CHAPTER 5

WELL CONSTRUCTION

Wells

- Shallow (< 15 meters)

- Deep (> 15 meters)

Shallow Wells

Include

- Dug wells
- Kanats
- Vertical wells
- Horizontal wells

They are drilled by:

- digging, boring, driving, and jetting techniques

Deep Wells

They are drilled by:

- **cable tool method**
- **hydraulic rotary method**
- **reverse rotary method**
- **air rotary method**

Test Holes

- **Before drilling a well in a virgin area, test holes are drilled**
- **This determines depths to GW, GW quality, and physical character and thickness of aquifer without the expense of a well which might prove to be unsuccessful**

- **Diameter : 8” –10”**

- **Methods of drilling**
  - **cable tool**
  - **rotary method**
  - **jetting method**

- **If a test hole is at a good site, it can be reamed with the rotary method into a large permanent well**

Well logs -

Record of geology as a function of depth

-samples of cuttings collected in glass jars for different depth

-These analayzed for grain size distribution

-Well drillers required to submit well logs with the states by law - OWRB

Kinds of Wells

Shallow wells

Dug wells:

Found in archeological excavations; still serve as source of rural water supply in Middle Eastern, Asia and African countries

Kanats:

Found in Iran, South Europe, Asia, and Africa

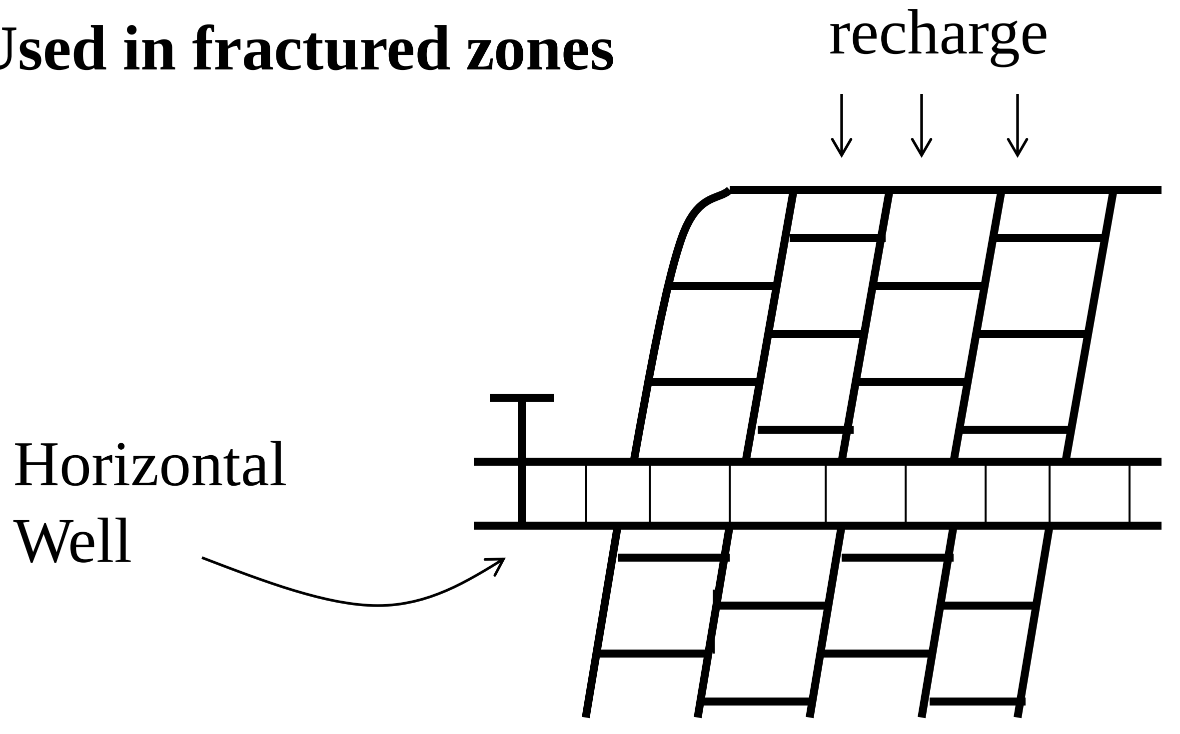
Vertical wells:

Now adays all well are vertical, pumped wells

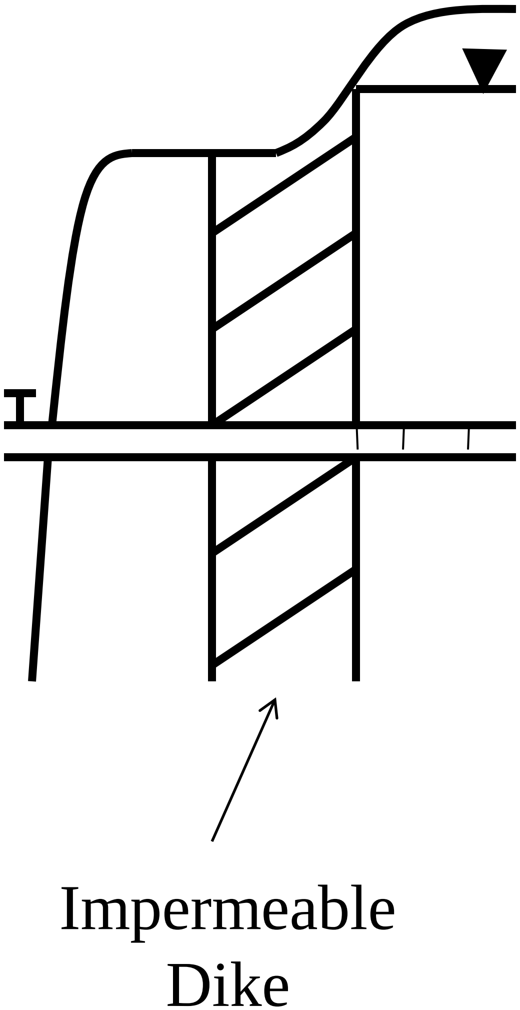
Well dia.	Q, gpm
6 in.	< 100
12 in.	350 - 700
24 in.	1500 - 300

Horizontal Wells

- **Used in fractured zones**



Vertical Bedding


Impermeable
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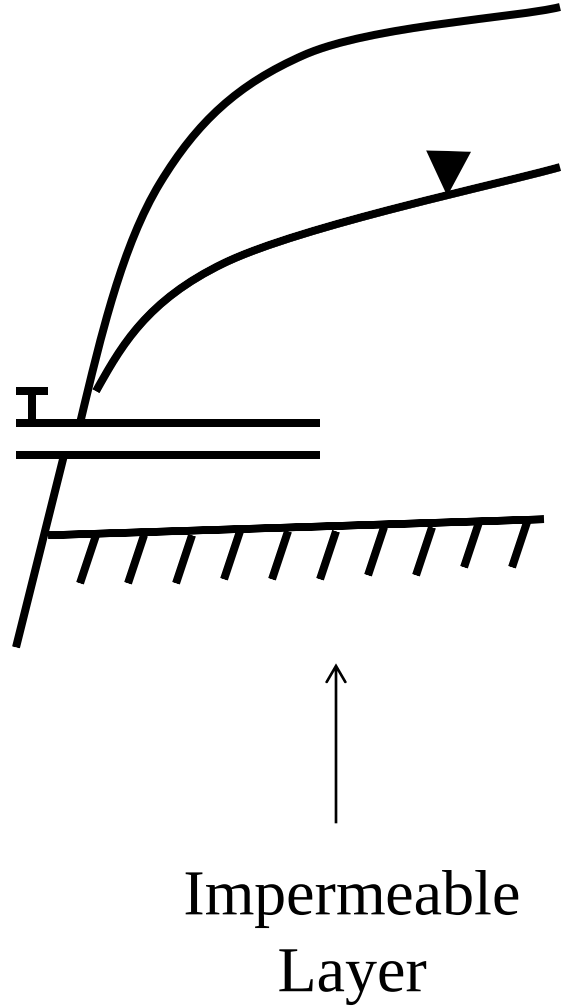

Impermeable
Layer

A. Drilling Methods of Shallow Wells

1. Dug wells:

- Depths - 10' to 50'
- Diameter - 3' to 10'
- Below W.T. 10' to 20'
- Yield < 100 gpm (domestic wells)
  500 - 1000 gpm (properly constructed wells)

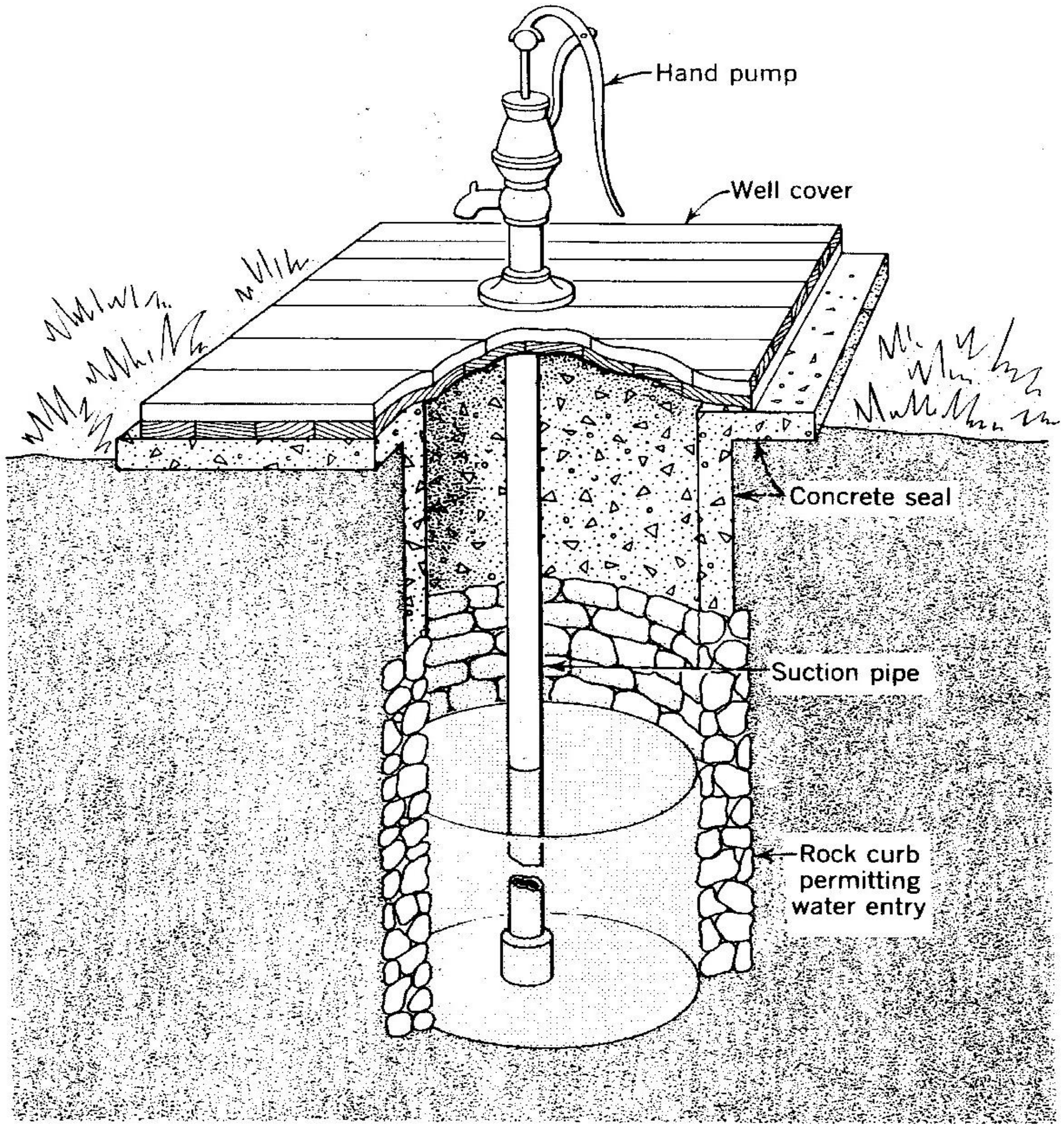


Fig. 5.2 A modern domestic dug well with a rock curb, concrete seal, and hand pump.

- **Consolidated – no casing is required**

- **Unconsolidated – a rock, brick or concrete curb is required to allow water entry**

- **Gravel should be backfilled around the curb and at the bottom of well to control sand entry and possible caving**

2. Bored Wells:

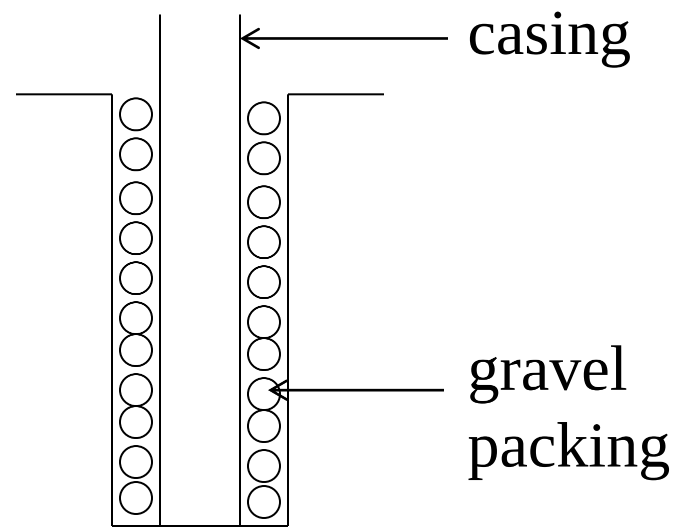
•Constructed by earth auger operated by hand or machine

•Diameter - 6'' to 8''

•Depth < 50‘

•Best suited to noncaving

formations, metal casing rigid



3. Driven Wells:

- Series of connected pipes driven by repeated impacts into ground to below W.T.

- Diameter - 1 ¼ '' to 4''

- Depth - < 50'

- Suction - type pump used to pump GW to GS

- W.T. depth < 10' - 15' from GS

- Yield - 20 to 25 gpm

A driven well with driving mechanism

- Low cost, rapidly installed

- Suitable for formations with no large gravel or rocks

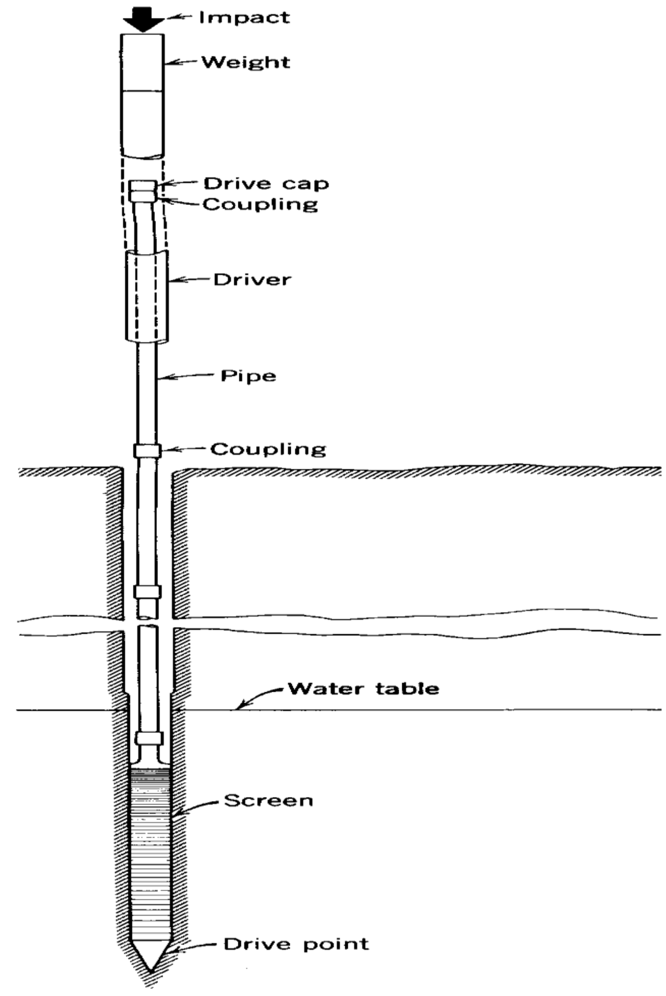


Fig. 5.4 A driven well with driving mechanism.

4. Jetted Wells:

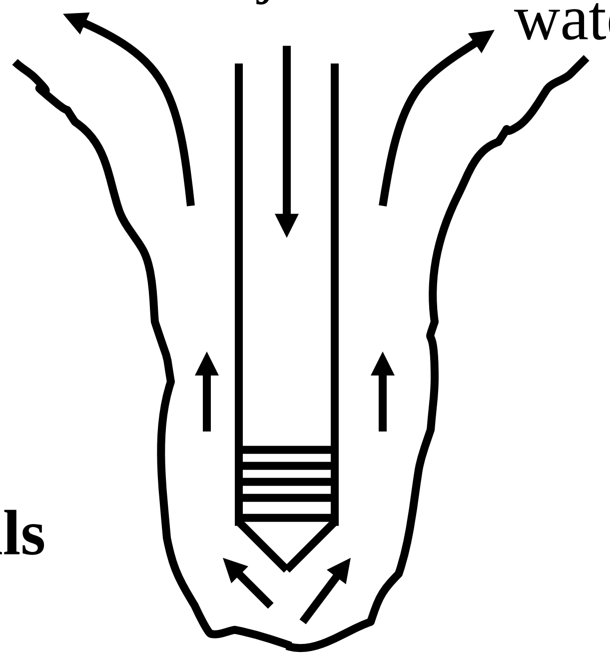
- Cutting action of a drawdown - directed jet of water
- High-velocity jet washed earth away while casing, which is lowered into a hole, conducts water and cuttings up and out of well

- **Diameter - 1 ½ '' to 4''**

- **Depth - < 50'**

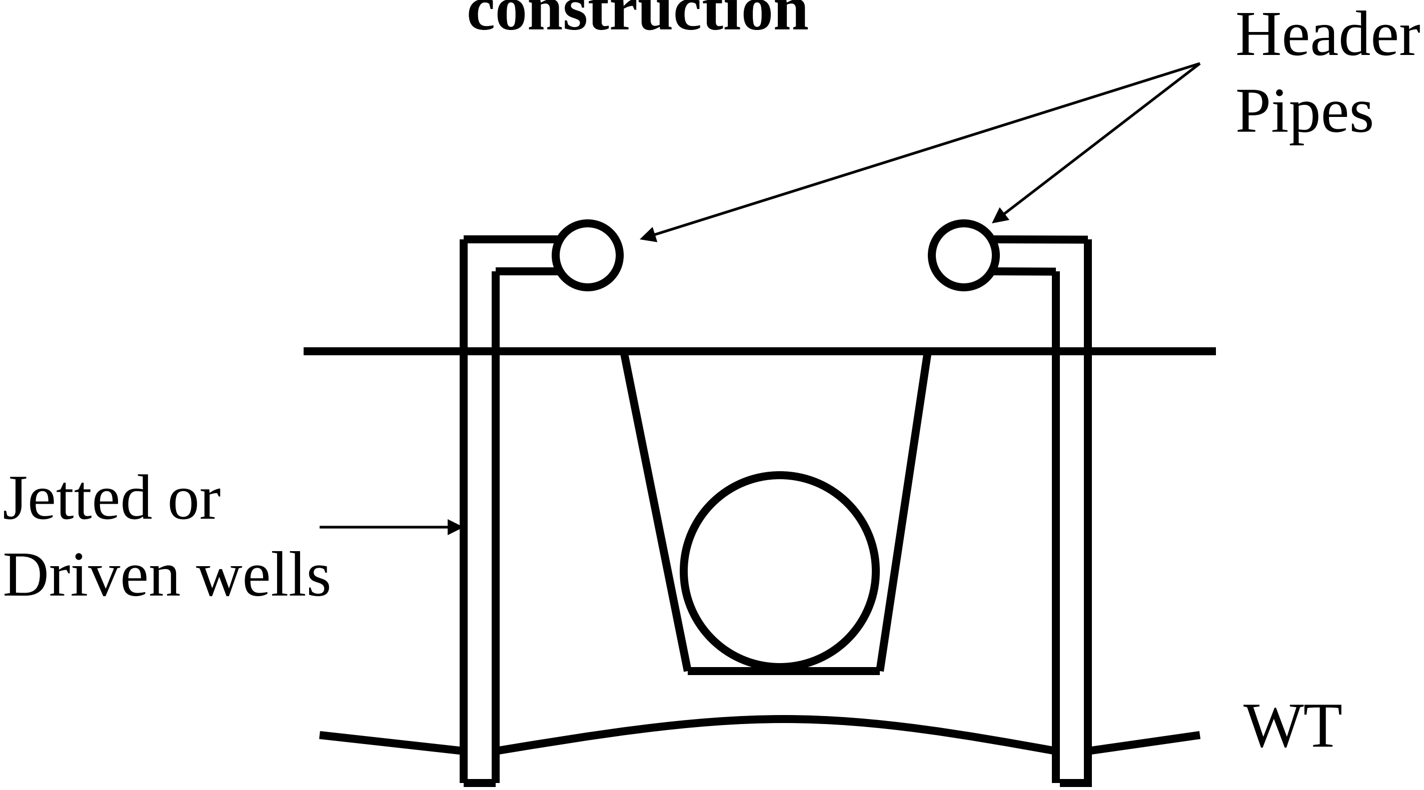
- **Yield – small**

- **Suited for consolidated materials**



- **Because of speed of jetting and portability of equipment, they are useful for exploratory test holes and for well-well-point system**

- **Well-point system**
  - **Purpose – to dewater an excavation site for construction**



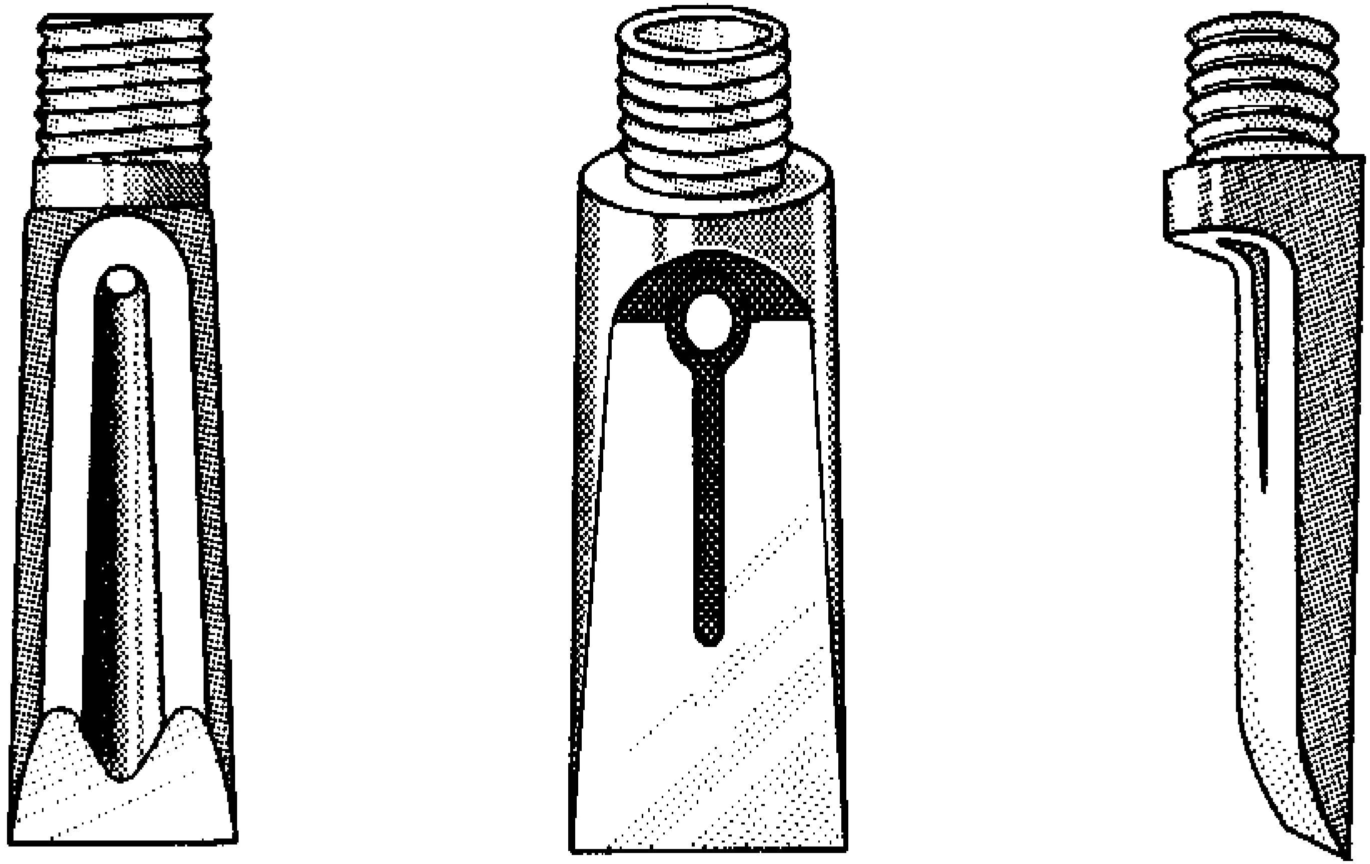


Fig. 5.6 Various designs of jetting drill bits.

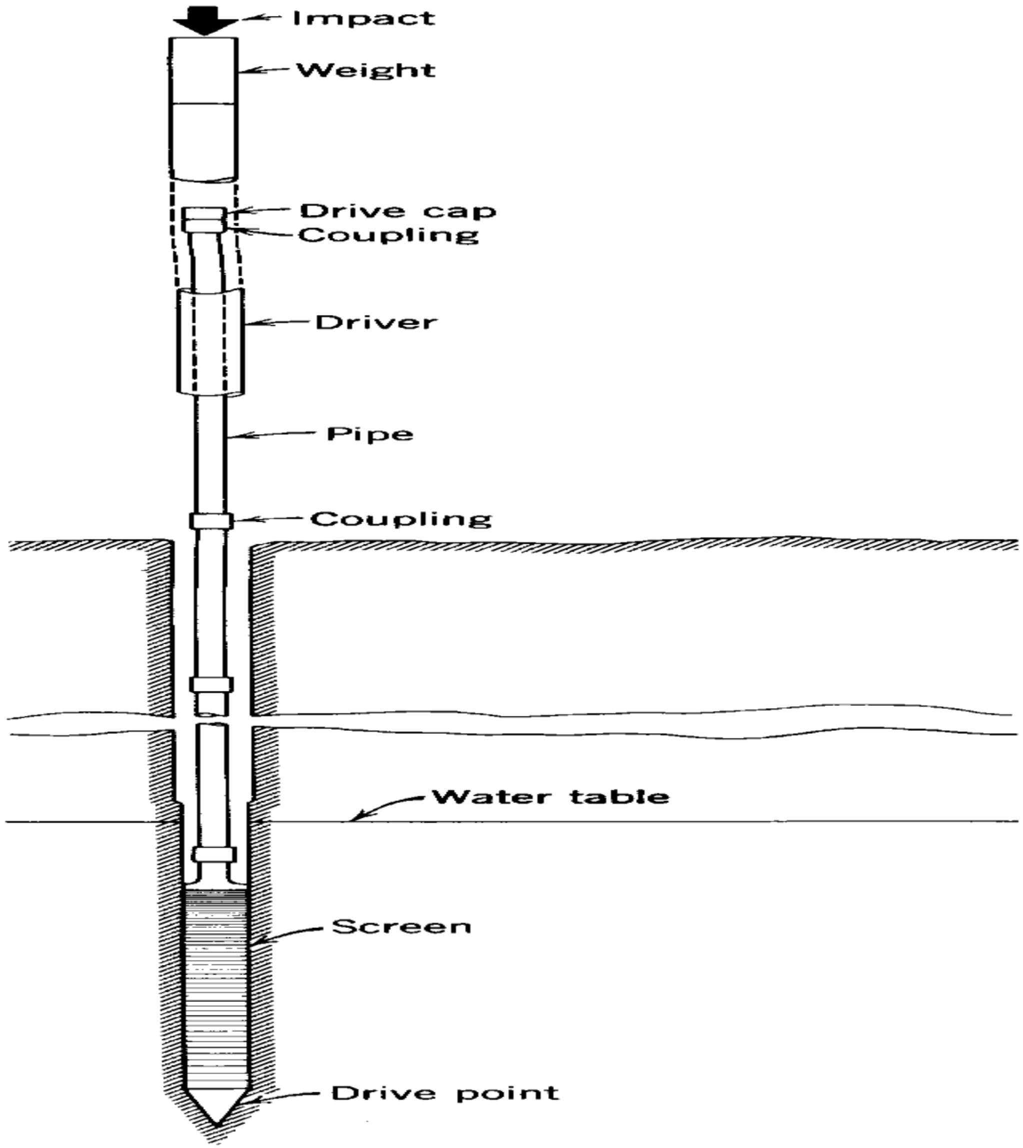


Fig. 5.4 A driven well with driving mechanism.

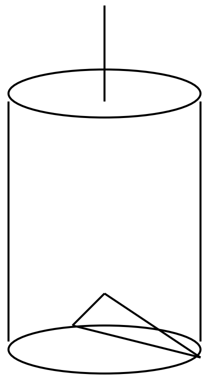
B. Drilling Methods for Deep Wells

1. Cable –Tool (percussion) Method

Equipment includes

- Well drilling rig mounted on a truck
- String of percussion tools
- Bailer
- Diameter - 2'' to 3'' (6 cm to 80 cm)

- **Suited for consolidated and unconsolidation formations**
- **Drilling is done by regular lifting and dropping of the string of tool**
- **String of tools – rope socket, drilling stem, drilling bit**
- **Bailer – one way valve**
- **Length – 10' to 30'**
- **Capacity – 2 to 90 gal.**



Bailer

- During drilling, tools make 40 to 60 strokes/min, ranging from 16'' to 40'' in length

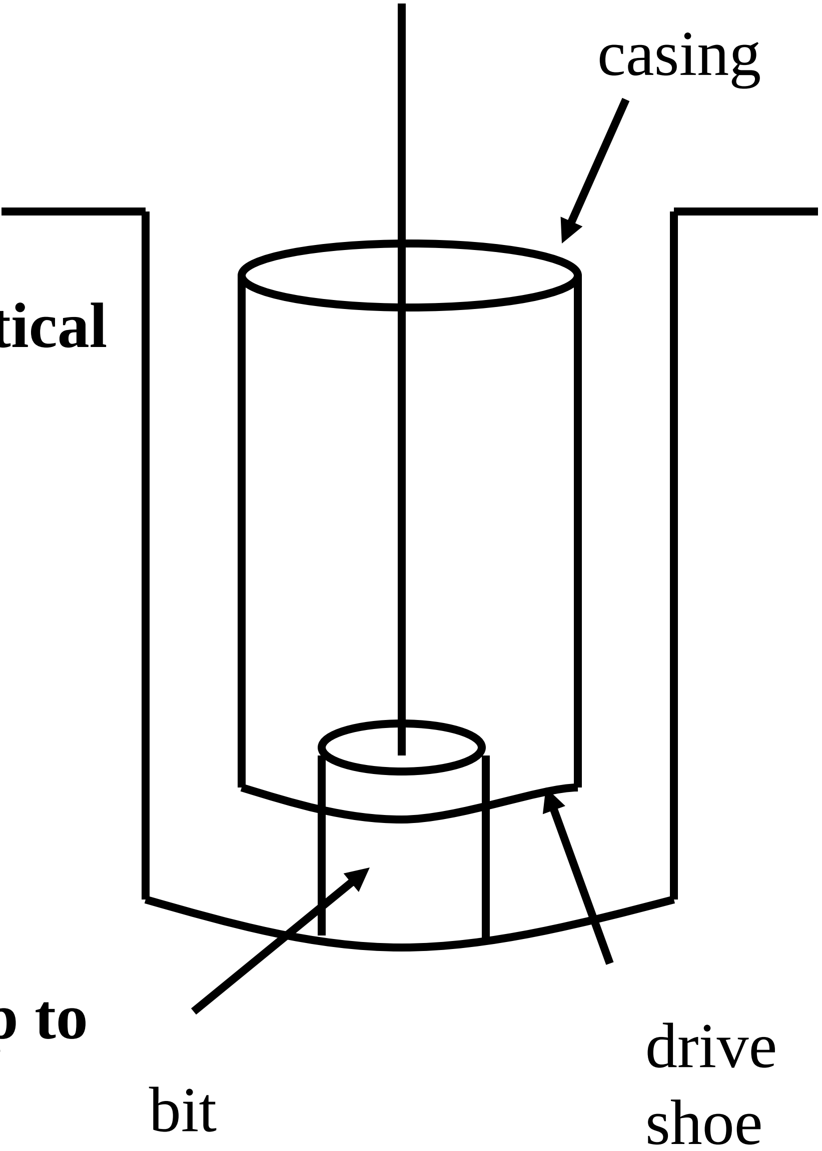
- Drilling line (rope) is rotated so that bit forms a round hole

- Additional rope is allowed so that bit forms a round hole

- Water added in the hole forming a paste, reducing friction on falling bit

Casing properly aligned

- **6'' /100 ft – deviation from vertical**
- **Vertical alignments avoids interference with pump installation and operation**
- **Max depth of well = 2000 ft (up to 6000 ft), because wt. of tools**



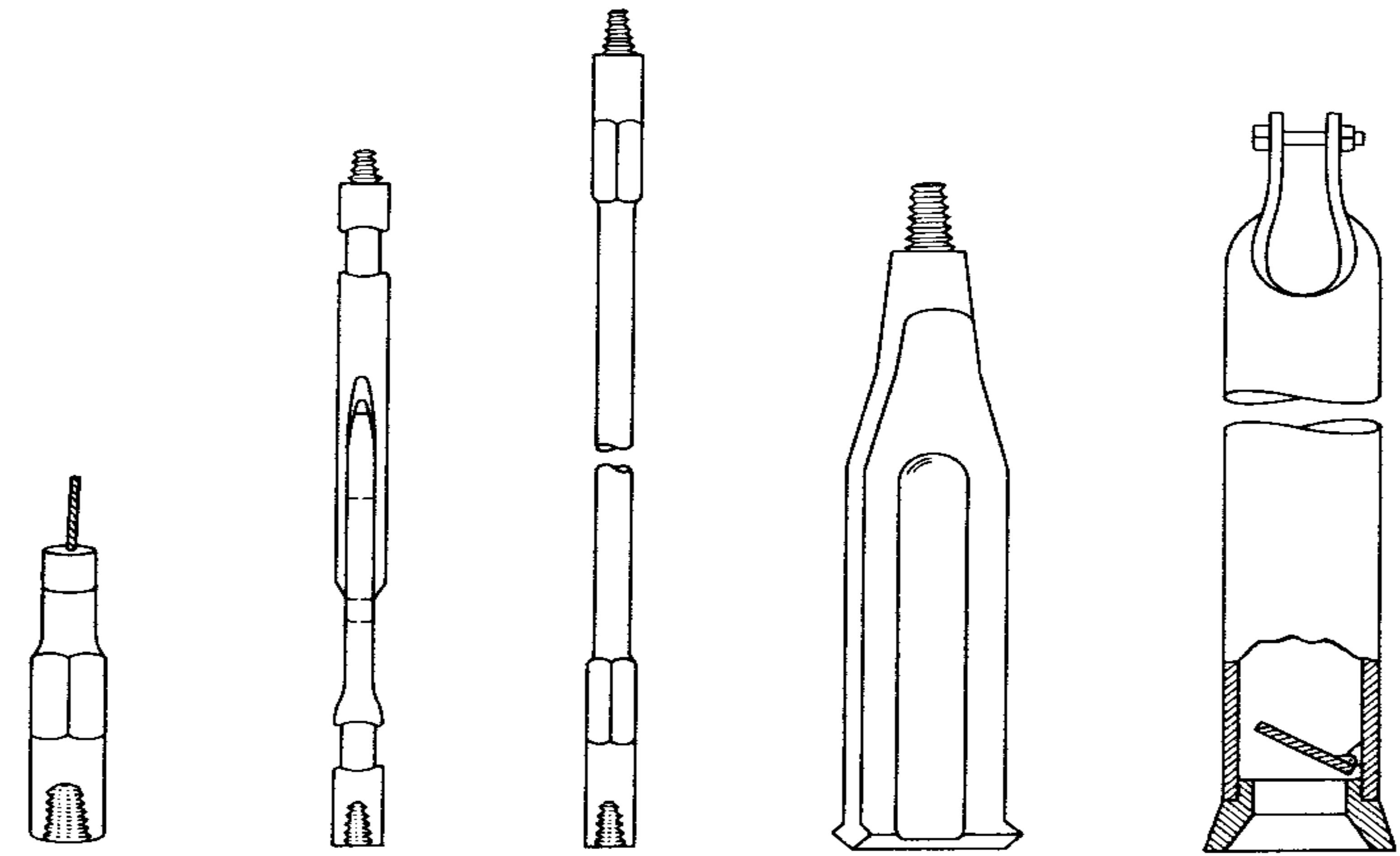


Fig. 5.10 Basic well drilling tools for the cable tool method.

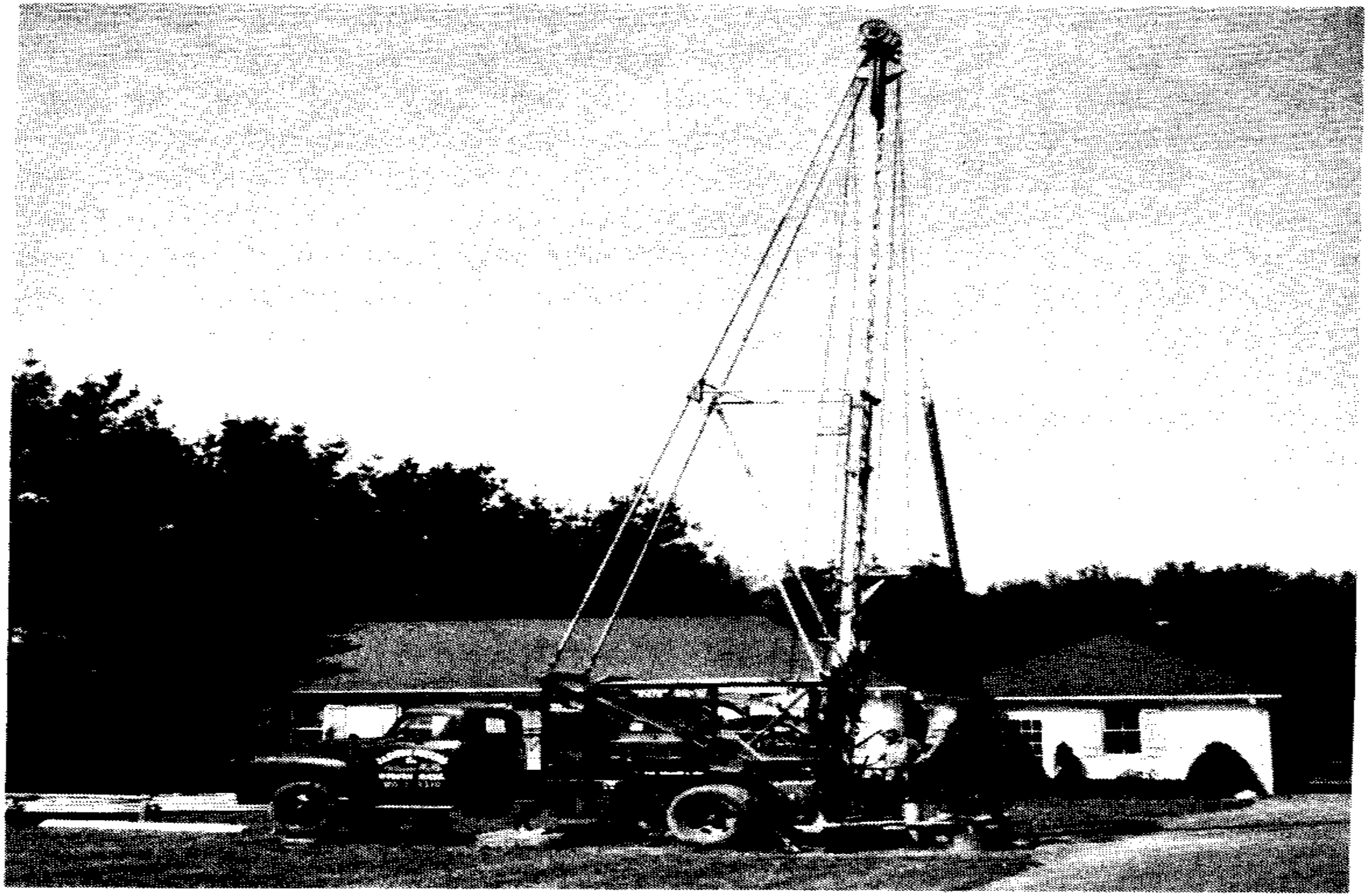


Fig. 5.11 Cable tool drilling rig in operation. The driller holds the cable to sense the progress of the drilling. A bailer is standing to the right of the rig (courtesy Bucyrus-Erie Company).

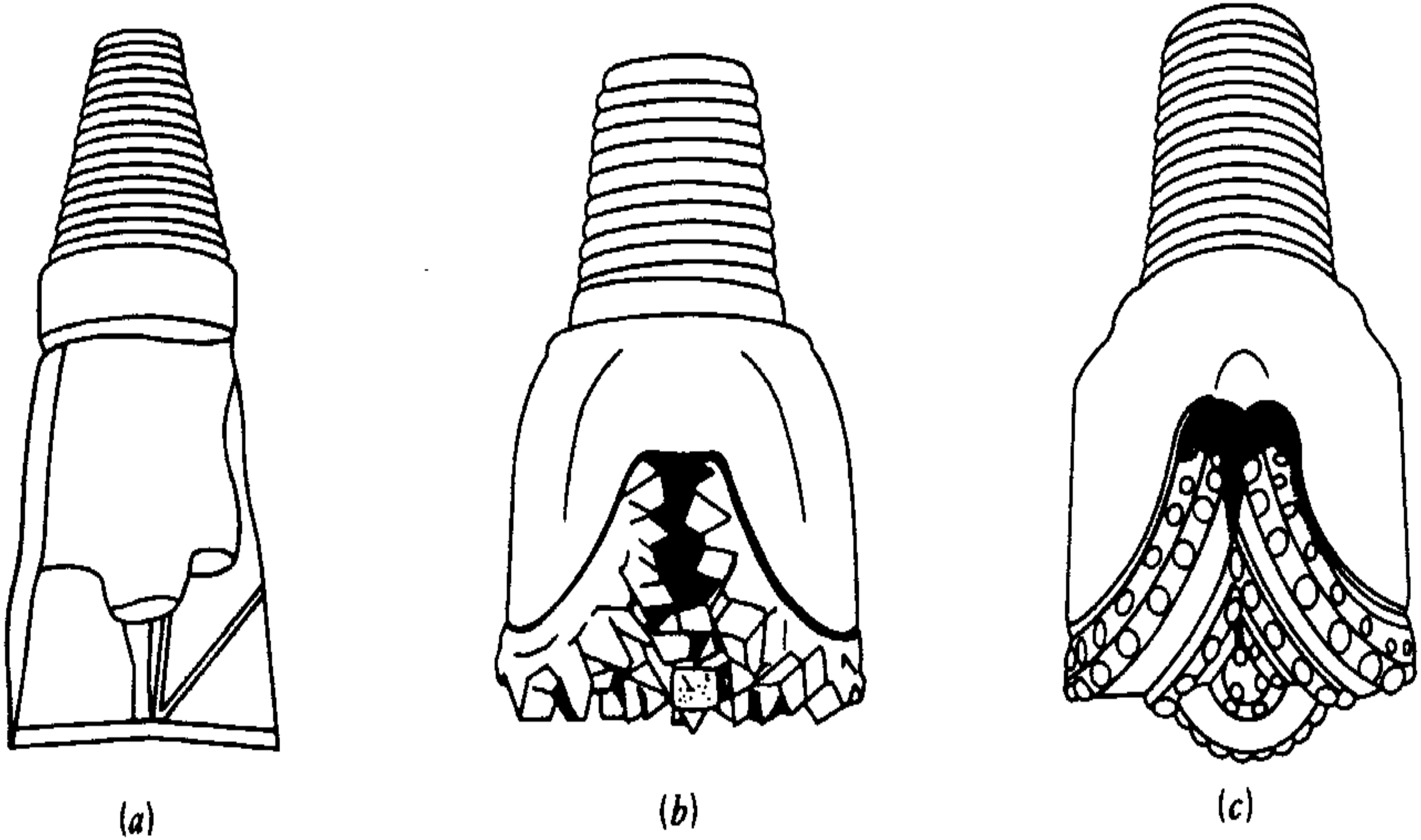


Fig. 5.12 Examples of rotary drill bits. (*a*) Fishtail bit. (*b*) Cone-type rock bit. (*c*) Carbide button bit (after Speedstar Div.[40]).

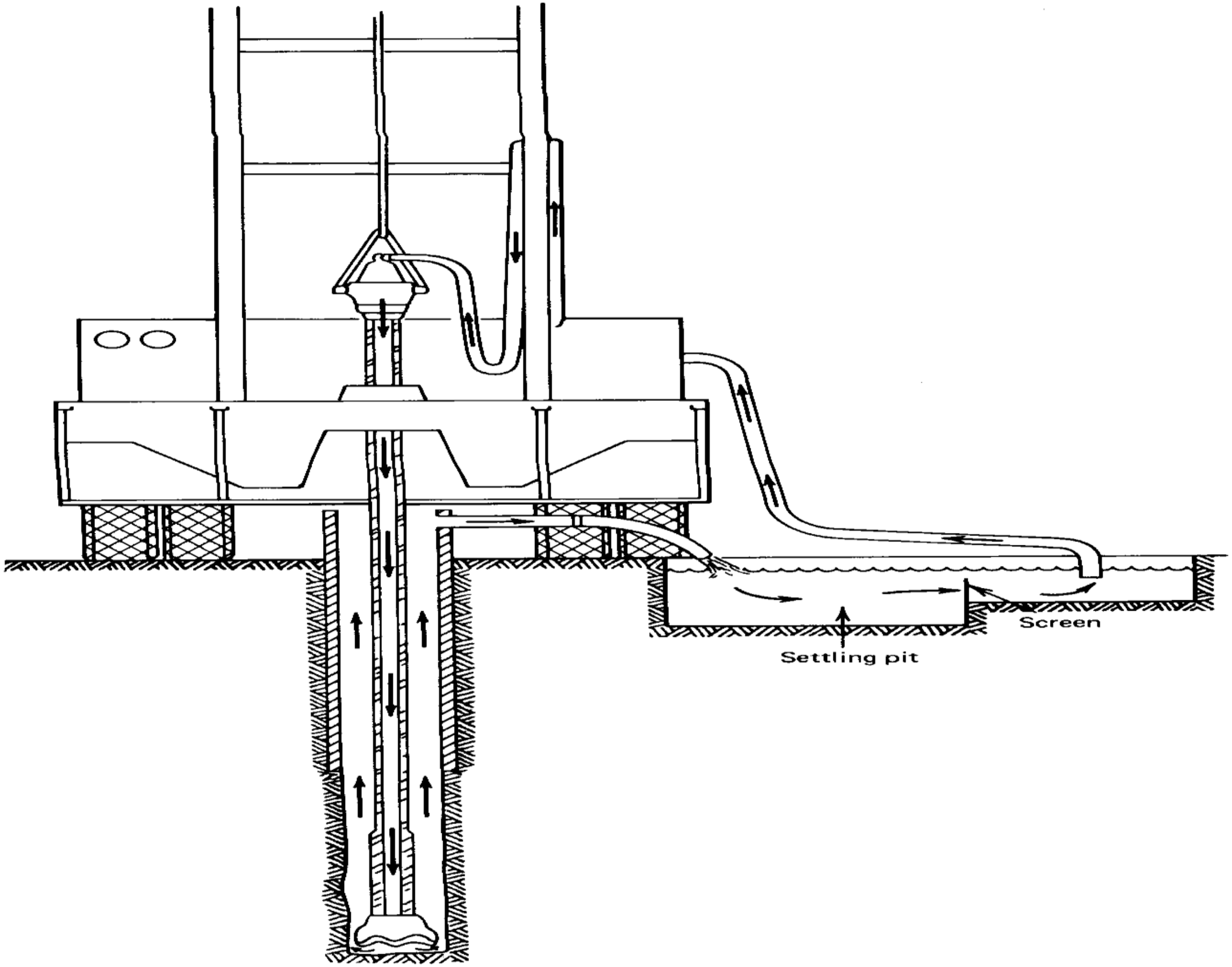


Fig. 5.13 Drilling mud circulation system for the rotary method (after Speedstar Div.[40]).

2. Hydraulic Rotary Method

- **Rapid method for drilling in unconsolidated formations**
- **Diameter – up to 18''**
- **Continuous flow of mud in a hollow rotating nit (30 to 60 rpm)**
- **Drilllers' mud – bentonite clay + water (1.02-1.14 gm/cm^3)**

- **Material loosened by bit carried up the hole by rising mud (upward vel. = 2 – 3 fps)**

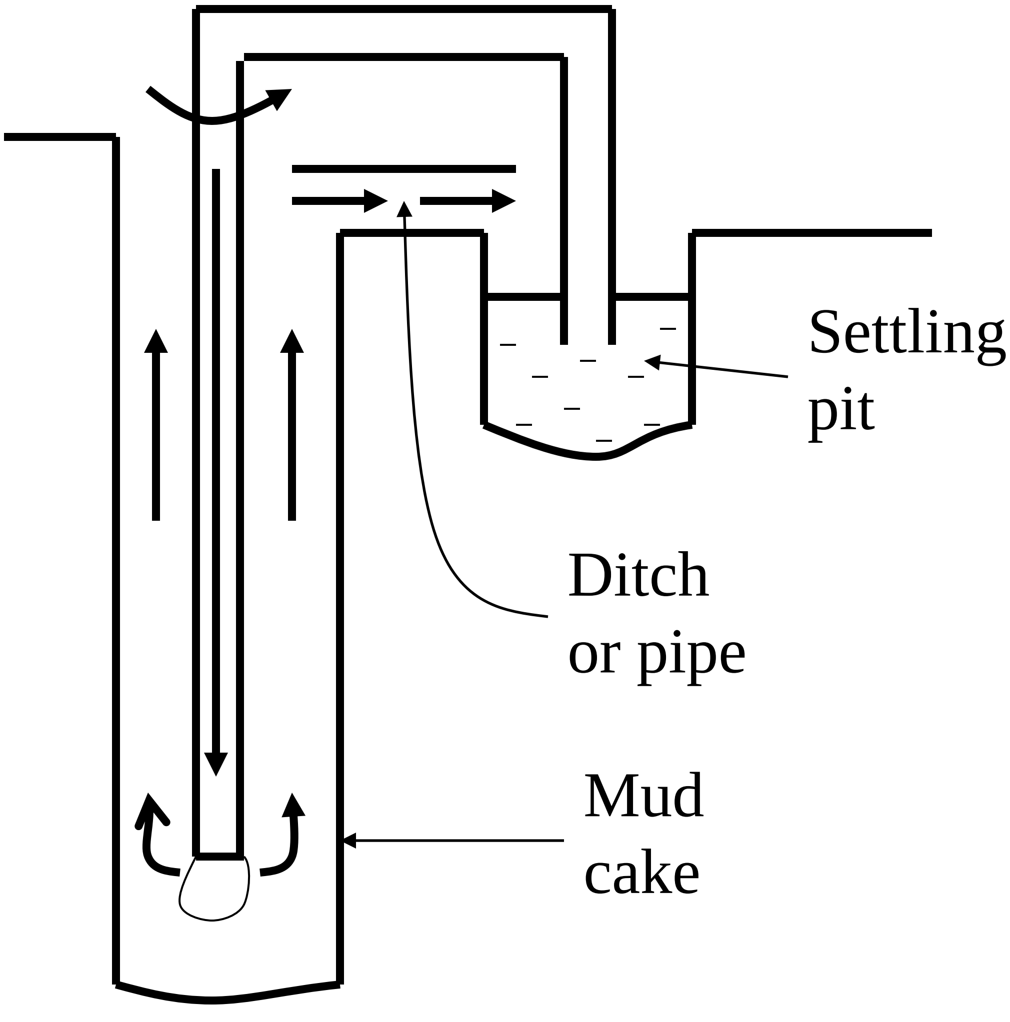
- **No casing ordinarily required because mud forms a clay lining on wall of well, which prevents caving**

- **Casing lowered in hole after drilling**

- **Washing action is necessary to dilute and take out the clay from hole**

- **Calgon (Na hexametaphosphate) with water forced in the casing thru the screen, and up the hole**

- **After washing gravel is placed around the casing**



3. Reverse Rotary Method

- Limited to unconsolidated formations
- Diameter < 48''
- Use a cutterhead on a rotating bit
- Water is introduced in the hole

- **Cutting removed by water, pumped by a centrifugal pump.**
- **Bit speed – 10 to 40 rpm**
- **Mixture circulated through a sump in which sand settles, but fine grains recirculated in hole where they aid in stabilizing walls**
- **Place casing and clean well by water in casing**

4. Air Rotary Method

- Similar to hydraulic rotary method
- Drilling fluids – air, mist, foam, aerated, mud, or other lighter fluids
  - With dry air,upward velocity carrying cutting = 30 –90 fps
  - Drilling speed increased than hydraulic Rotary method

- **Air drilling used in fractured rock**
- **When significant GW seeps into hole**
- **Air -liquid ratio = 200:1 used**
- **Used for consolidated formation**
- **Used for hazardous waste test holes**

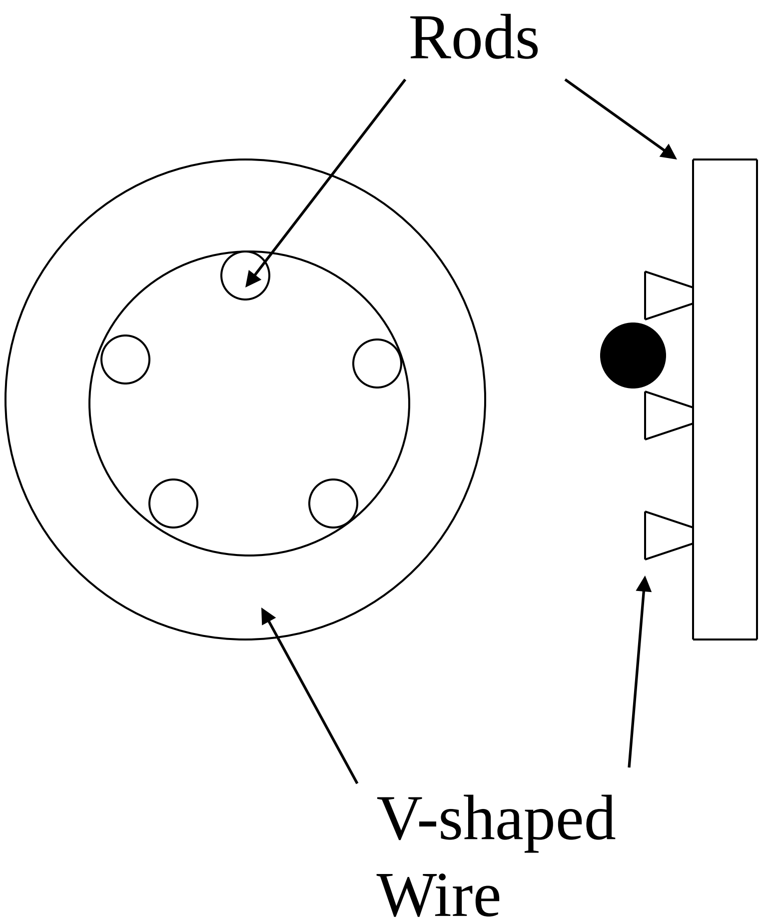
WELL COMPLETION

1. Screen and Perforating

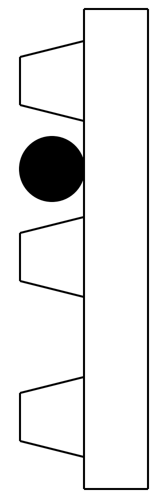
- Field perforation – Mills Knife used to produce vertical openings of 0.5'' wide x 5'' long
- Louver Knife permits openings with width of 1/8'' to 5/32''
- Perforated casing – louver type
  – shutter type

- Screen – V-shaped
  - – blocked less by nearly same size particle than round wire
- Openings large enough to allow 50%-80% of surrounding grains pass into well
- A slot size determined from grained-size distribution
- This passes 50%-80% of aquifer material and should be selected as the coarse remaining fraction forms highly permeable zone around well
- Well screens used with gravel packs

No Clogging



Clogging Possible



2. Gravel Packing

Purpose –

1) **To increase effective well diameter**

2) **Acts as strainer for fine material**

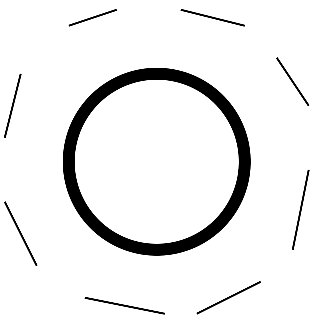
3) **Protects the casing from caving used for large-capacity well**

- Gravel thickness = 6'' to 12''

- Even small thickness of ½ '' effective in reducing sand movement into well

- Packs extends 10 ft above screen

  – Perforated size
  – Gravel size
  – Aquifer material



3. Length of Screen

$$S_L = \frac{Q}{7.48 A_0 V_C}$$

- S_L - optimal length of screen, ft
- Q - discharge, gpm
- A_0 - effective open area per foot of screen ft^2

  (effective open area = 50% of actual open area)
- V_c – optimal screen entrance vel., fpm (func of perm.)

K, gpd/ft²		Vc, fpm
> 6000		12
6000		11
5000	gravel alluv	10
4000		9
3000		8
2000	alluv	6
1000		4
500	fine	3
< 500		2

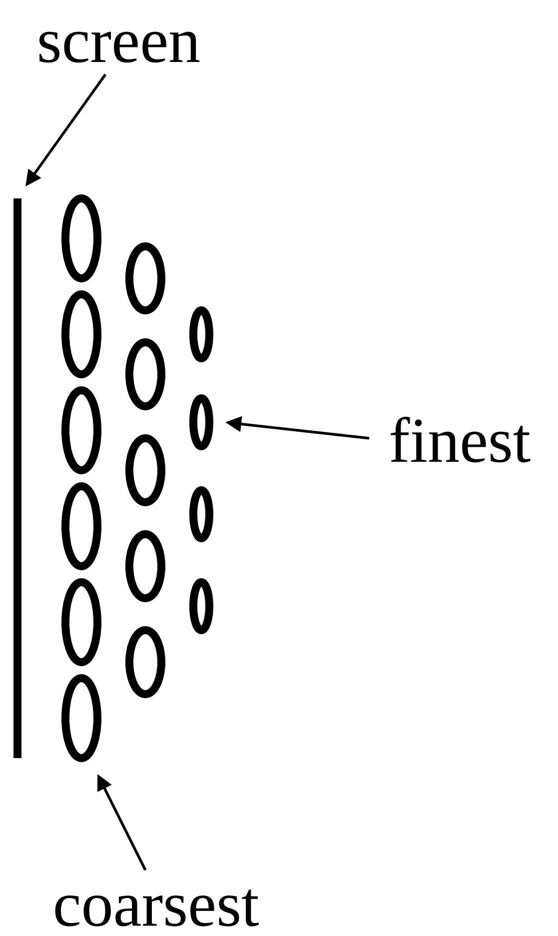
4. Well Development

Purpose

1) **Increases well yield**

2) **Prevents sanding**

3) **Obtains max well life**



Methods

i. Pumping

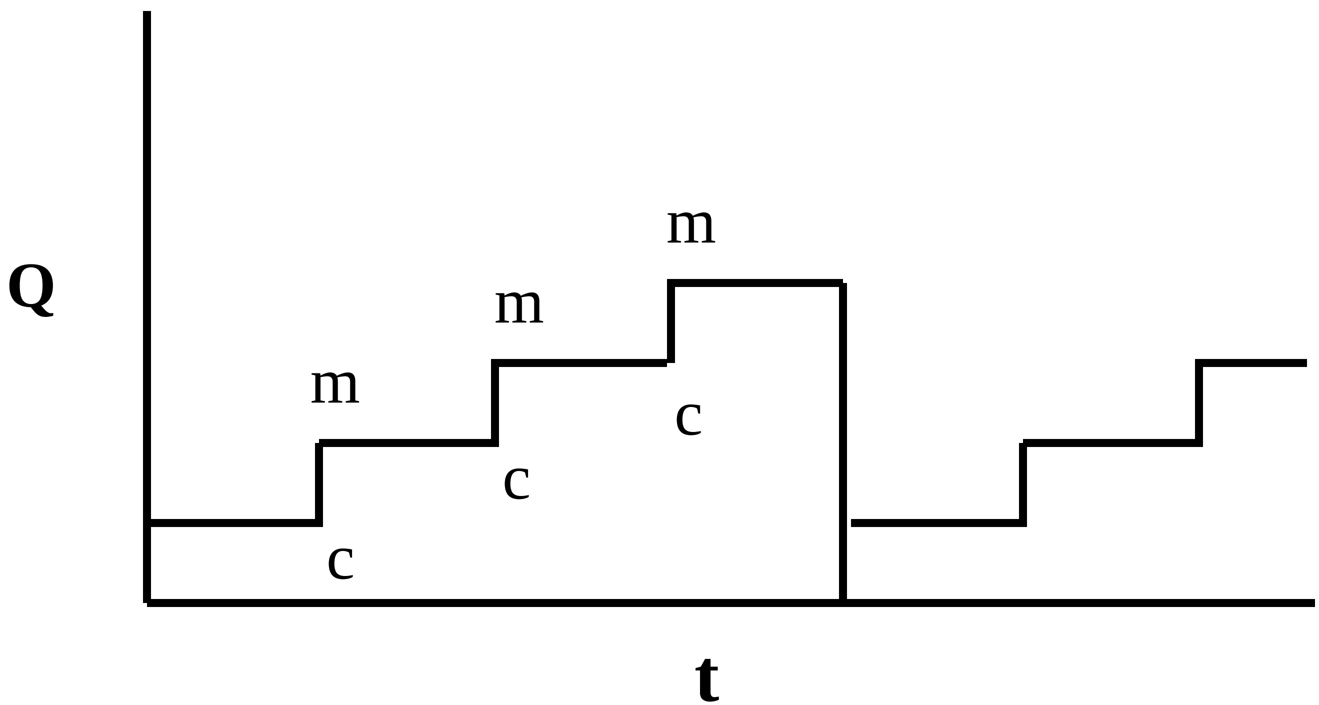
- Pump water starting with low Q and increase it in steps

- After water clears at maximum Q, pump shut down and water level returns to normal

- This regular and non-continuous pumping agitates the fines surrounding well

- **They are then pumped out**

- **Any coarse sediment in well is bailed out or pumped out by sand pump from bottom**



ii. Surging

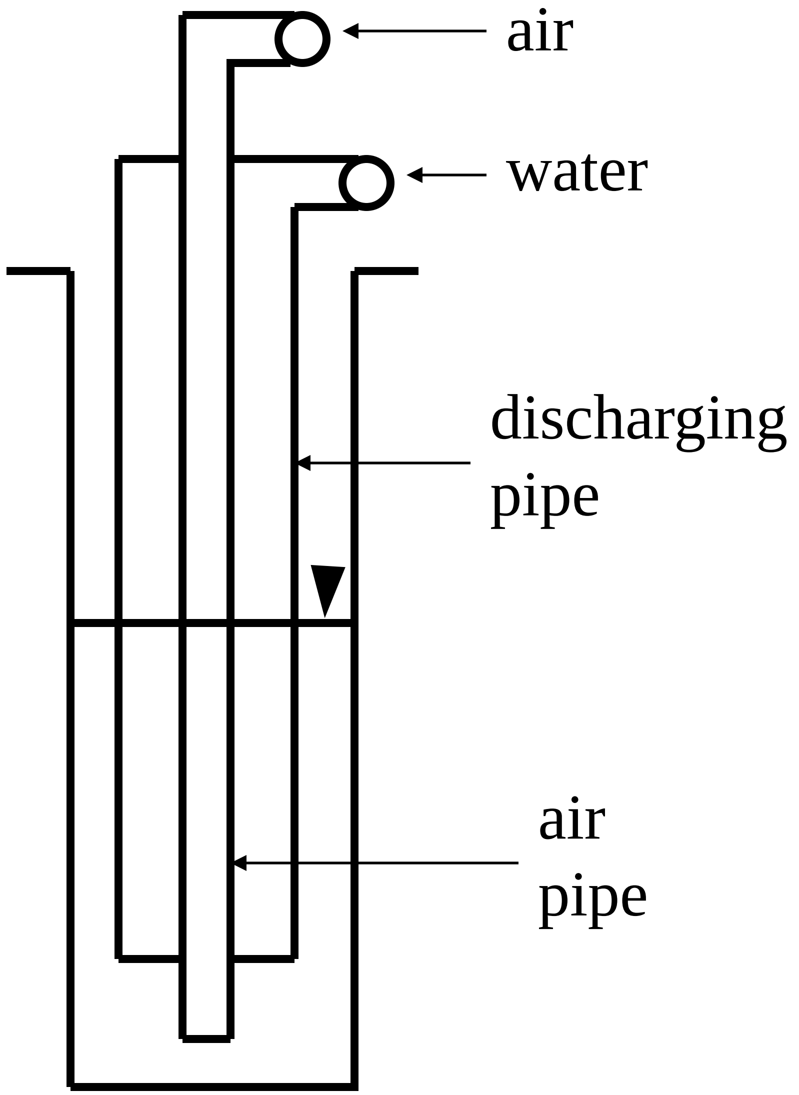
- Created by rapid up and down motion of plunger
- Plunger operated above screen
- Calgon added to well
- As plunger rises , it draws water into well, while lowering forces water into aquifer
- At intervals, pump out mud and water
- Surging continued until sand and mud enter well

iii. Use of Compressed Air

- Air and discharging pipes can be shifted vertically
- Initially pipes extend to the bottom
- Water depth is discharging pipe = 2/3 of pipe length
- 100 to 150 psi developed and air sent in air pipe
- This causes a powerful surge in well, first increasing and then decreasing as water is forced up the discharge pipe

- **This process loosens fine around screen and brings them in well**

- **Operation repeated at intervals along screen until sand accretion negligible**



iv. Dry Ice

- First, to loosen clay, Hcl acid is poured in well
- Casing is capped at top & compressed air is forced in well
- This forces chemicals into clogged strata
- Later, cap removed and dry ice added
- CO_2 gas released and builds pressure in well
- This causes a burst of muddy water from well

5. Pumping Equipment

Shallow wells

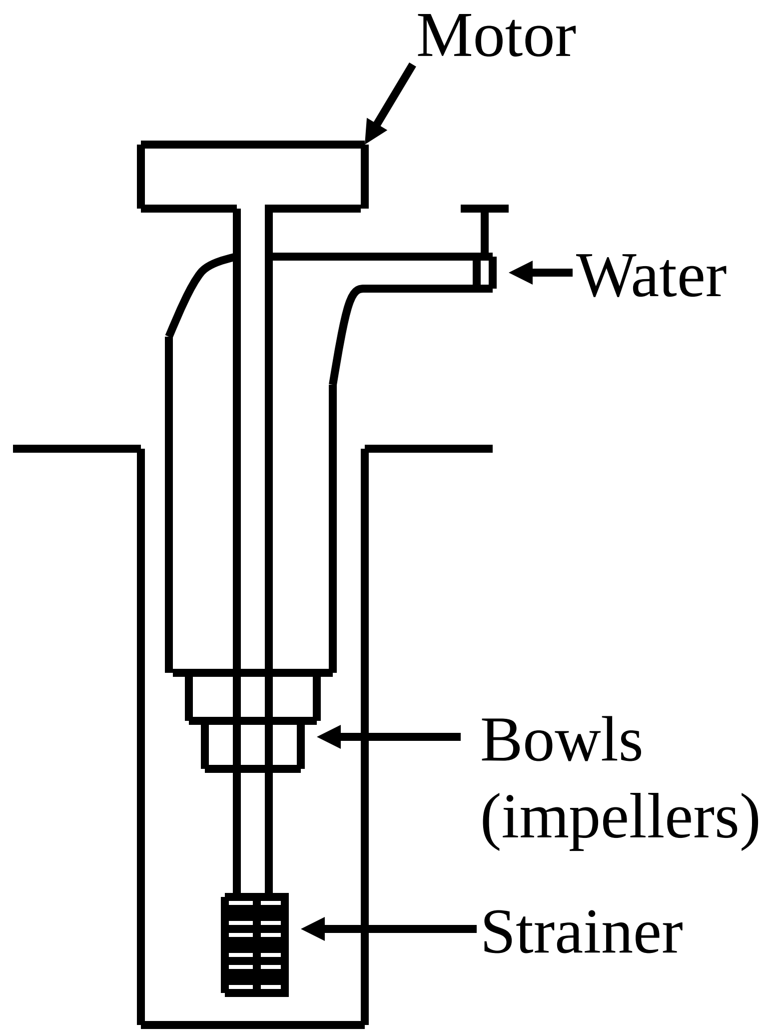
- Q < 100 gpm
- Suction lift < 25 ft

i. Hand pumps

ii. Turbine pumps

iii. Gear pumps

iv. <u>Centrifugal pumps</u>



Deep Wells

- $Q > 100$ gpm
- $h > 25$ ft

i. Plunger pump
ii. Deep – well turbine pump
iii. Displacement turbine pump
iv. Air lift pump
v. Submersible pump
vi. Jet pump

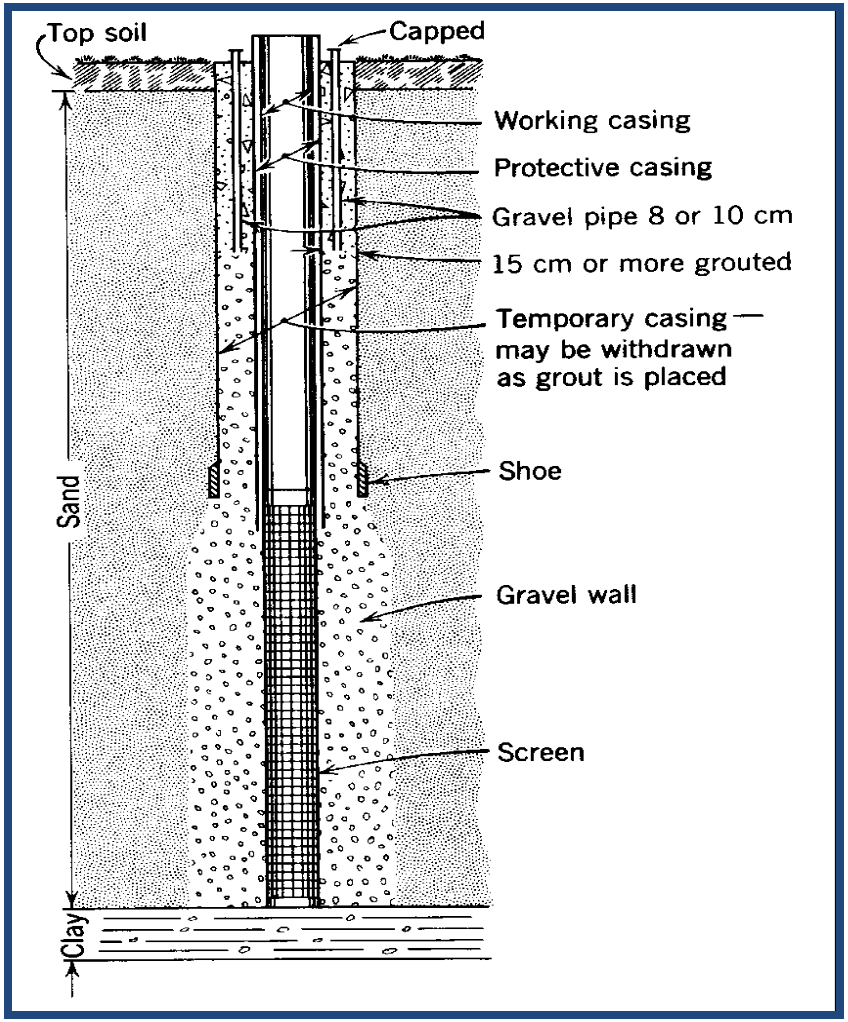
- Pump Manufacturers furnish advice on size and type of pump

6. Maintenance and Repair

- Good Life – 20 years

- Failure of well – decrease in yield causes

i. Pump – sanding and improper lubrication of motor



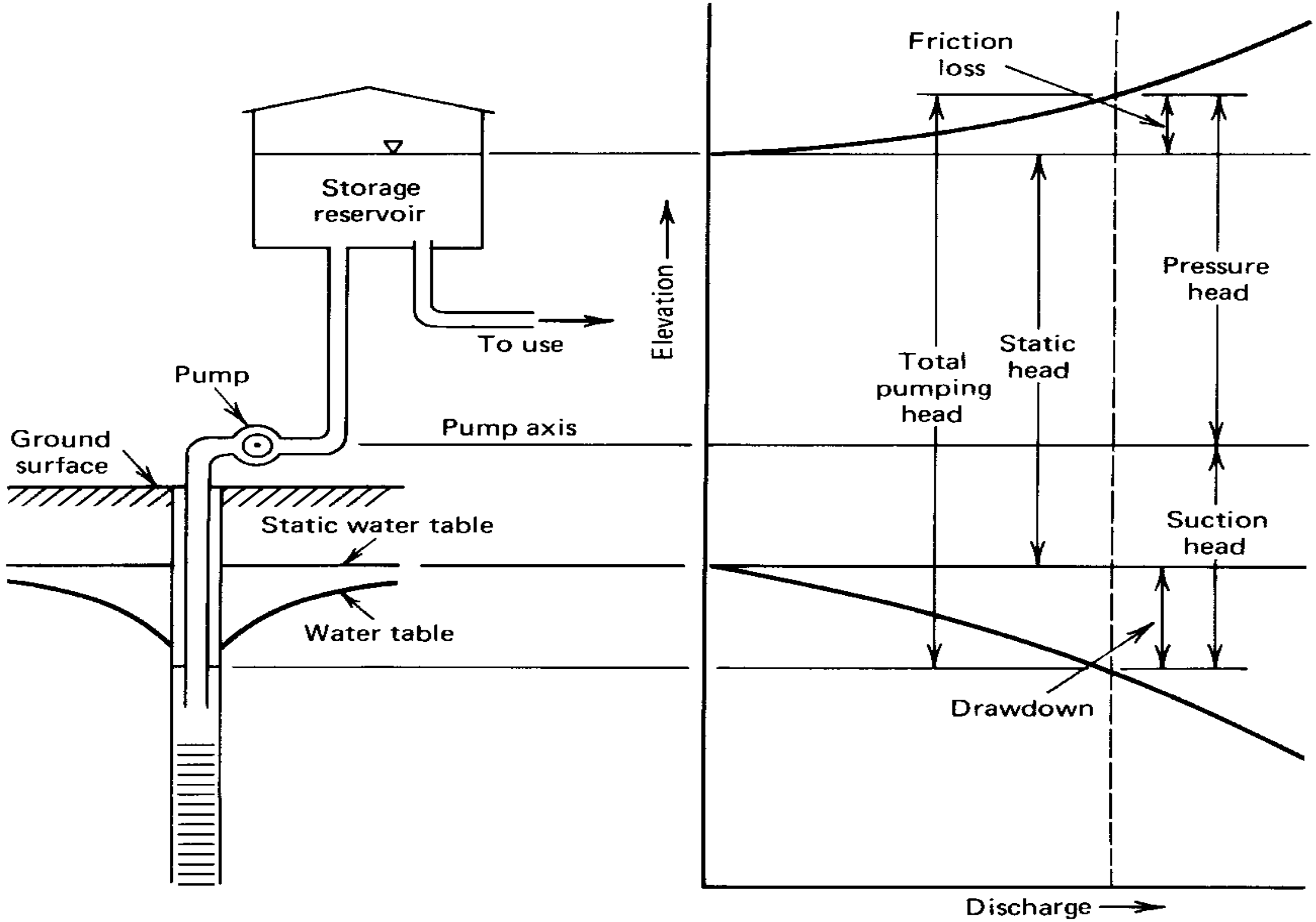


Fig. 5.21 Diagram illustrating total pumping head for a well supplying a storage reservoir. Note the increase in head as a function of well discharge.

ii. Depletion of water supply

iii. Faulty well construction – settlement, casing collapse of casing

iv. Corrosion – due to water

- Low pH < 7
- D.O. < 2 ppm
- H_2S > 1 ppm
- TDS > 1000 ppm
- CO_2 > 50 ppm
- Cl_2 > 500 ppm

v. **Incrustation – deposition of minerals on screen**

- **If water has high pH > 7.5**
- **Carbonate hardness ($CaCO_3$) > 300ppm**
- **Iron > 2 ppm**
- **Manganese > 1ppm**

vi. **Cleaning –**

- **Mechanical – surging etc.**
- **Chemical – Hcl, Calgon**