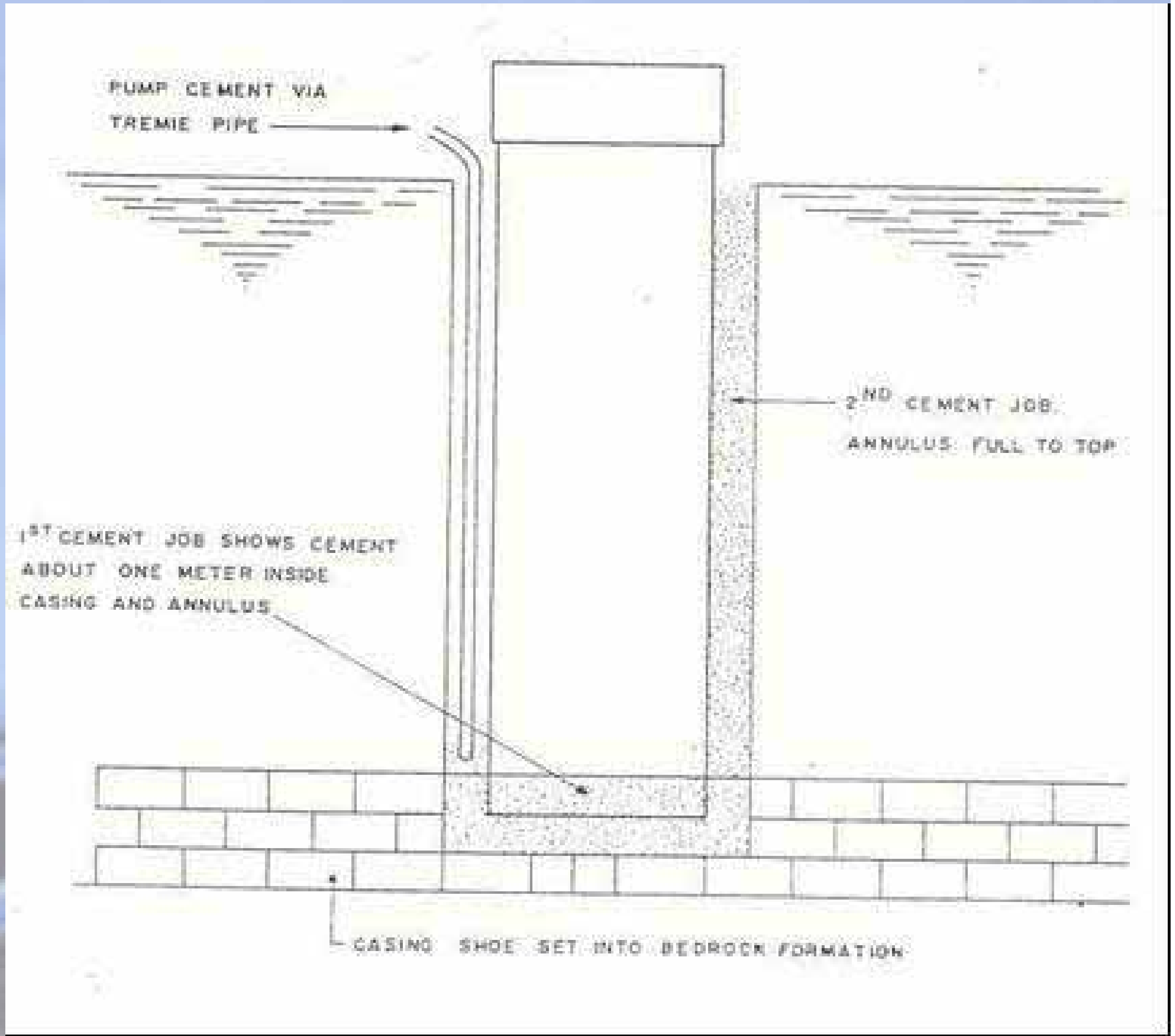
6. Grouting

Figure 4.3 Three cement trucks are required to provide enough cement to grout the casing in this 150 m borehole. The cement is pumped from the stock tank into the borehole by a positive displacement duplex pump, shown on the left.

6. Grouting

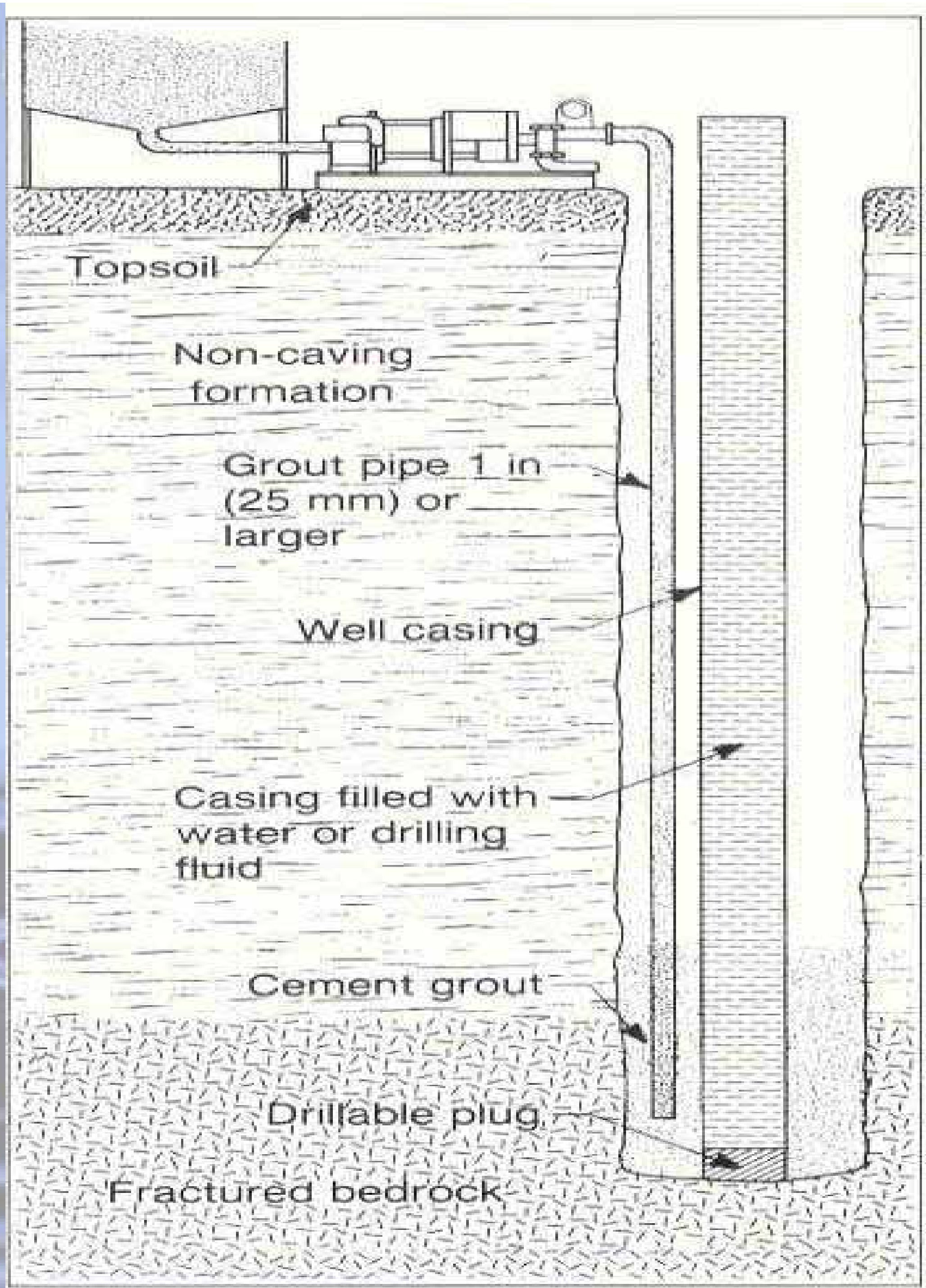
Figure 4.4

Cementing via tremie pipes



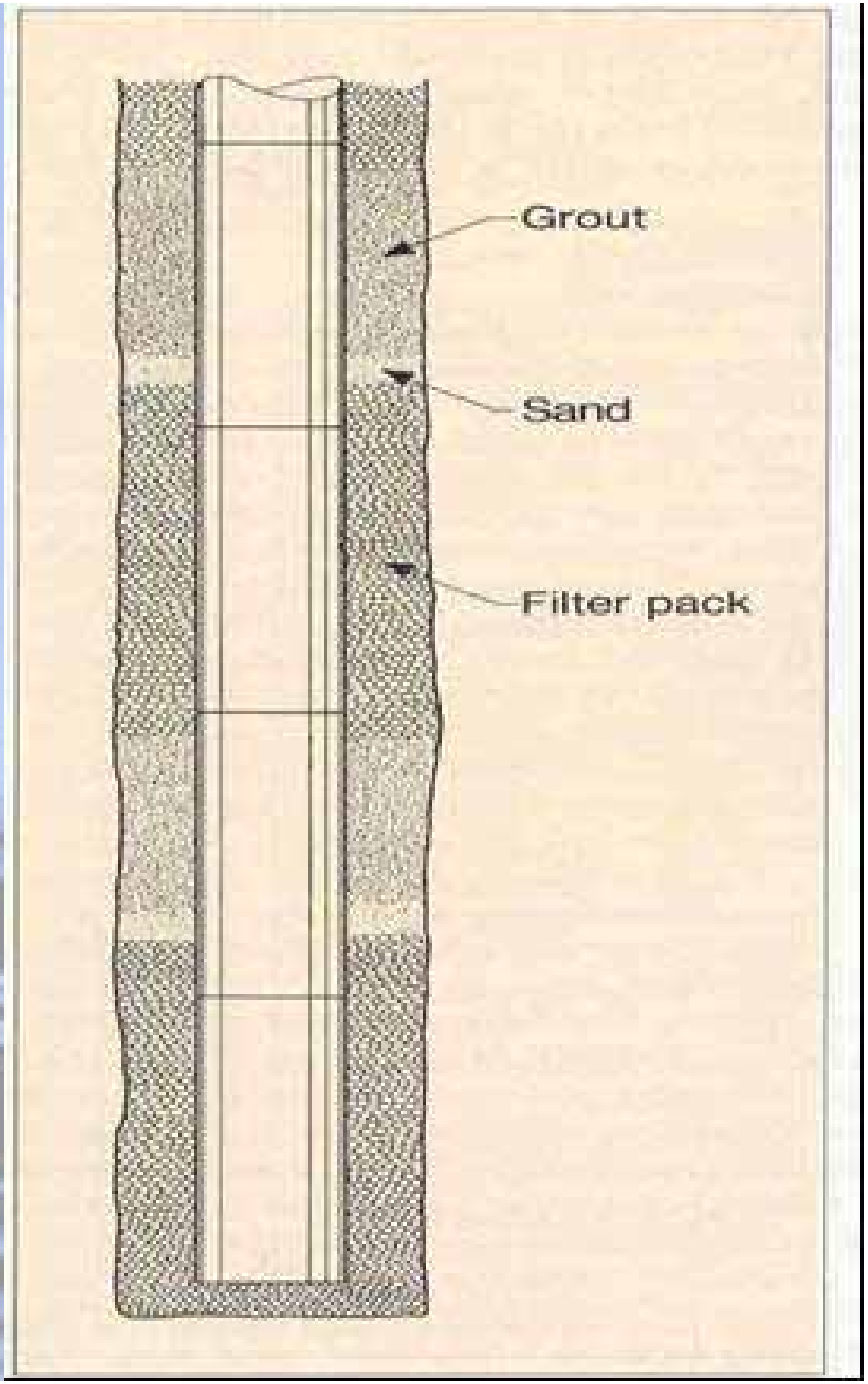
6. Grouting

Figure 4.5 Grouting can be accomplished by means of a tremie pipe suspended in the annulus outside the casing. During grouting, the bottom of the tremie should always be submerged a few feet beneath the grout level. As the grout level rises, the tremie should be withdrawn at approximately the same rate.



6. Grouting

Figure 4.6 Sand is sometimes placed on the top of the filter pack to prevent grout from penetrating into the pack



7. Other Elements of Casing Design

- **Bail plug (sediment trap)**: blank casing at the base of well to collect material which settles to bottom. This can be occasionally bailed out, especially during development.

- **Bottom cap**: seal at the base of casing/screen string to prevent influx of aquifer material from base.

- **Reducer**: specially fabricated piece to join casing elements of different diameters.

- **Centralisers**: device to hold the lower casing and screen string centrally during emplacement.

7. Other Elements of Casing Design

- **Hanger (annulus seal)**: device used to place of a reducer when the casing string is emplaced in two parts. The seal can take the form of an expandable or lead packer which allows the emplacement of a gravel pack, or of a neoprene seal attached to the casing string, which does not.

- **Top piece or riser pipe**: a section of blank casing at the top of the screen section. This is a precautionary measure in case there is settlement of the gravel pack leading to exposure of the screen fines.