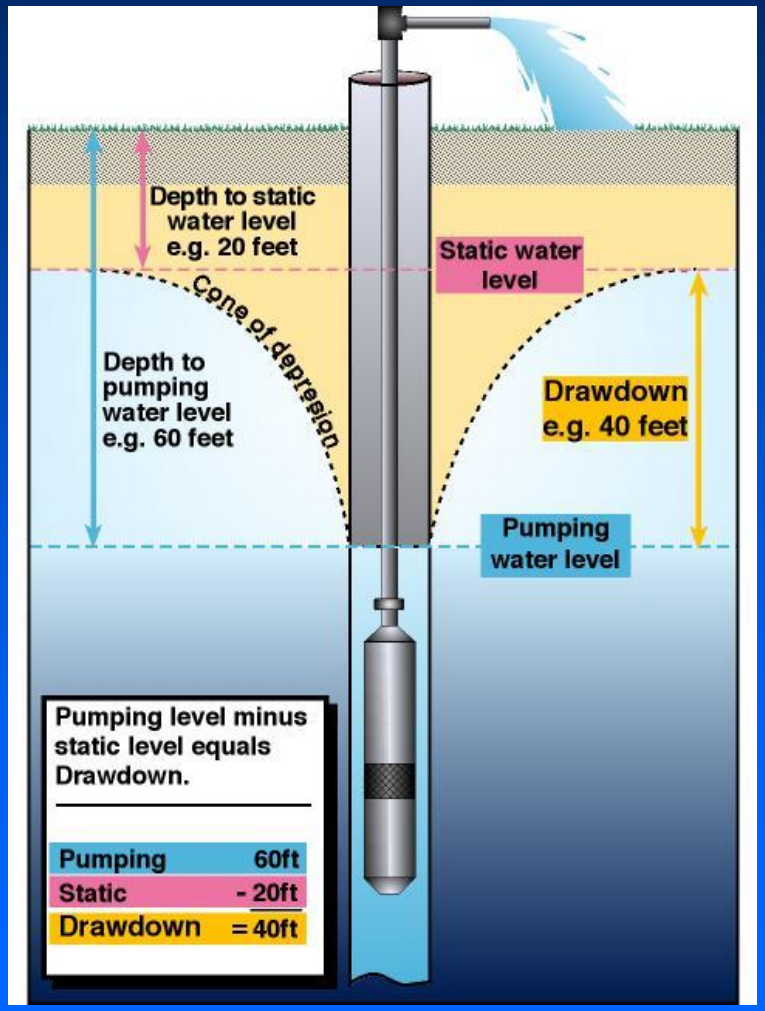
WATER WELL Design and Construction



WATER WELL DESIGN

- **Well is** a hydraulic structure that is designed and constructed to permit economic withdrawal of water from an aquifer
- Water well design and construction include:
  - Selection of appropriate site
  - Selection of appropriate drilling method
  - Selection of appropriate construction materials
  - Analysis and interpretation of pumping test data to determine well and aquifer performance

WATER WELL DESIGN

- Provide the demand that meets needs of owner
- Obtain highest possible yield with minimal drawdown (consistent with aquifer capabilities)
- Provide good quality water (potable and low turbidity)
- Provide long service life (25+ years)
- *Minimize the impacts on neighboring wells and environments (e.g. aquatic).*

Stages of Well Design

Preliminary design.....based on existing information

- Available data and information from nearby boreholes (well design)
- The intended purpose of the well (water supply, irrigation, industrial...)
- The over all design period, design population, level of service, etc
- Possible sources of pollution
- Cost

Final design ----- based on the findings of the actual drilling

- Nature of the unsaturated zone, aquifer type and hydraulic properties
- Well depth and diameter
- Casing diameter, strength, length and others
- Groundwater quality results

COMPONENTS OF FINAL WELL DESIGN

Well cap/ seal

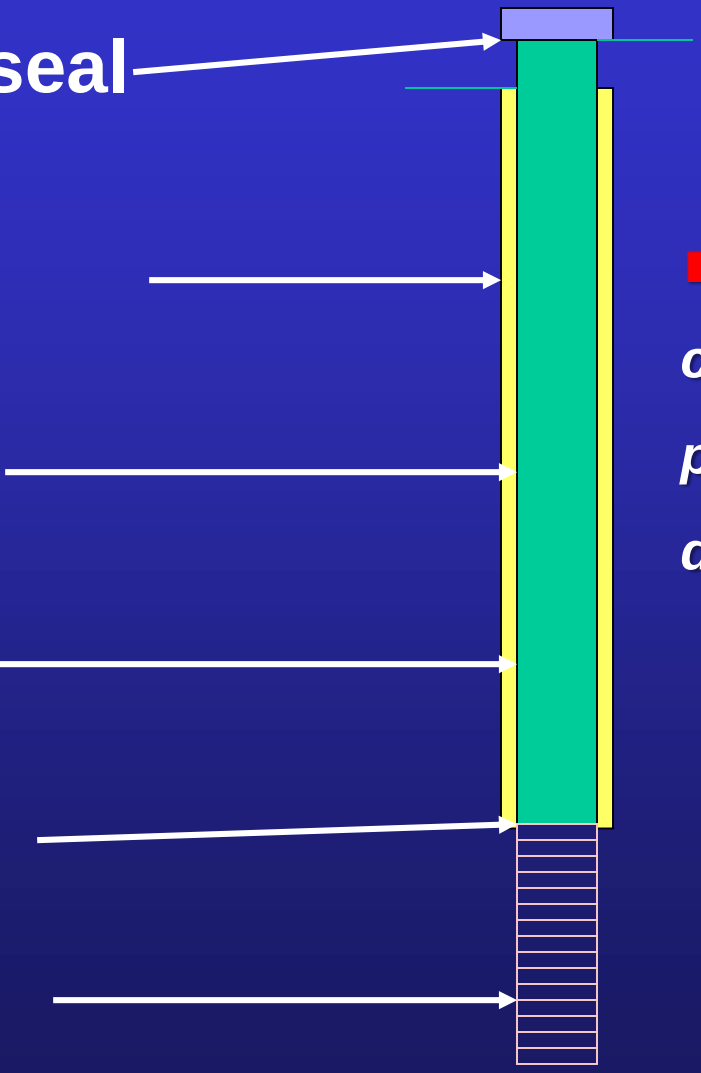
Borehole

Casing

Grout

Packer

Screen



- ***Test well** drilling can be considered as option to prepare the preliminary design*

Detail considerations during Well design

1. Geological considerations

- Type and physical and chemical properties of rocks should be considered

2. Hydrogeological considerations

- The slope of the ground surface
- The surface soil and expected subsurface formation
- The recharge zone and the current and long term water balance
- The water quality and whether it is aggressive or mineralized etc.
- The expected aquifer thickness, type and depth
- Possible source of pollution, distance, and direction

- Keep reasonable distance from possible sources of pollution:-
  - Buried fuel tanks
  - Sewerage systems
  - Landfills
  - Waste disposal sites
  - Industries which can produce poisonous chemicals and by-products

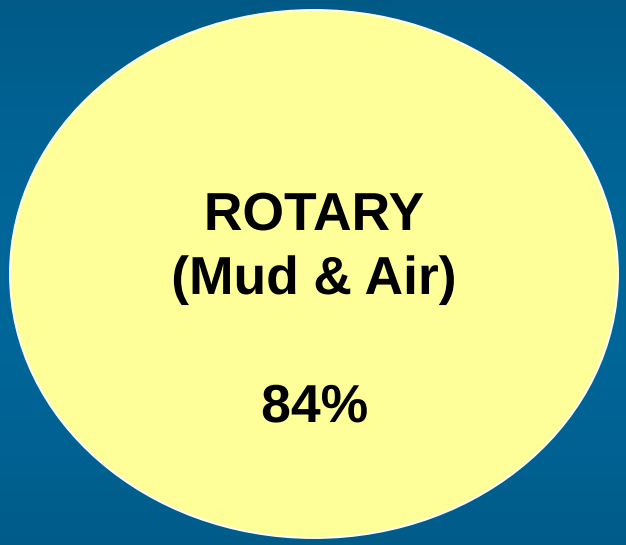
⇒Otherwise the design has to include appropriate **protection mechanism**

3. Drilling Methods

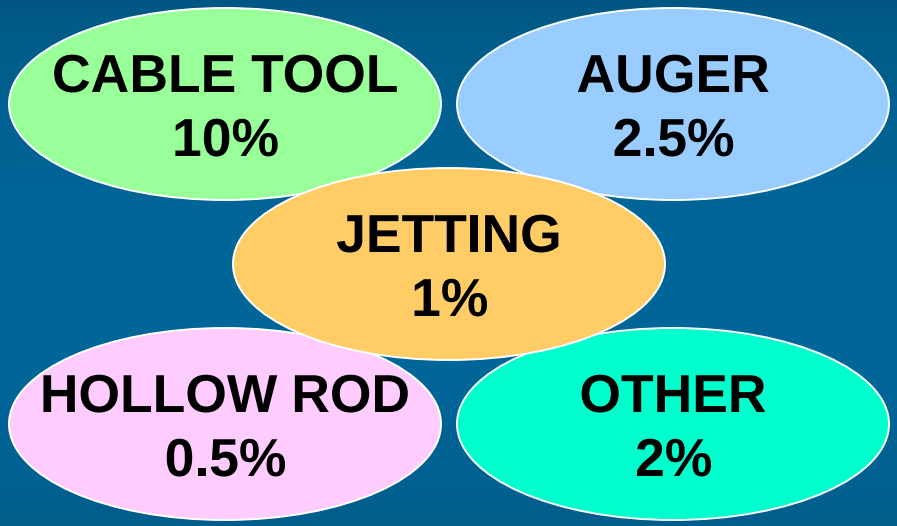
- Cable tool drilling / Percussion rig
- Rotary drilling
- Others (Auger, Jetting, Hollow rod…)

….DRILLING METHODS

MOST COMMON:



LESS COMMON:



- The governing factors for the type of machine and method are:
  - Type of the geological formation
  - Drilling depth and diameter

Cable tool drilling/Percussion Rigs

- Crushes the rock under the weight of a tool dropped down the hole on a length of cable
- Suitable for unconsolidated and soft formations
- Relatively slow

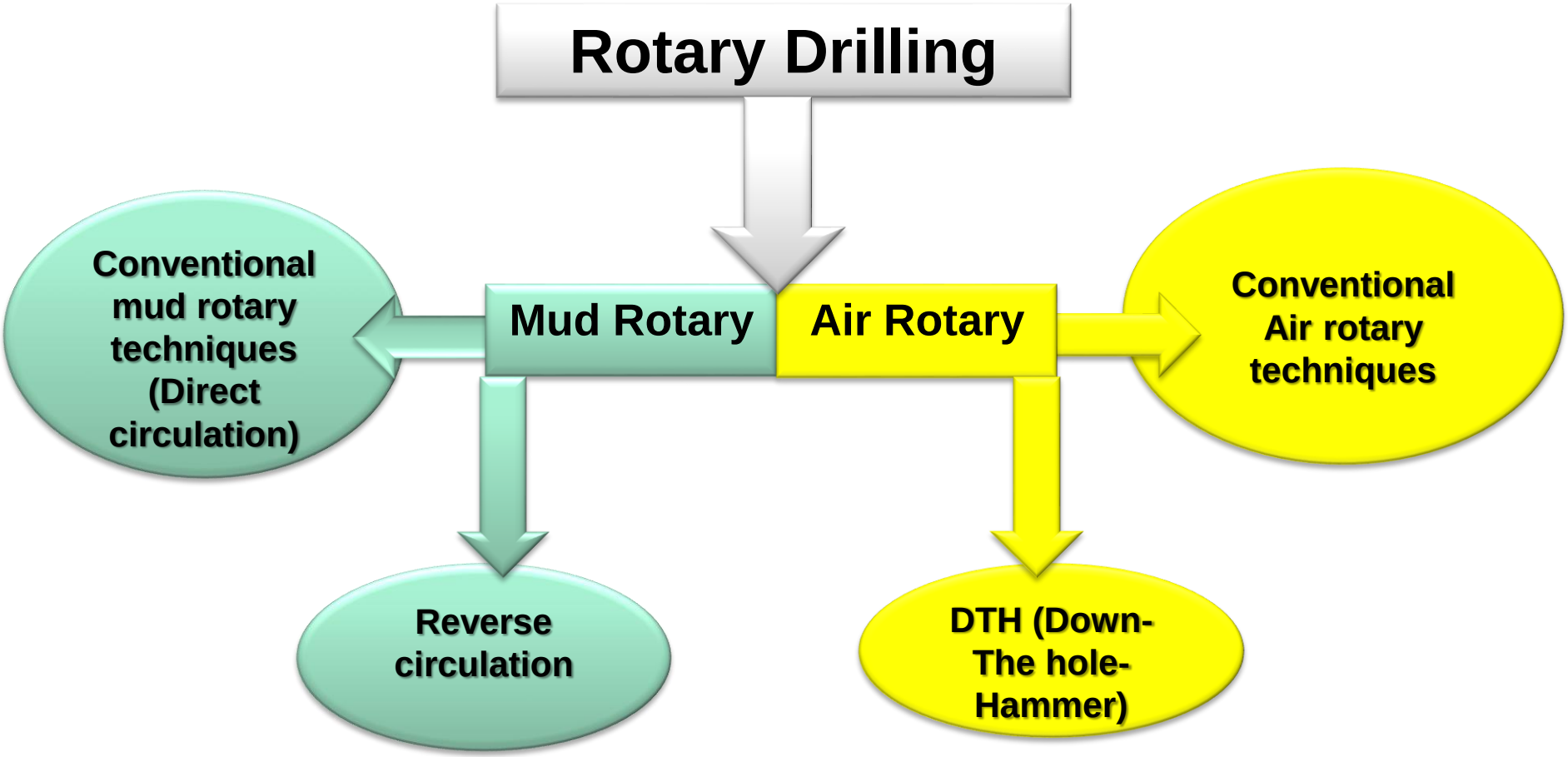
Rotary drilling

- Faster
- Can be used for all rock types
- Can drill to great depths (1000^{+} m)
- Drill bits attached to the end of a segmented string of steel drilling rods
- As the drilling rods rotate, the bit grinds through the soil and rock
- Air, water or drilling mud used as a circulation fluid to remove cuttings of rock and soil

Drilling bit (Cutter) may be made from:

- Steel
- Tungsten carbide
- Natural diamonds
- Polycrystalline diamonds

Tricon drilling bit



A combined percussion and rotary method that penetrates rapidly in consolidated formations.

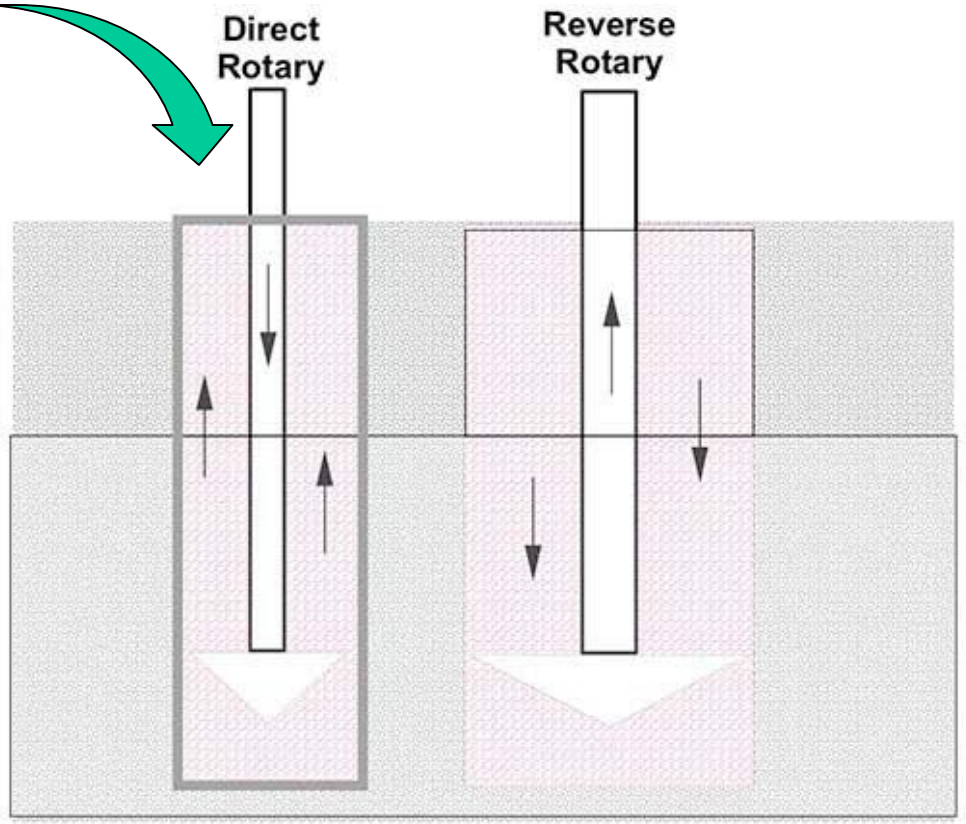
Conventional (Direct) circulation

⇒ The drilling fluid is circulates from the drill pipe and then flows up the annulus between the outside of the drill stem and borehole wall.

Reverse circulation

⇒ The direction of flow of drilling flow is opposite to that of direct circulation drilling. Drilling fluid flows from the annulus between the drill pipe and hole wall to the drill stem.

Drilling pipe



Rotary drilling bit

Hammer bit/DTH

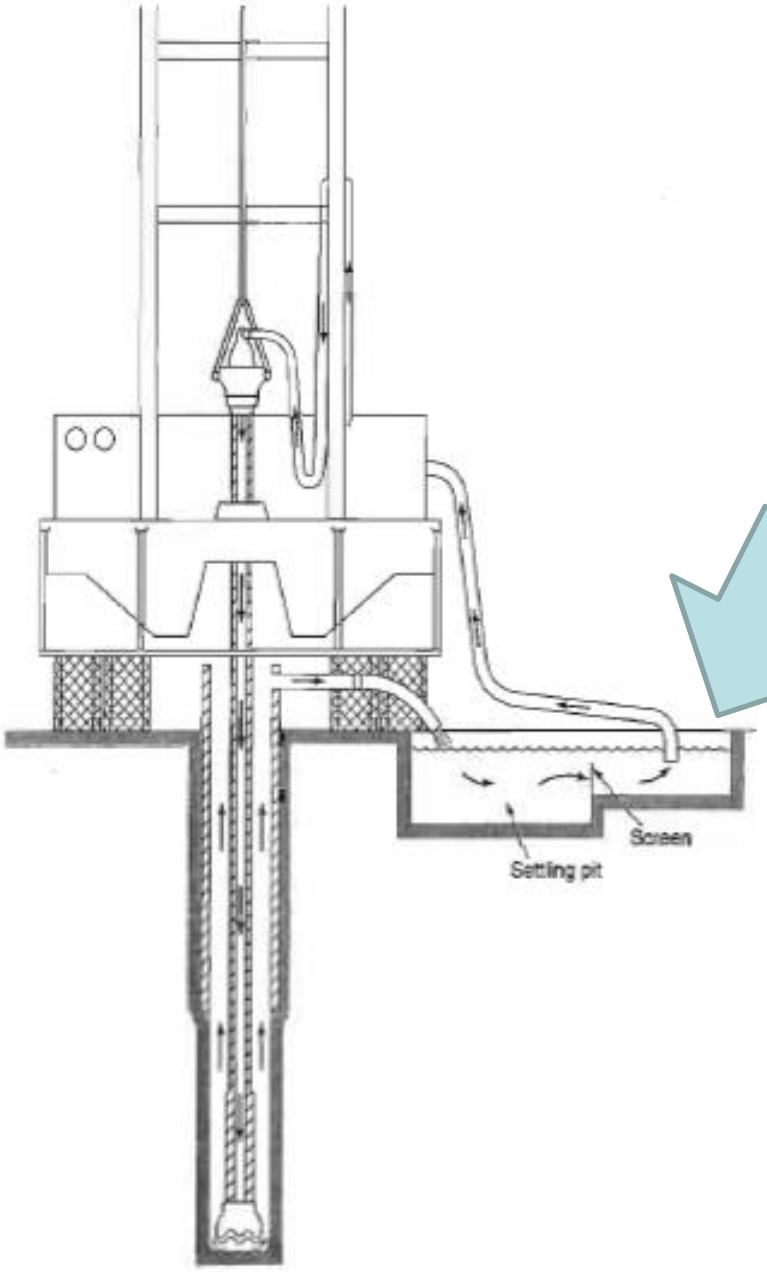
Drilling fluids

The purpose of drilling fluid is:

- Remove cuttings
- Cool and clean drilling bit
- Lubricate drill assembly
- Maintain wellbore stability
- Prevent loose of circulation

Types of drilling fluids

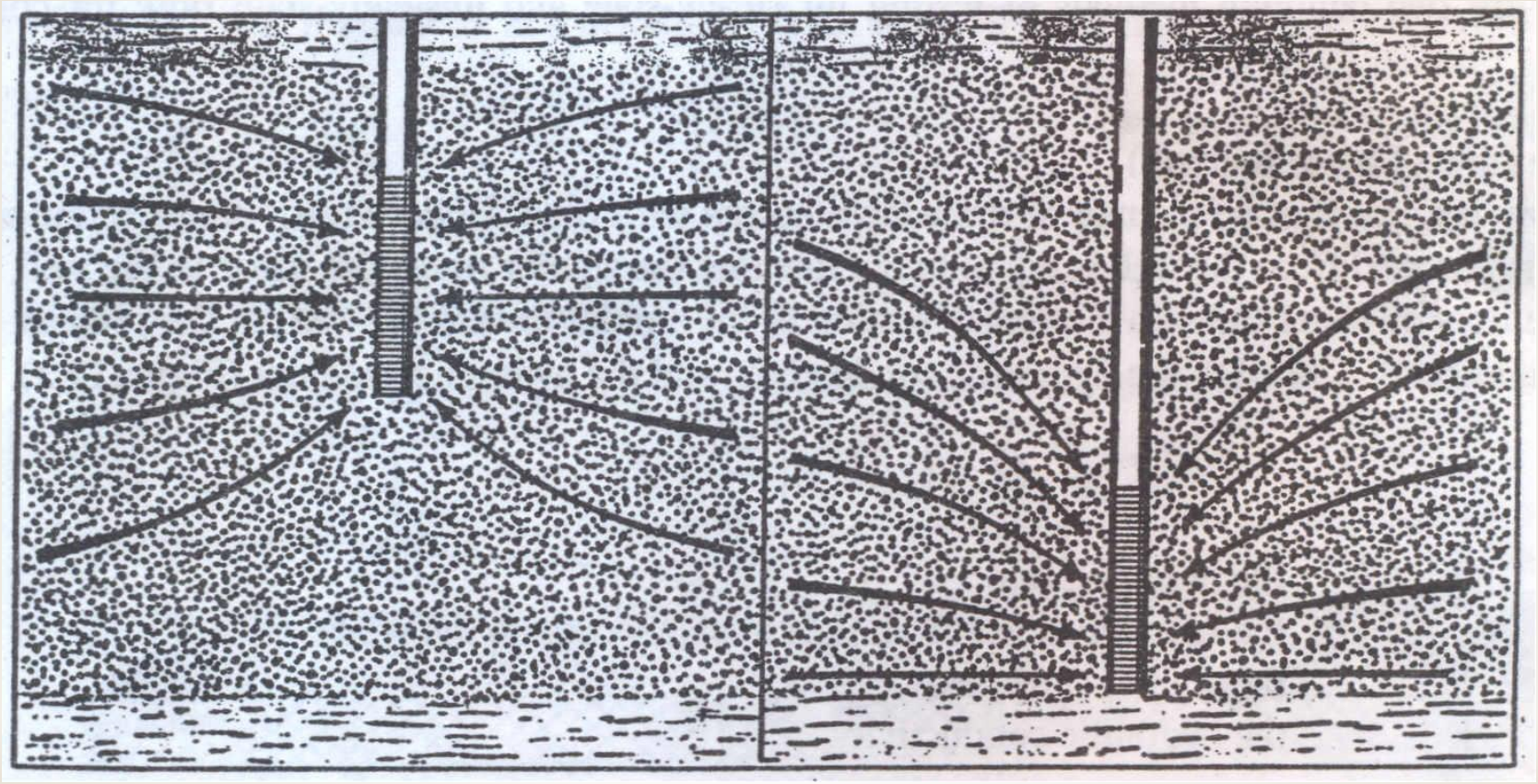
- Mud
  - ⇒ Water based ----Most common and least costly
    - – Bentonite, natural clay…
  - ⇒ Oil based
- Air
  - Dry air and Foam


Mud pit
Screen
Settling pit

4. Drilling depth

- The initial depth is proposed based on the ***Preliminary design***
- The final depth is based on the ***actual field findings/Final design***
- The two important points to be considered in designing well depth are:
  - ⇒Partial penetration
  - ⇒Full penetration
- It is advisable to penetrate fully the aquifer for the following reasons:
  - ⇒To obtain **adequate amounts of water** by penetrating the whole aquifer thickness
  - ⇒To be able to accommodate the possible high draw down that may occur either due to:
    - Over pumping
    - Less recharge due to extended drought

Partial and Fully penetrating wells



- As opposed the above noted advantages of full penetration of the aquifer, partial penetration is favored when:
  - ⇒ The aquifer is very thick to minimize the **construction cost**
  - ⇒ To avoid **poor quality** of water which may form part of the aquifer

5. Drilling diameter

Diameter of a well depends on:

- The intended purpose of the well (rural, urban, irrigation, etc.)
- The expected subsurface formation
- The drilling method
- The diameter of the casing and the pump

If telescopic drilling is required for some reason, the initial drilling diameter must account for the final well diameter

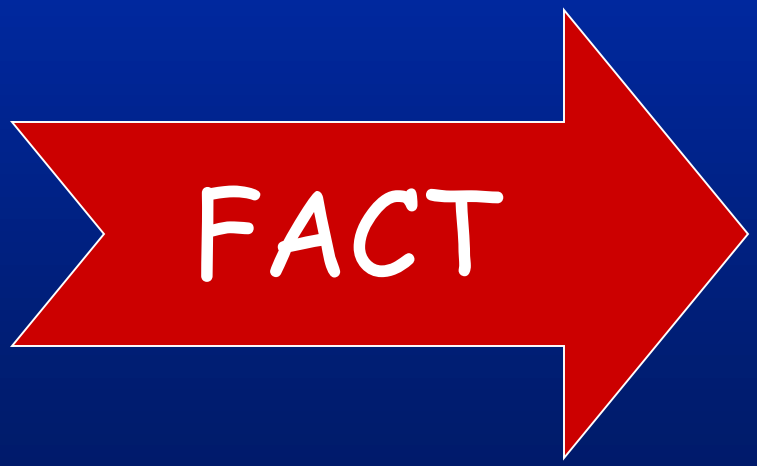
Well Diameter and Yield **relationship**

Well diameter	3"	4"	5"	6"	8"	10"	12"
Yield in %	100	104	107	110	114	118	121

- Doubling the diameter the yield increase only about 10%

Possible reasons for drilling of large diameter wells can be :

- **When large quantities of water required for irrigation, town water supply and industrial purposes**



DOUBLING WELL DIAMETER

10% YIELD INCREASE

DOUBLING SCREEN LENGTH

DOUBLES WELL YIELD

6. Well logging

- Is the record of any phase of well drilling
- Indicate the **water bearing formation** and facilitate the **casing installation** (screen)
- ***Can be classified as:***

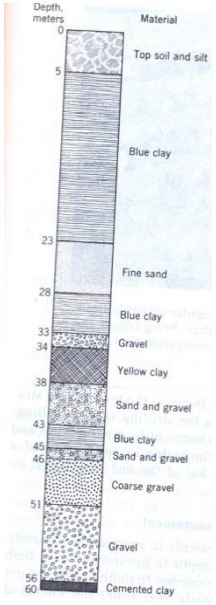
Geological logging

- The frequency of sampling and the subsequent sample handling
- Sampling interval is usually recommend to be 2 m

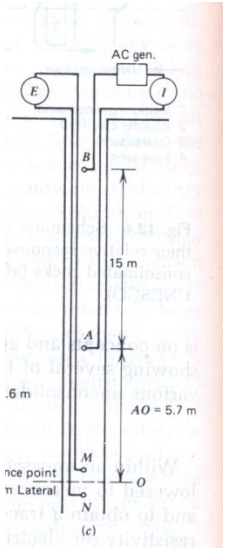
Geophysical logging

- Measure the electric resistance of the surrounding media and obtain a trace of variation in depth
- Includes **Resistivity (Short and Normal) and Gamma logging**

Geological logging



Geophysical logging



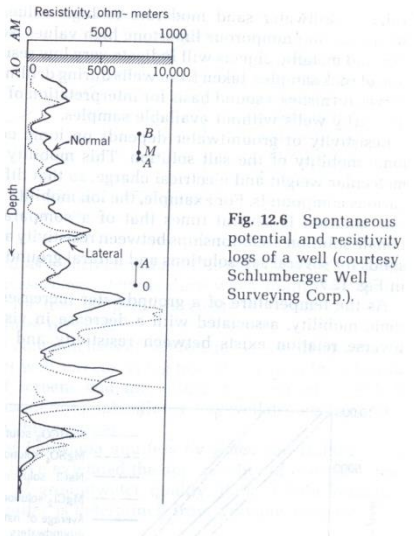
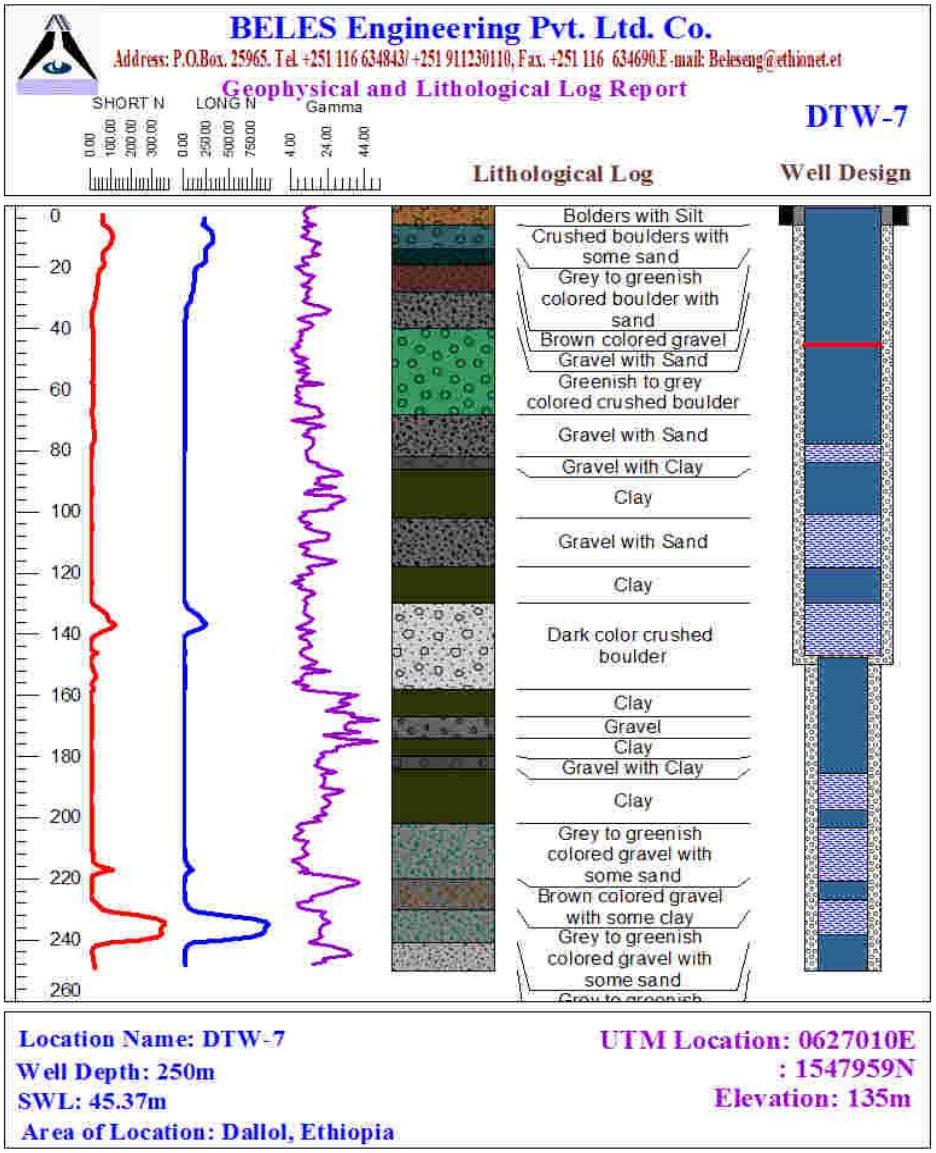


Fig. 12.6 Spontaneous potential and resistivity logs of a well (courtesy Schlumberger Well Surveying Corp.).

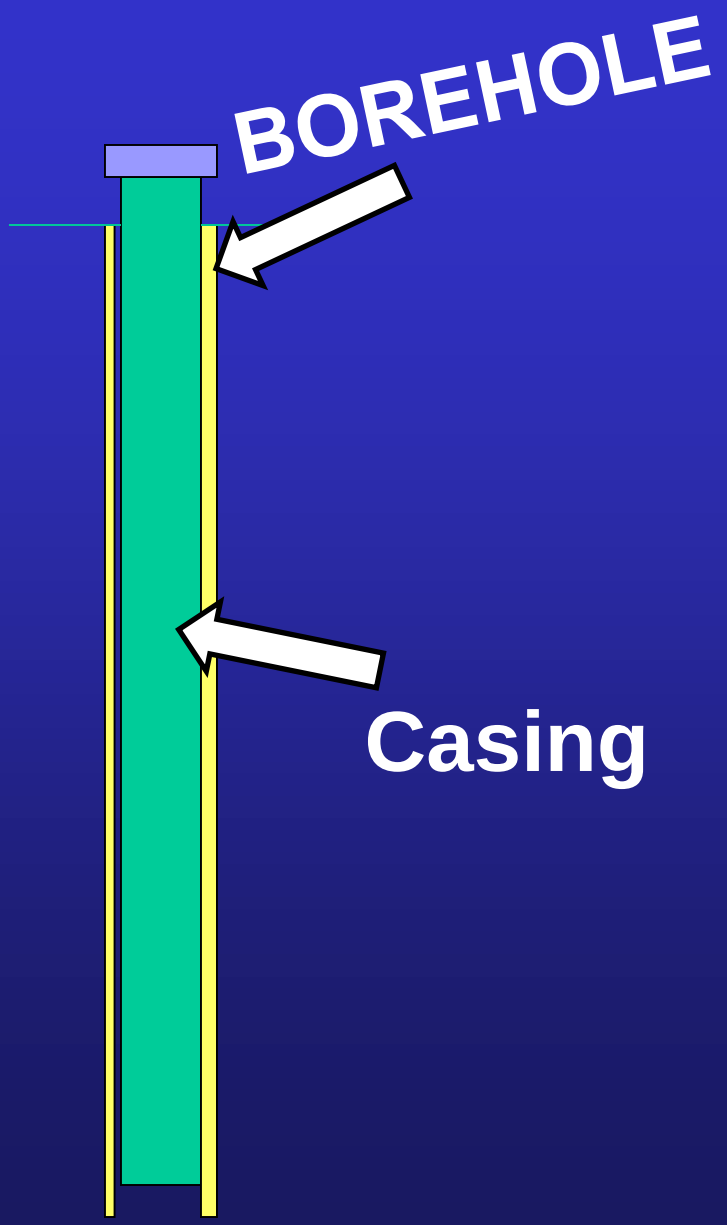
A good example of Well logging (Geological and Geophysical log)



7. Casing

Casings serve to

- Protect the borehole wall from caving
- Protect surface water from entering into the well
- Seal out undesired groundwater
- Protect Pump from damage



Casing Installation

Types of casings

- Poly Venile Chloride (PVC)

Steel (Mild or stain less steel)

- **Note:-** Non metallic materials should be used where corrosion or encrustation by irons bacteria is a problem

  - Shallow well

CASING COMPARISON

PVC	vs.	STEEL
Non-corroding		Corrodes
Lower strength		Higher strength
Fewer water quality complaints		Rusty water
Rotary construction only		Suitable for any drilling method
Low cost		High cost

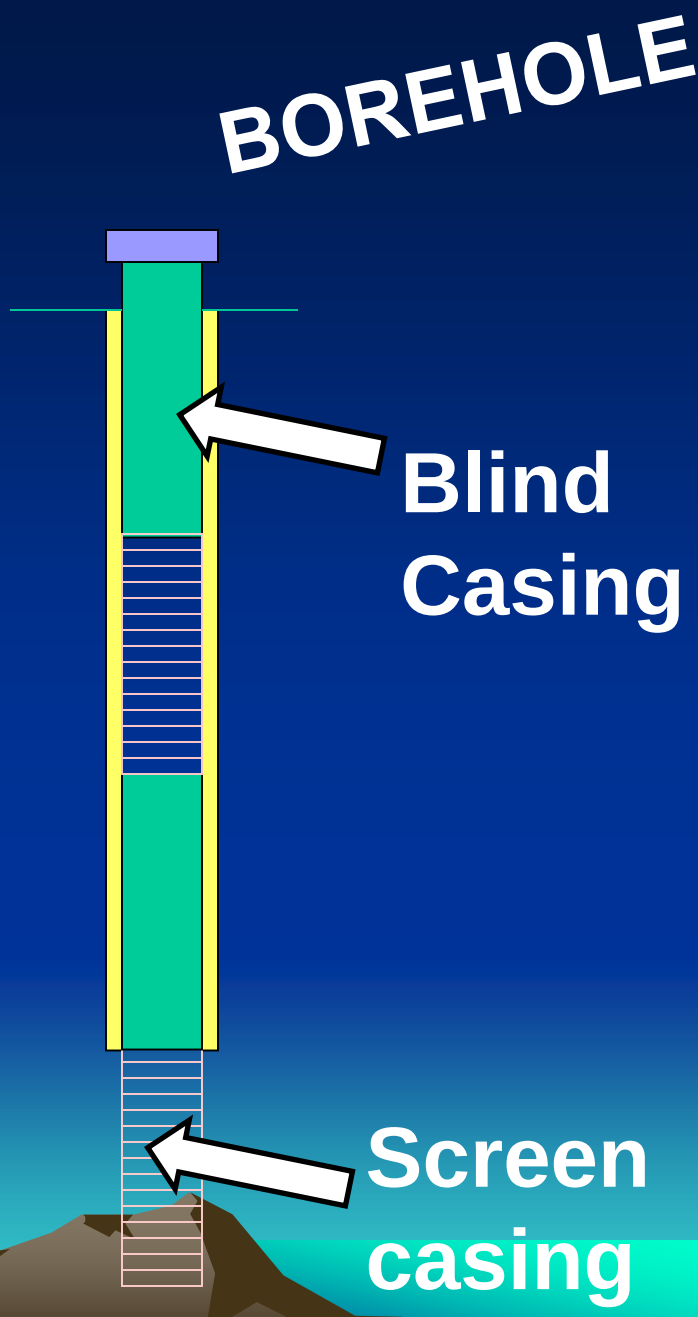
Casing selection is based on:

- Types subsurface formation
- Depth and diameter of the well
- Quality of the water
- Cost of the material

Casing Design

- Blind--- **IMPERMEABLE ZONES**
- Screen---**PEARMEABLE ZONES**

⇒ Casing design is can be achieved by closely examining the **Geological and geophysical, rate of drilling and water strike**



Screen casing

1)Types of screen

⇒ Continuous slot, V shaped slots, continuous wire slot ….

⇒ Slots can also be prepared by hacksaw, welding (**Not recommended**)

2) Diameter of screen

⇒ Enough screen opening that allow water to flow into the well **smoothly**

3) Percentage of open area

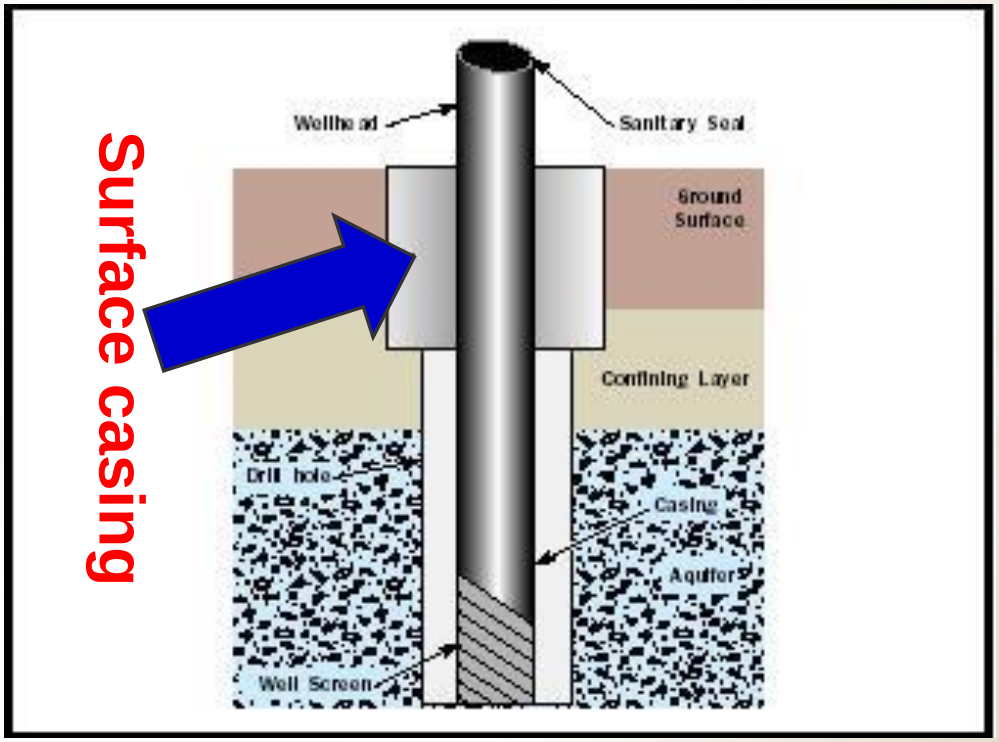
⇒Common practice to design an open area between 15 to 20%

⇒Depends on the grain size of the aquifer and the degree of well development

⇒For best well efficiency, the percentage should be the same as, or greater than, the average porosity of the aquifer material

Surface casing

- Protect the borehole wall from collapsing
- Protect surface water and other pollutants from entering into the well
- Steel casing
- Usually ≥ 6 m depending on the thickness of the soil overburden
- Wider in diameter (compared with the rest part)



4) Length of screen

⇒Depends on the aquifer thickness, nature of stratification, and possible available drawdown during pumping

Homogenous and non-homogenous unconfined aquifers

- Homogenous unconfined aquifer (one-half to one-third part of the aquifer with screen)
- Non-homogenous unconfined aquifers (one-third of the aquifer with screen)
- Unconfined aquifers the screen should be positioned in the lower portion of the aquifer because the upper part is usually dewatered during pumping

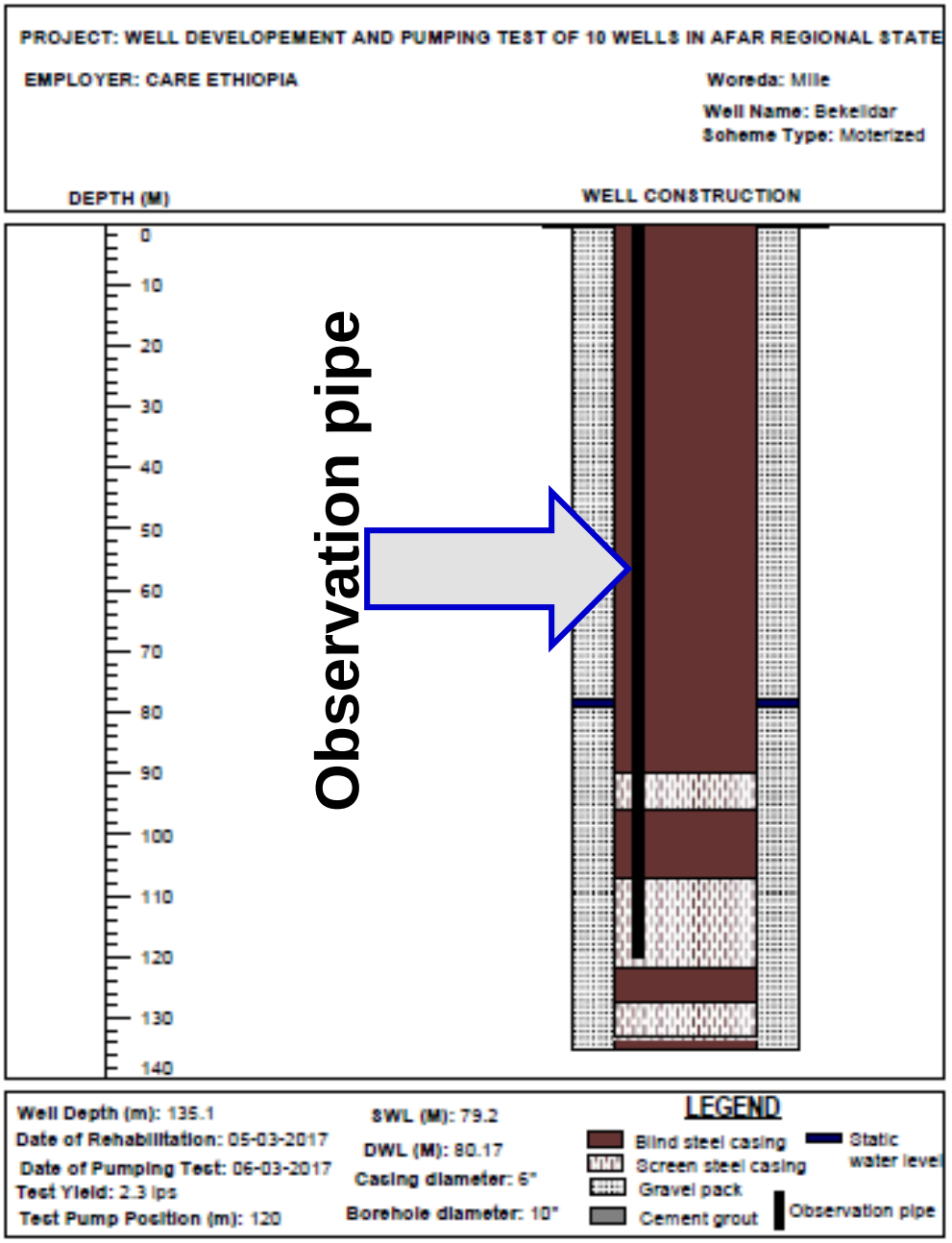
Homogenous and non-homogenous confined aquifers

- 80-90% of the water bearing formation can be covered with the screen

Observation pipe

- Is ¾” an open-ended pipe placed in a borehole that has been drilled to the desired depth.
- The bottom tip of the pipe is fitted with a perforated to allow the inflow of water.
- The purpose of the observation pipe is to measure the water level in well.

Annex 1: Well construction of Bekeli dar.



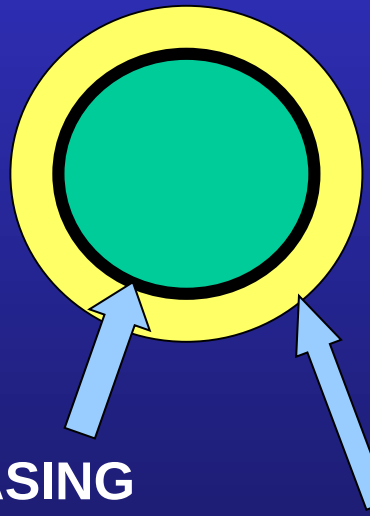
8. Gravel pack

- Reasons for gravel packing:
  - ⇒To protect sand from passing into the screen
  - ⇒To strengthen the construction by supporting the wall of the well
  - ⇒To increase the yield of the well by removing the formation material and replacing it with special type of graded coarse material
- Gravel is usually packed about 3 m above the top part of the screen
- Gravel material should be clean, smoothly rounded, and equal size
- Applying different size of gravel may create a problem like **clogging** of the screen
- To **avoid bridging** care should be taken during pouring the gravel

Gravel pack

Observation pipe

TOP VIEW



CASING

BOREHOLE

River gravel

How the amount river gravel needed can be calculated?

9. Well development

- The act of cleaning out clay and silts introduced during the drilling processes and finer parts of the aquifer material around the well screen.

The purpose of well development

- Is to remove the mud cake (drilling fluids) and then to obtain **smooth groundwater flow** from the formation into the well

The most common development techniques are:

Mechanical surging

⇒ Forces water to flow into and out of the screen by operating a plunger-like surge block in an up-and-down motion in the casing (Reversal of flow)

High-velocity (jetting)

⇒ Is a very effective way to develop sand and gravel aquifers and artificial gravel packs.

Over pumping

⇒Pumping at a higher rate than the well will be pumped during exploitation.

Backwashing

⇒Pumping a well at a high rate for a short period, shutting down the pump to allow water in the column to fall and backwash the screen, and then repeating the process until the water is clear.

Air lifting

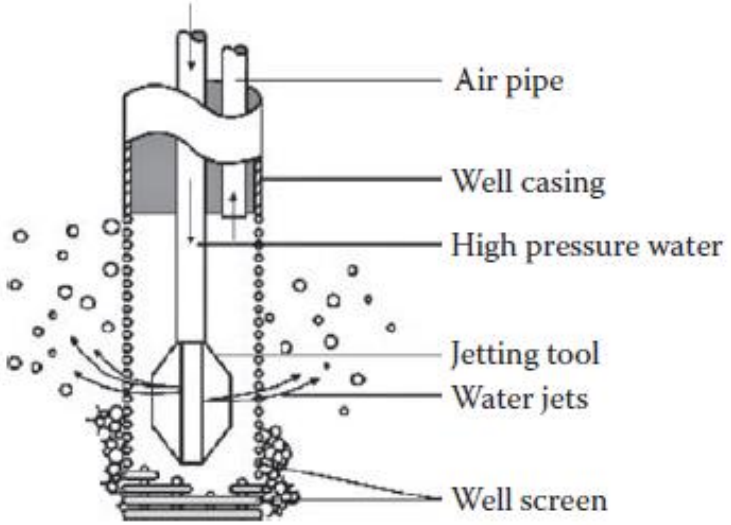
⇒Air is injected into the well to lift the water to the surface.

Dispersing agent

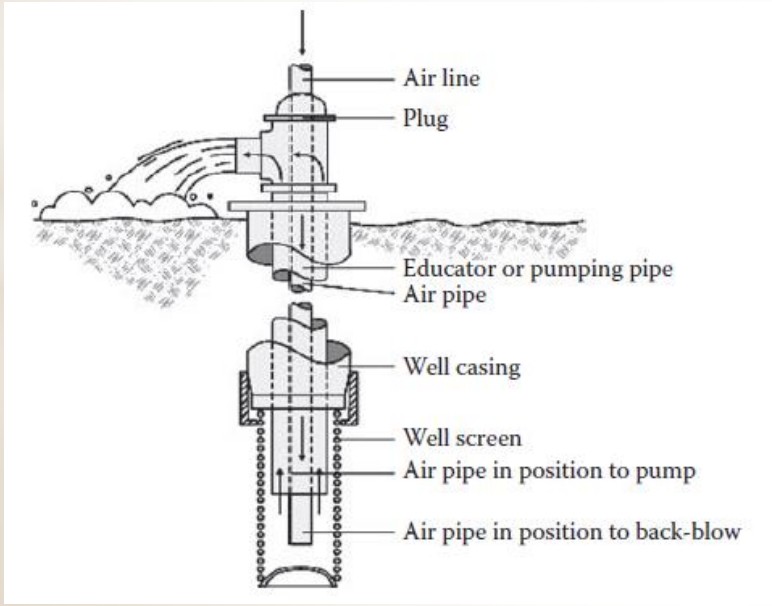
⇒Chemicals agents (e.g. Foam) can be added to disperse the mud cake or formation to avoid their sticking to sand grains and speed the development processes.

Mechanical surging

High velocity Jetting of water



Air lifting



Dispersing agent – chemicals

Well Maintenance/Rehabilitation

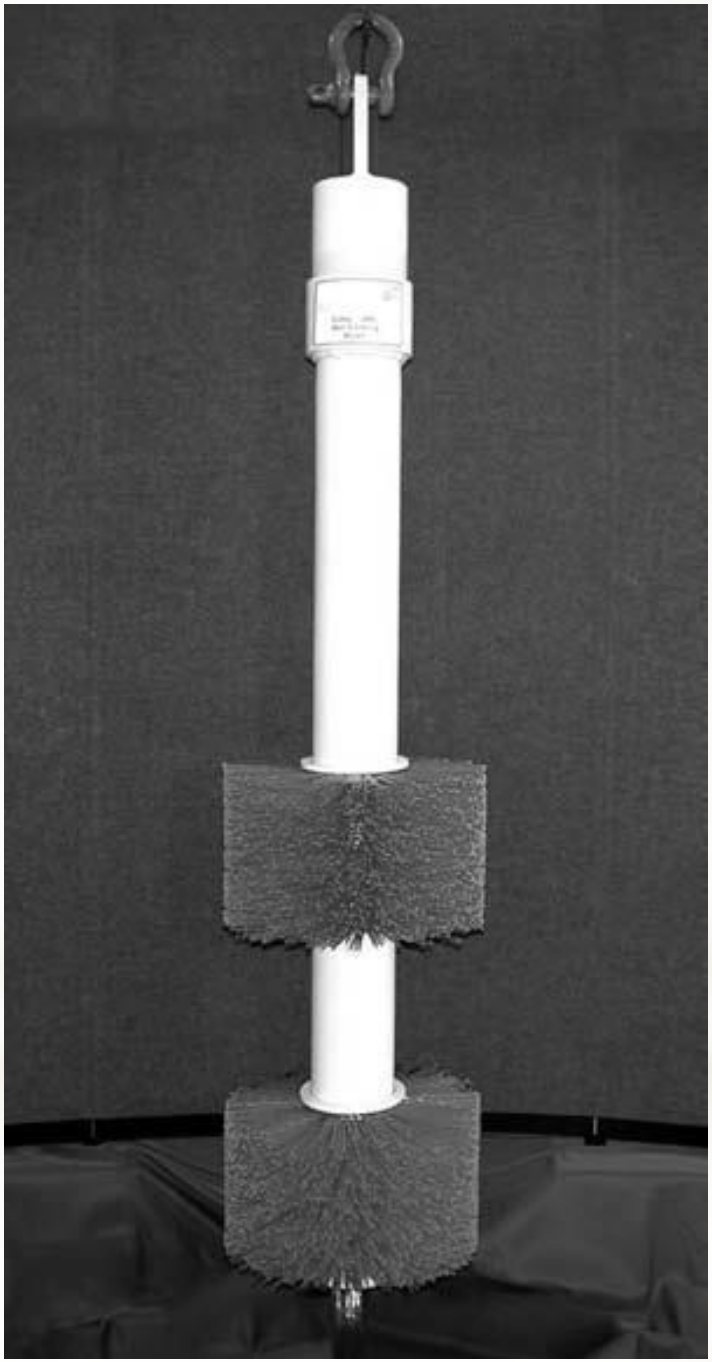
⇒The performance of a well usually declines after some years of operation resulting in higher drawdown, reduced discharge (<25%) and higher pumping costs.

⇒The major causes of a reduction in well performance are:

- Chemical encrustation or clogging of the screen due to bacteriological activity
- Plugging the formation around the well screen by fine particles (clay and sand in the pores)
- Pumping of sand due to poor well design or corrosion of the well screen

⇒Maintenance/rehabilitation usually carried out through well development together with brushing and addition of chemicals.

Brushing



10. PUMPING TEST

The main purpose of pumping test operation is:

- To determine the performance of a well (Well test)
- To determine the hydraulic parameters of the aquifer (Aquifer test)

Specific purpose

⇒To check the **well efficiency** (construction performance)

⇒To determine the potential of an aquifer and **sustainable abstraction rate (safe yied)**

⇒To select the appropriate **type of pump and its position in the well**

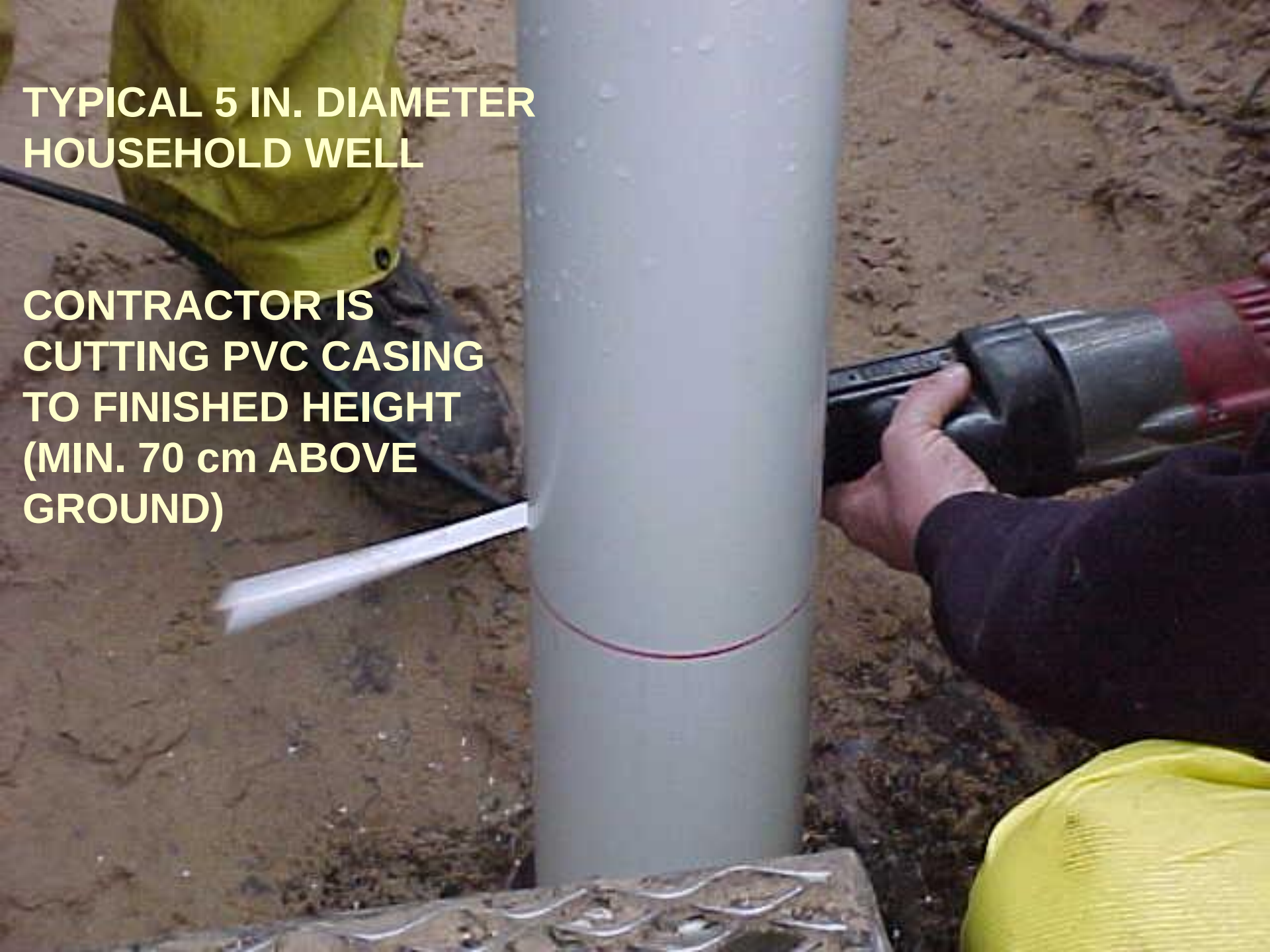
⇒To obtain information about the **groundwater quality** of the well

11 Grouting / Sanitary Seal

- On completion of gravel pack, seal the **upper 5m** of the remaining annulus space with cement
- Before grouting put pure sand (0.3-0.6 mm) on the top of gravel to protect the cement from moving down to the screen position

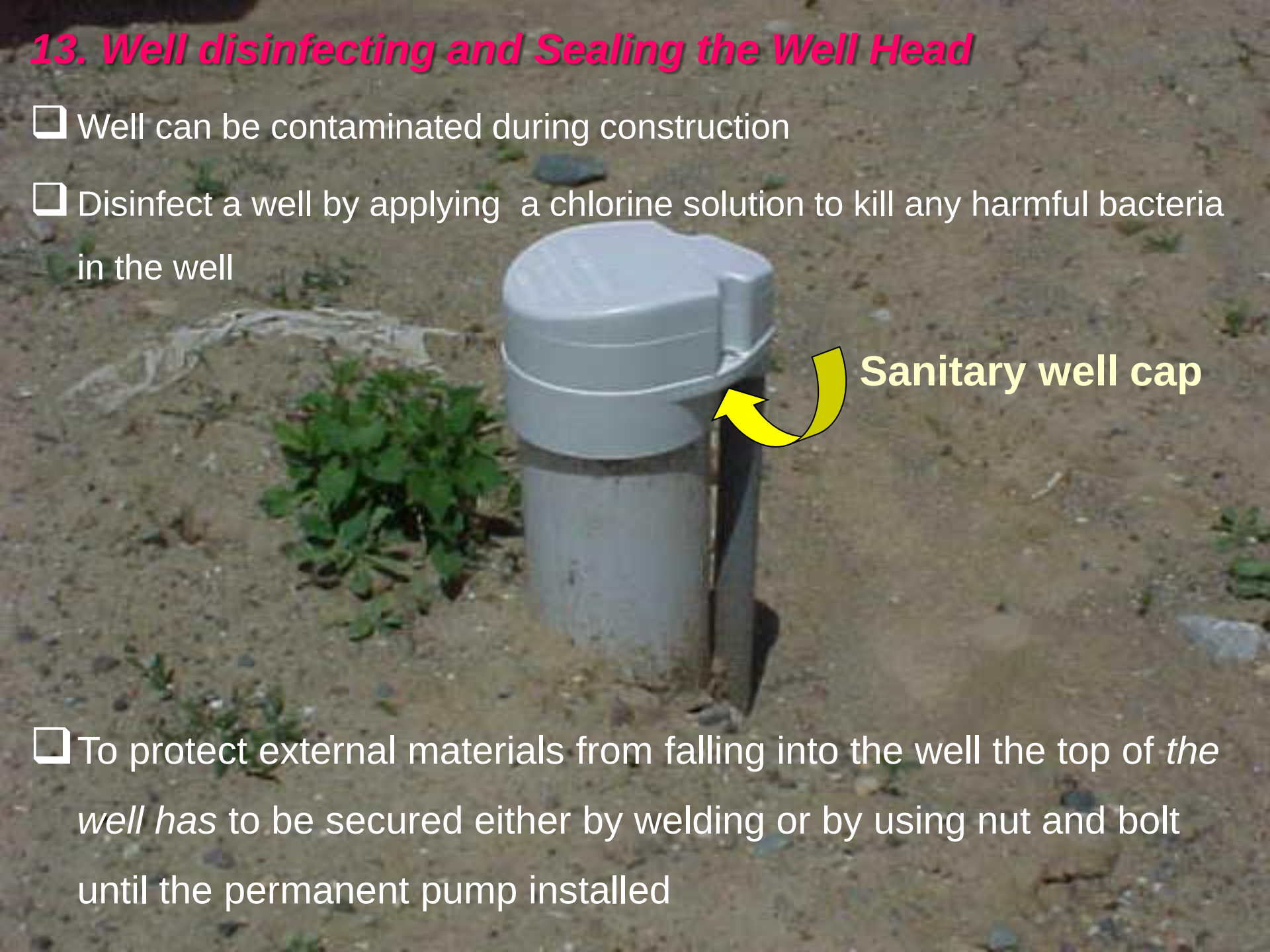
12. Well Head Construction

- A concrete, horizontal apron 2mx2m with a minimum thickness of 0.2m and the well at the center
- Prevent surface water from entering into aquifer
- The surface casing shall be cut off horizontally not less than 0.7 cm above ground level
- The observation pipe shall be cut off below the level of the surface casing but not lower than 0.5 cm above ground level


TYPICAL 5 IN. DIAMETER HOUSEHOLD WELL
CONTRACTOR IS CUTTING PVC CASING TO FINISHED HEIGHT (MIN. 70 cm ABOVE GROUND)

13. Well disinfecting and Sealing the Well Head

- Well can be contaminated during construction
- Disinfect a well by applying a chlorine solution to kill any harmful bacteria in the well



- To protect external materials from falling into the well the top of *the well has* to be secured either by welding or by using nut and bolt until the permanent pump installed

QUESTIONS

A good example of Well logging (Geological and Geophysical log)

When the radioactive elements (e,g K, U, Th and others) decay, they release gamma ray radiation that can be measured in borehole

Natural gamma rays logs (gamma logs) measure the gamma rays radiation emanating from the formation adjacent a borehole. Higher levels of gamma rays emissions typically are associated with high abundance of clay (K is the most abundant) minerals in shale or clay layers that could be significant confining units.