

# GROUND WATER EXPLOITATION- AN INTRODUCTION



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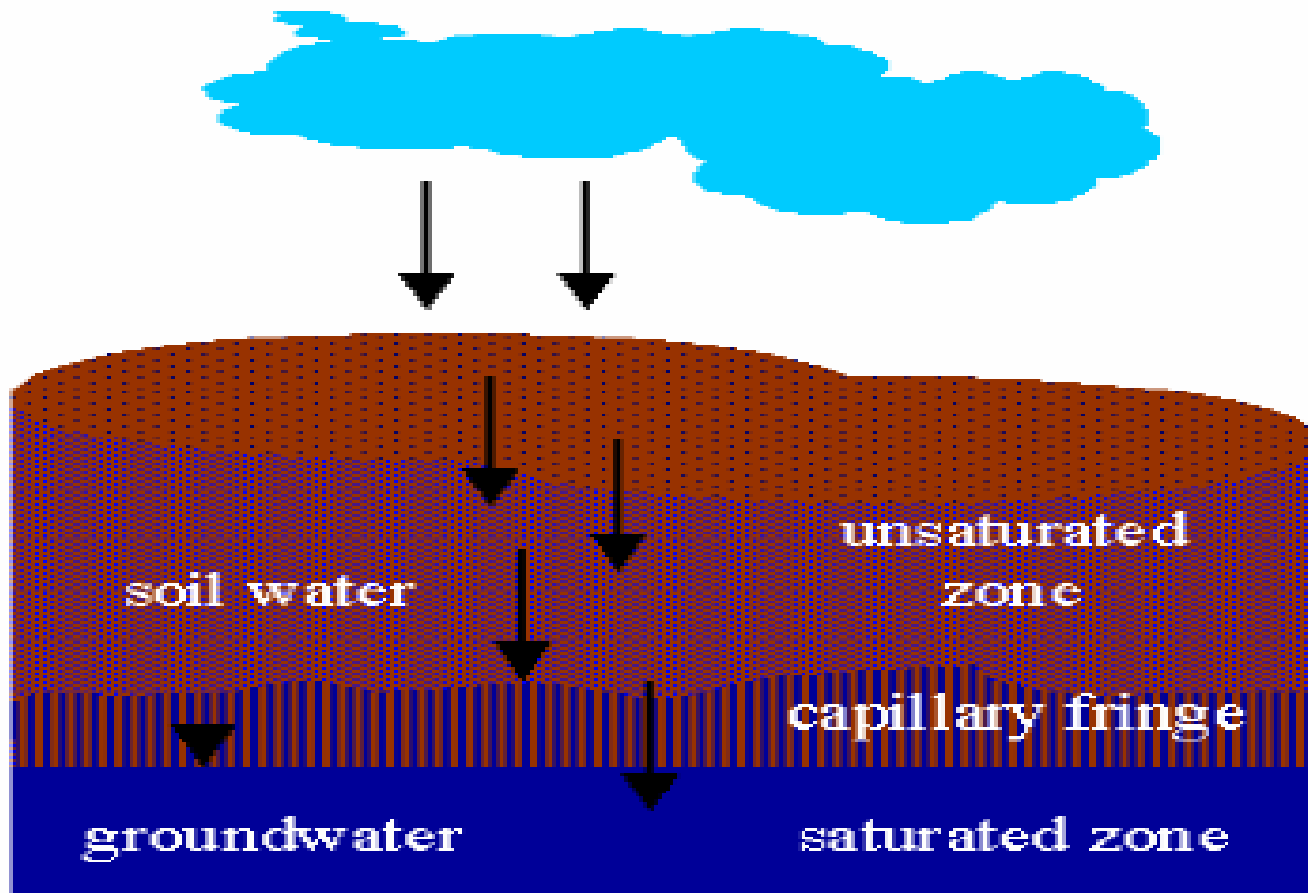


# GROUND WATER

- Ground water is a mineral that occurs in the subsurface within sediments, rocks, desertic sand, ice & snow.
- It gets replenished from meteoric precipitation.
- Ground water is most widely distributed precious resource of the Earth.
- Among the natural water resources, ground water forms an invisible component of the system.



# GROUND WATER



Precipitation

Infiltration

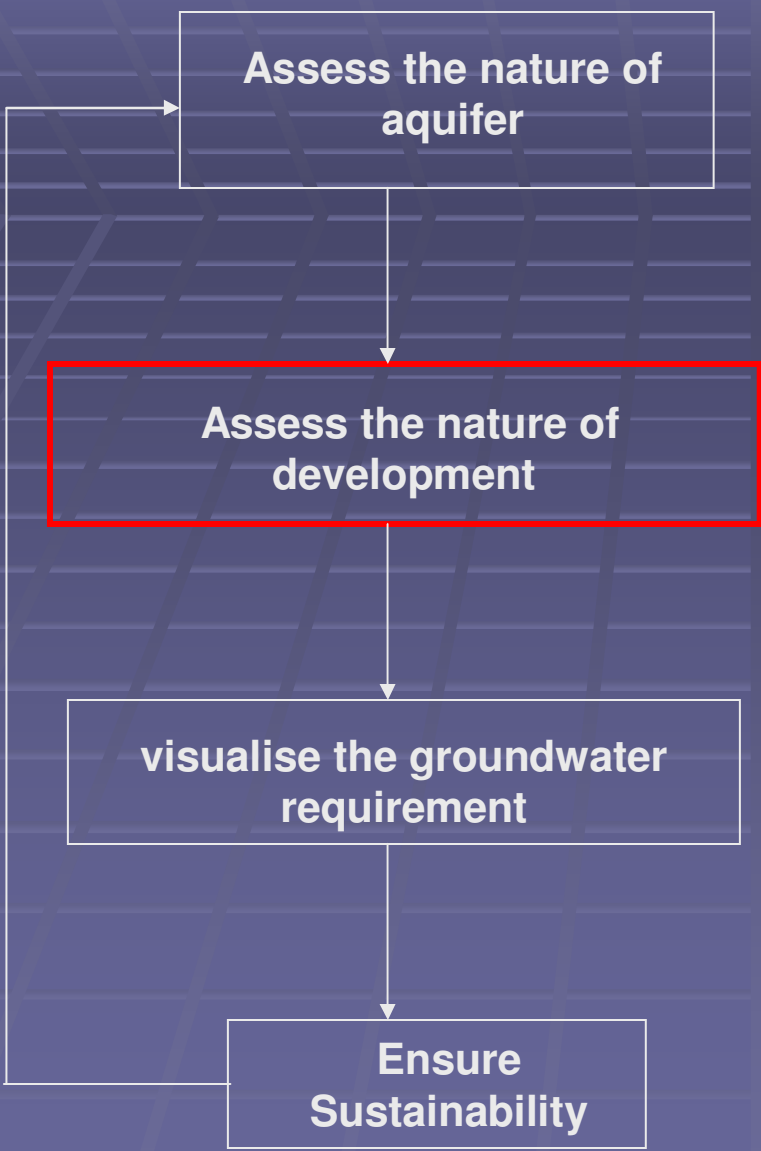
Recharge

# OBJECTIVE OF GROUND WATER EXPLORATION

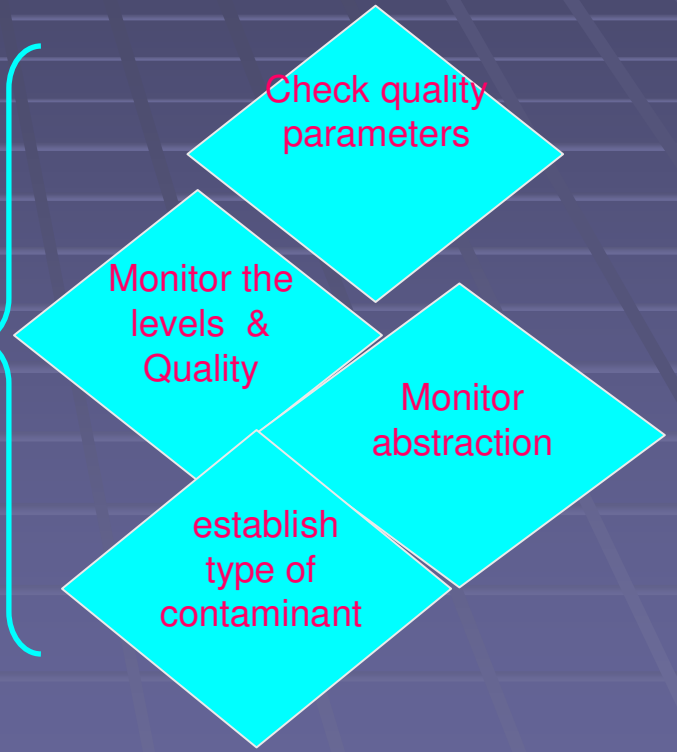
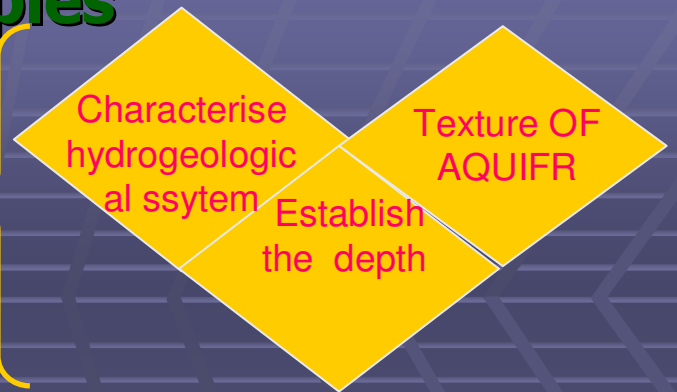
- Usually the ground water exploration projects pass through the phase of regional surveys, leading to detailed surveys and ultimately resulting in the exploitation of ground water by means of bore holes, wells.
- The main objective of these surveys is to study and understand the hydrological cycle of the region, to have an overall concept about the type, nature & number of aquifers, the quality of ground water.



# Groundwater Exploration Principles



Monitoring



**KEY**

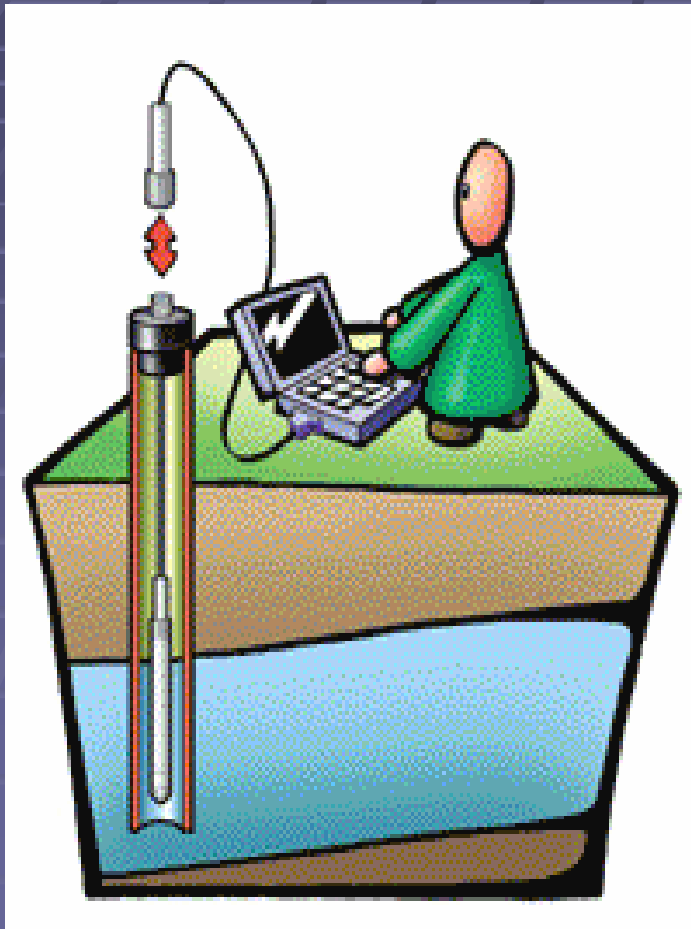
- ◆ Quantity
- ◆ Quality

# METHODS AND TECHNIQUES OF GROUND WATER EXPLORATION

AERIAL	SURFACE	SUB-SURFACE.	ESOTERIC.
1. Photogeologic Methods.	1. Geological Methods.	1. Geological.	1. Water divining.
2. Landsat/ IRS	2. Geomorphological methods.	2. Hydrogeological.	2. Astrological.
3. Infrared imagery.	3. Hydrogeological Methods.	3. Tracer techniques.	3. Biophysical.
4. Electro magnetic [EM] techniques.	4. Geophysical Methods.	4. Geophysical Logging techniques.	
	a). Electrical & EM. b). Seismic. c). Magnetic. d). Gravity.		
	5. Geobotanical Methods.		
	6. Geochemical Methods.		



# STAGES OF GROUND WATER EXPLORATION



- 1<sup>st</sup> stage- integrated hydrogeological & geophysical investigation.
- 2<sup>nd</sup> stage- Drilling.
- 3<sup>rd</sup> stage- well design, construction & development.





# GROUND WATER EXPLOITATION

- The proper exploitation of ground water resources involves apart from the location of suitable source, the construction of properly designed wells.
- The design and the execution of water supply systems and their maintenance is an integral part of the scheme of exploration and management.
- Numerous problems of ground water exploration & exploitation require systematic use of scientific techniques.





# GROUND WATER ABSTRACTING STRUCTURES

- The ground water abstracting structures are man made which collect & hold water for exploitation.
- The common ground water abstracting structures are Dug wells, Dug cum bore well, bore well, collector well & Infiltration gallery.
- Wells are vertical shafts excavated or holes drilled in earth to the level of water table for extraction.
- The wells have to be designed to get the optimum quantity of water economically from a given geological formation.



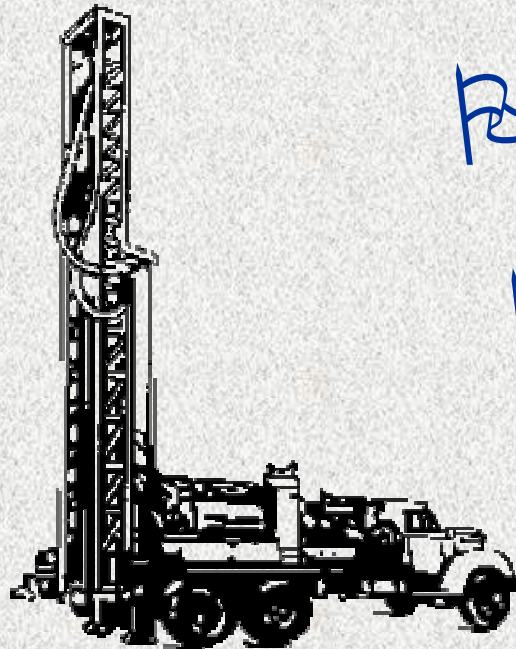


# GROUND WATER WELLS

- The success of ground water exploration programme depends on the exploitation of it also. The ground water explored should be extracted by abstracting structures like dug wells & bore wells adapting proper exploitation techniques.
- The well design & construction depends upon many factors like hydrogeological setup, topography, rainfall and techniques adapted etc.

# TYPES OF WATER WELLS

## Types of Water Wells



↳ DRILLED

↳ DRIVEN

↳ DUG 

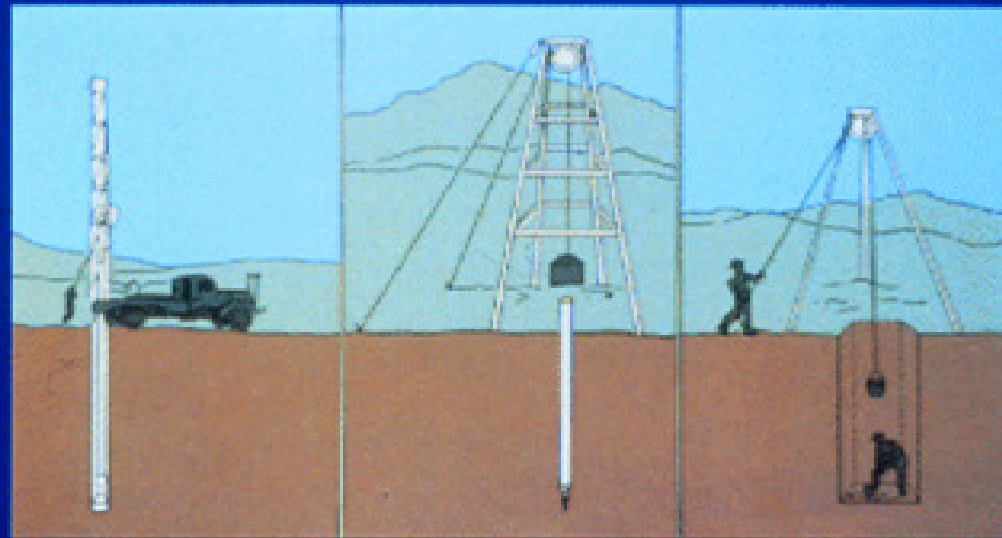




# TYPES OF WELLS

## Private Water Sources Wells

### Types of wells



Drilled

Driven

Dug



# DRILLED WELLS

## DRILLED WELLS

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- Casing material: Steel or PVC plastic
- Installed by well drilling contractors
- Much more common than driven or dug wells
- Most are >50 ft. deep (avg. 125 ft.)
- ***MOST SANITARY WELL TYPE***

# COMMON TECHNIQUES OF GROUND WATER WELL DRILLING

1. Percussion.
2. Mud rotary.
3. Reverse Circulation.
4. Air Rotary.
5. Down- the- hole drilling.





# CABLE- TOOL PERCUSSION DRILLING

**Cable Tool**



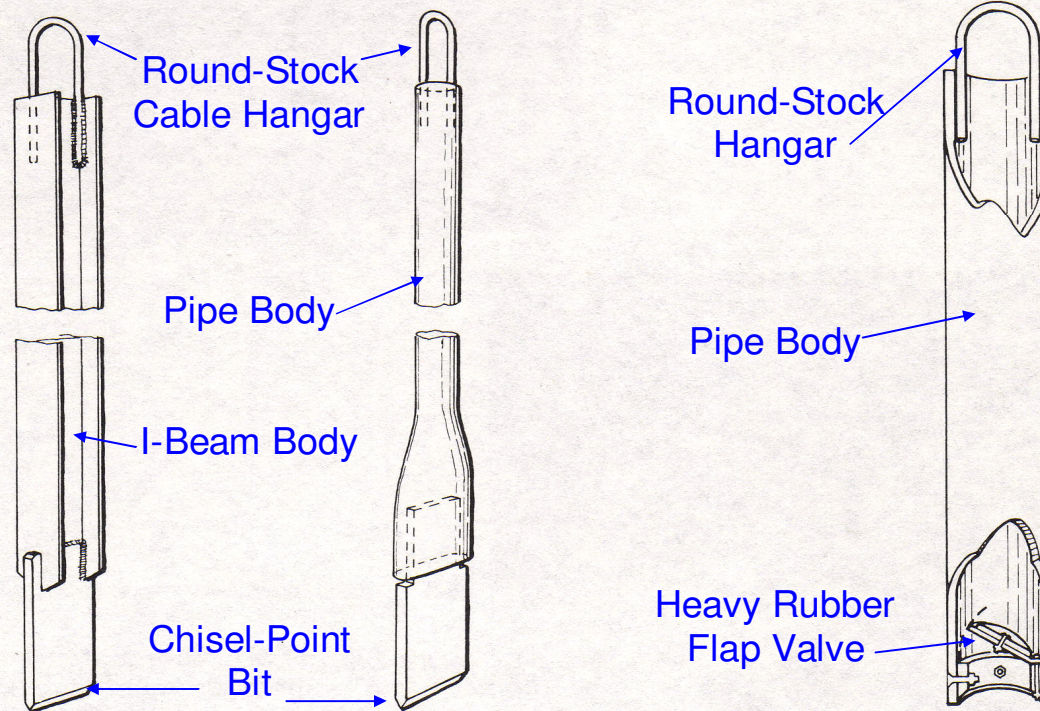
- The cable tool bit is essentially a crusher. The performance depends upon the foot pounds of energy that it delivers when striking.
- The factors affecting the drilling rate efficiency – resistance of rock, weight of drill tools, length of stroke, strokes per minute, diameter of bit, clearance between tool joints & inside of hole, density & depth of accumulated sludge.



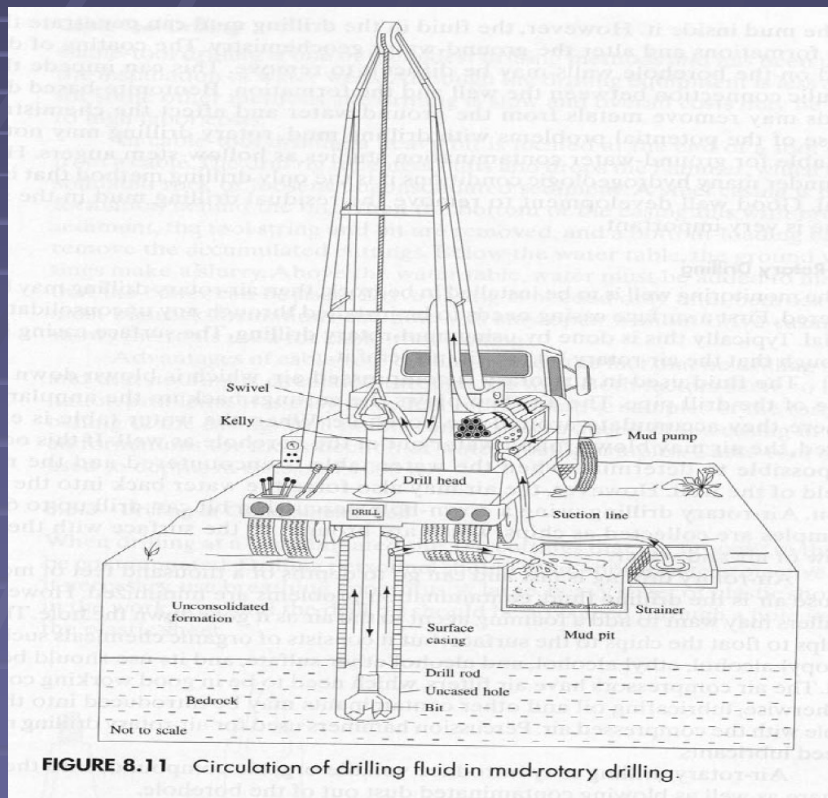


# PERCUSSION DRILLING TOOLS

## Percussion Drilling Tools



# MUD ROTARY DRILLING



- This is done by means of a rotating bit & removing the cuttings by continuous circulation of drilling fluid. The two key items in this method are bit & the drilling fluid.





# REVERSE CIRCULATION DRILLING

- This is done with the flow of drilling fluid reversed used in conventional rotary method.
- Reverse circulation offers the cheapest way of drilling larger diameter holes in soft unconsolidated formations.
- Conditions that favors the use of this method include sand, silt, soft clay, absence of clay or boulders.



# DRILLING FLUID

## Bentonite Drilling Fluid - *Functions* -

- **REMOVAL OF DRILL CUTTINGS FROM BOREHOLE**
- **STABILIZE THE BOREHOLE**
- **COOL AND LUBRICATE DRILL BIT**
- **CONTROL FLUID LOSS TO GEOLOGIC FORMATIONS**
- **DROP DRILL CUTTINGS INTO MUD PIT**
- **FACILITATE COLLECTION OF GEOLOGIC DATA**
- **SUSPEND CUTTINGS WHEN DRILLING FLUID CIRCULATION STOPS**





# AIR ROTARY DRILLING

- The drilling fluid may be air, foams. This method is specially suitable for limestones.
- Air drilling is used in fractured rocks.
- Air foam is used to remove cuttings. With dry air upward velocities are in the range of 10 to 30 meters per second in the annular space between the drill pipe and hole.



# ROTARY RIG.



**MUD PIT**





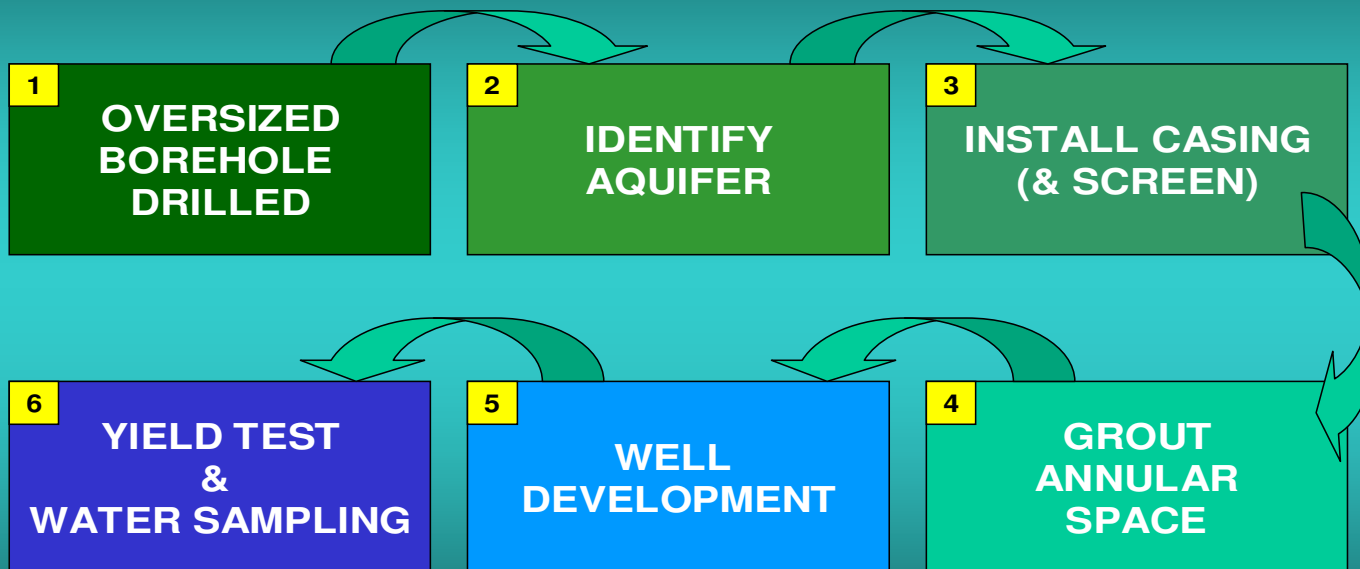
# ROTARY RIG





# ROTARY WELL CONSTRUCTION-SEQUENCES

## *TYPICAL ROTARY WELL CONSTRUCTION SEQUENCE*



# TUBE WELL IN ALLUVIAL AREA

## Following steps are involved:

- (1) Diameter of bore-hole
- (2) Proper Pilot Borehole Drilling
- (3) Electrical Logging
- (4) Reaming of bore-holes
- (5) Installation of well Assembly
- Type of casing (pipes)
- Diameter of Casing
- Well Screen length (Slotted Pipes)
- Screen size (Slot size)
- Filter pack (Gravel packing)
- (6) Development of tube wells





# TUBE WELLS

- Tube wells can be drilled into unconsolidated formation which require a well screen.
- The tube wells are of three types.
  1. Screened well.
  2. Screened well with gravel pack.
  3. Cavity wells.

# OBJECTIVE OF WATER WELL DESIGN

## WATER WELL DESIGN



- ❖ Provide well that meets needs of owner
- ❖ Obtain highest yield with minimal drawdown (consistent w/ aquifer capabilities)
- ❖ Provide suitable quality water (potable and turbidity-free for drinking water wells)
- ❖ Provide long service life (25+ years)

***NEW: Minimize impacts on neighboring wells & aquatic environments***



# WELL DESIGN- CRITERIA

- The choice of open well or bore well & the method of well design depends upon topography, geological conditions of the underlying strata, depth to water table, rainfall, climate and the quantity of water required.
- A water well design involves selection of proper dimensions like the diameter of the well & casing, length & location of the screen including slot size, shape & percentage open area.





# WELL DESIGN

- The success of well depends on well design and construction. The tube well design shall ensure an efficient and economical well with a service life of more than one decade.
- The size of the well should be properly chosen since it significantly affects the cost of well construction.
- Well must be large enough to accommodate the pump to be installed.
- Before installation of screen it is essential to check the verticality of borehole.
- The optimum length of well screen is chosen in relation to the aquifer thickness, available drawdown and stratification of aquifer.
- Theory and experiments have shown that screening of bottom one third of the aquifer [unconfined] provides the optimum design.
- The screens must be provided below the maximum summer water level.





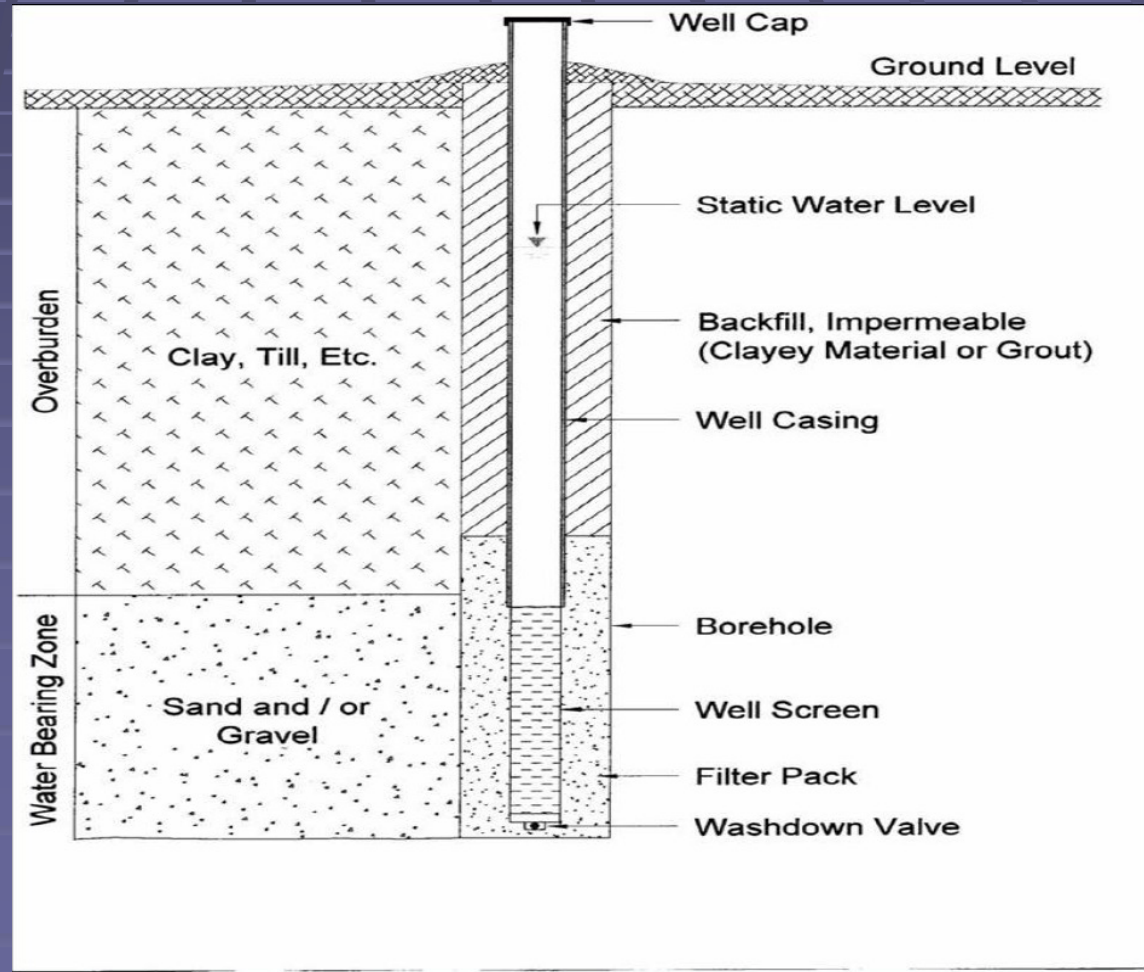
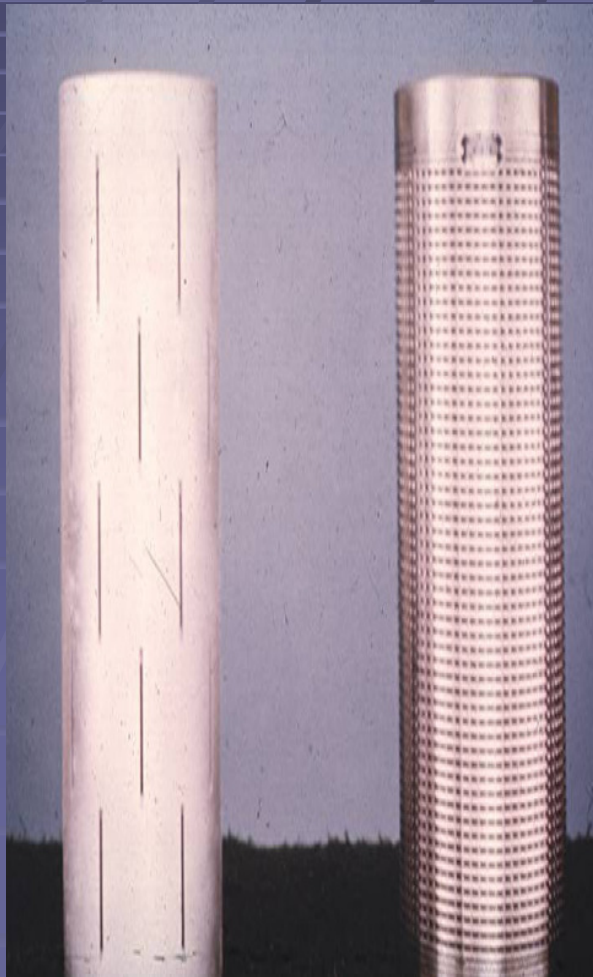
# WELL SCREENS

- Provision of a suitable well screen is the most important part of well design.
- The selection of screen size includes, type of screen, the entrance velocity, the open area & diameter & length of the screen.
- The earliest screens used in India were the agricultural strainer, comprising an iron pipe with circular holes wrapped around with a brass screen.
- Johnsons of USA manufacture screens with stainless steel wire wound around several longitudinal lugs so that the spacing between wires can be adjusted.
- PVC pipes with longitudinal lugs in the inside with slots cut in the form of narrow spirals.





# TYPICAL DRILLED WELL CONSTRUCTION WITH SCREEN WELL



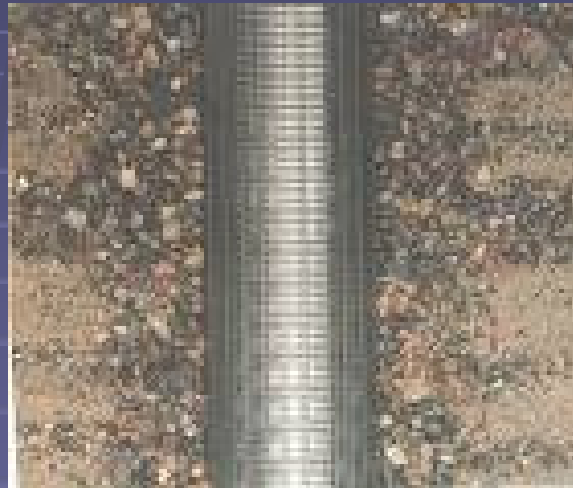


# SCREENED WELLS



**Naturally  
Developed**

WELL SCREEN  
SET IN  
NATIVE GEOLOGIC  
MATERIALS  
(SAND OR GRAVEL)



**Filter  
Packed**

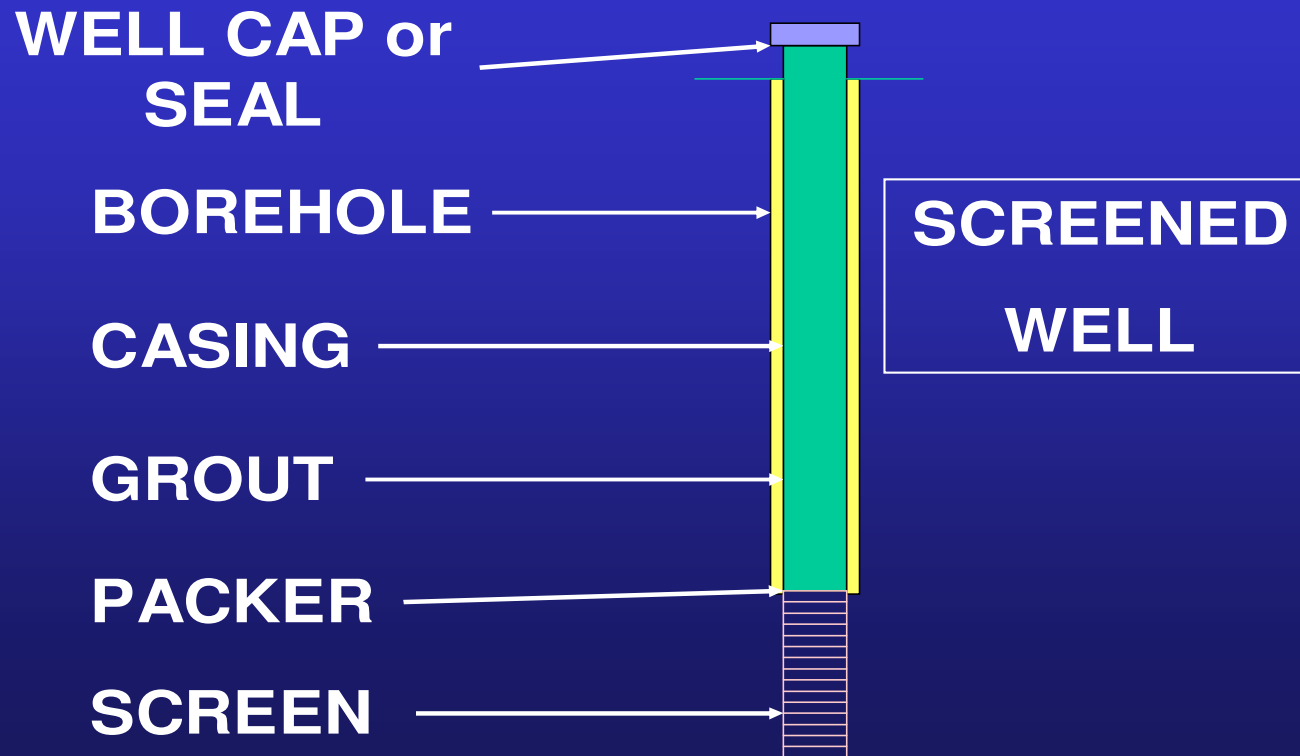
(a/k/a Gravel-Packed)

GRADED-WASHED  
SAND PLACED  
OUTSIDE  
WELL SCREEN



# SCREENED WELL

## DRILLED WELL COMPONENTS





# WELL DESIGN

## WELL DIAMETER:

**MYTH**

*Doubling well diameter appreciably increases well yield*

**FACT**

**DOUBLING WELL DIAMETER**

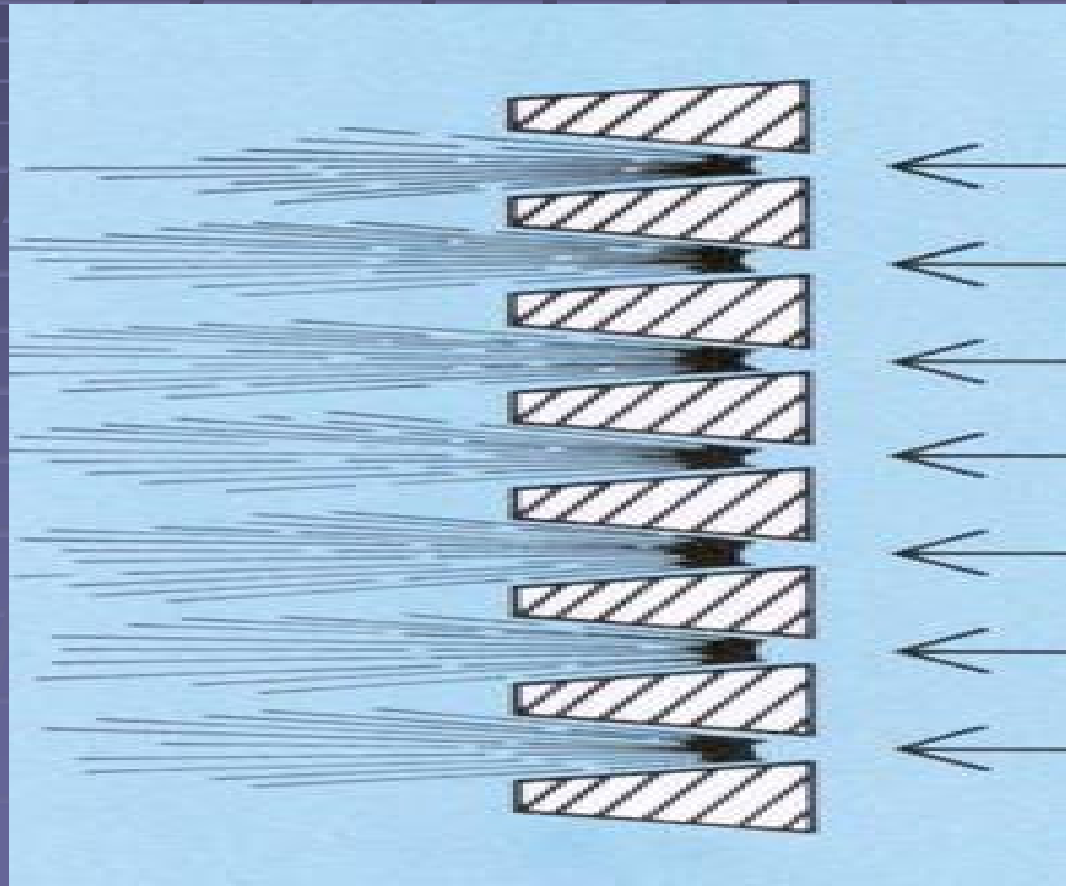
**10% YIELD INCREASE**

**DOUBLING SCREEN LENGTH**

**DOUBLES WELL YIELD**



# CROSS-SECTION OF SCREEN WIRE





# CASING MATERIALS COMPARISON

## CASING MATERIALS COMPARISON

**PVC PLASTIC**

vs.

**STEEL**

**Non-corroding**

**Lower strength**

**Fewer water quality  
complaints**

**Rotary construction only**

**1/3 cost of steel**

**SDR 17 needed past 200 ft.**

**Corrodes**

**Higher strength**

**Rusty water**

**Suitable for any  
drilling method**

**No heat of hydration  
impact from cement grout**



# WELL CONSTRUCTION

- The suitability of well construction depends upon the geology, depth to water level and design of tube well.
- Placement of gravel or pebble packing around a well has to be done carefully to avoid segregation or bridging.
- The gravel pack materials should be clean, rounded, smooth and uniform. The maximum grain size should be less than 10 mm.
- In saline water zones utmost care to be taken in design & construction of tube well. In some coastal sedimentary terrains the shallow aquifers will be brackish & the deep confined aquifers will be fresh. Arresting & sealing of these saline water zone is done by packing with dry clay balls of about 10 to 12 mm which is in practice in TWAD Board & among the agriculturists in Tamilnadu.
- This method of sealing & cementing proved to be very successful & fruitful.
- The dry clay balls when comes in contact with saline water, will get swelled & there by forming a compact impervious layer around the saline water zone through which the saline water will not percolate down, so that the deep fresh water aquifers are protected from mixing with saline water.





# FILTER - PACK

## *BENEFITS*

- ↖ Greater porosity
- ↖ Higher hydraulic conductivity
- ↖ Reduced drawdown
- ↖ Higher yield
- ↖ Reduced entrance velocity
- ↖ Faster development
- ↖ Easier grouting
- ↖ Longer well life
- ↖ Improved well rehabilitation
- ↖ Reduce sand pumping

# CONSTRUCTION OF BORE WELL IN SEDIMENTARY TERRAIN



Bore well

Kankar

Clay

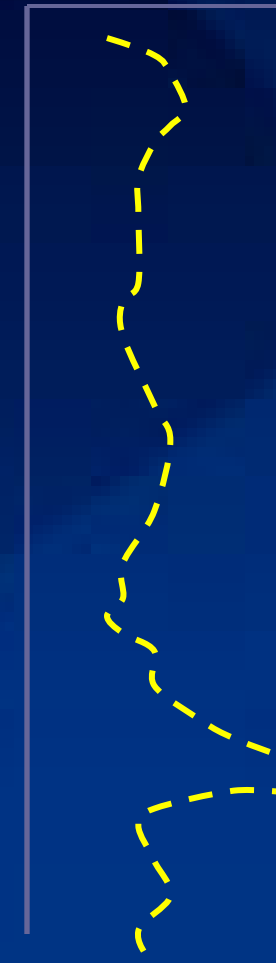
Sandy-clay

Sand

shale



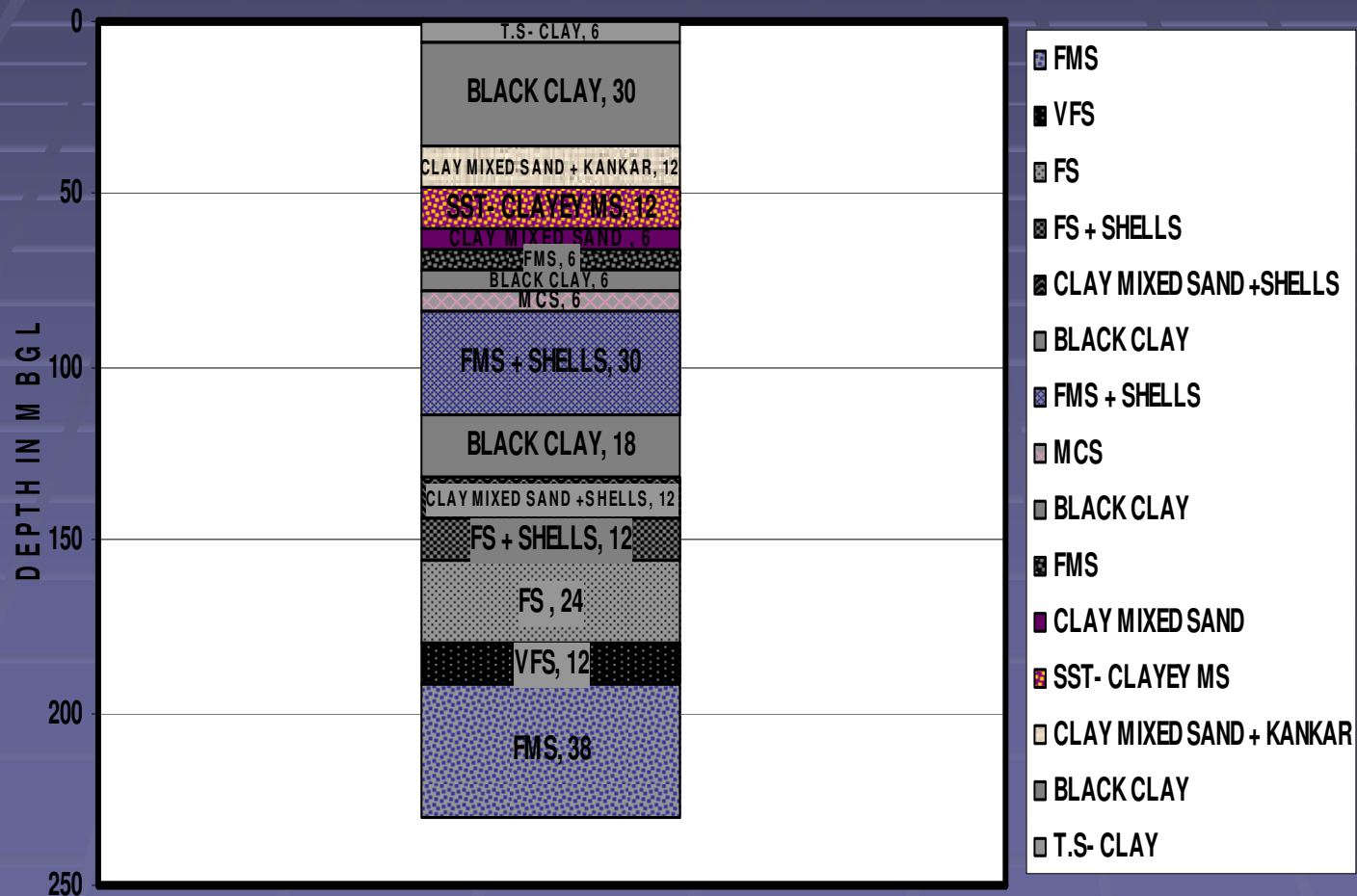
Logging Rest.  
-curve





# PINNATHUR, LITHOLOG

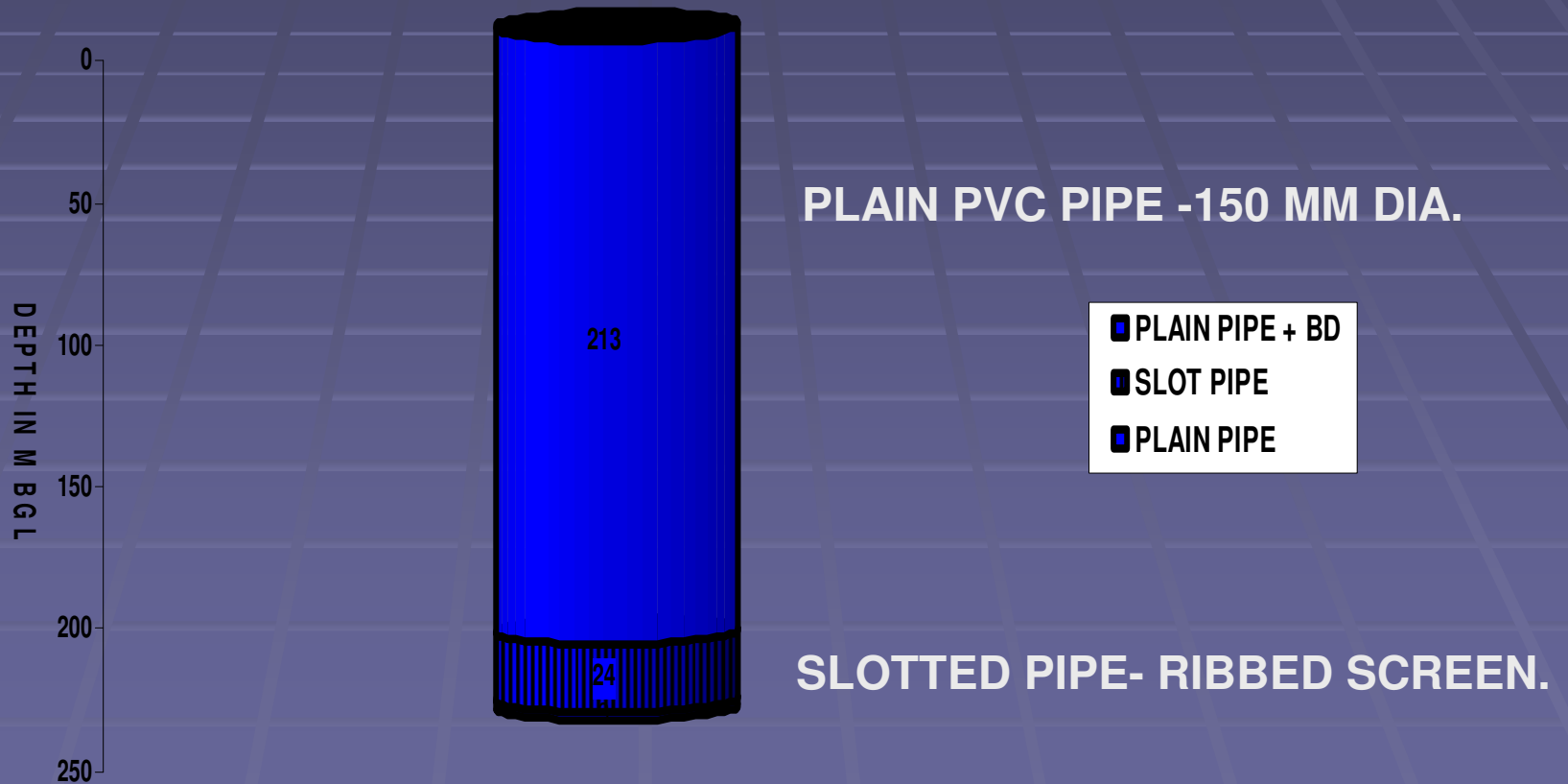
## PINNATHUR LITHOLOG



# PINNATHUR, CHIDAMBARAM TALUK, TUBE WELL DESIGN



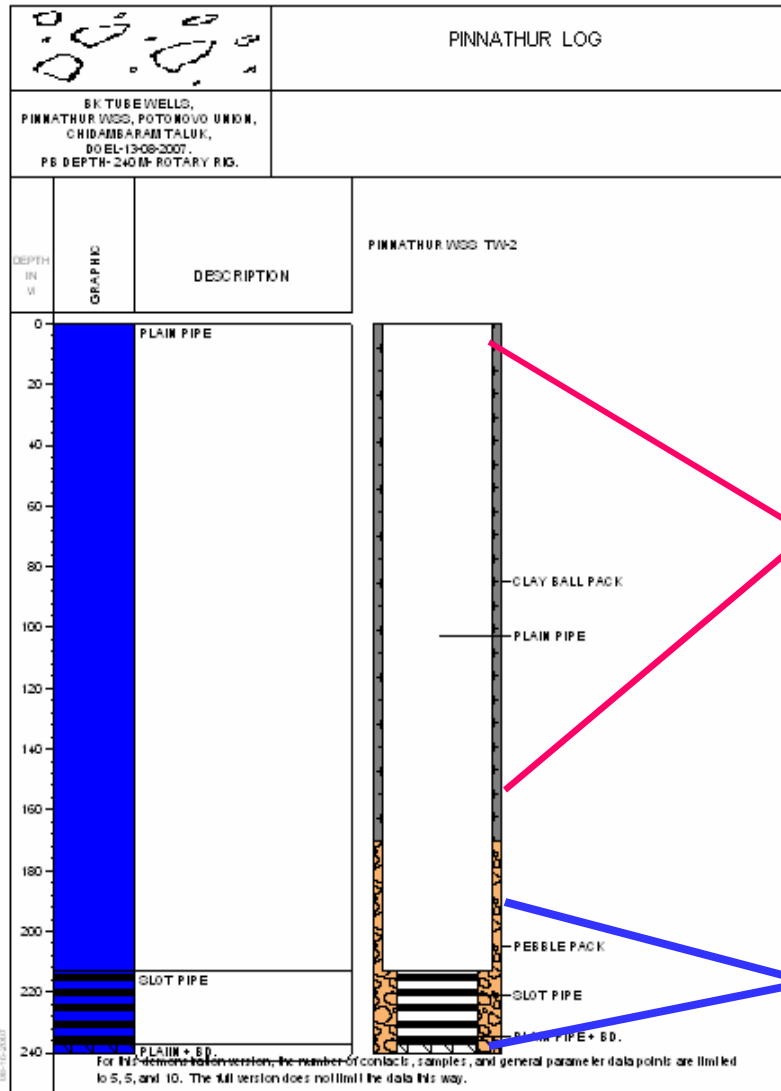
PINNATHUR WSS PD





# PINNATHUR, TUBE WELL CONSTRUCTION

DEPTH OF TUBE WELL- 242 M.  
 DIA- 150 MM.  
 DRY CLAY BALL PACK- 0- 170 M.  
 PEBBLE PACK- 170 – 242 M.



SALINE WATER ZONE.

DEEP CONFINED FRESH WATER AQUIFER ZONE.



# CONSTRUCTION OF TUBE WELL IN COMBINATION AREA

There are areas where both alluvium and the lower portion of hard rock contains water. In such areas, tub wells are constructed deploying both Direct Rotary drilling rig and Down the hole hammer rig. These tube wells require combined methodology of construction as spelt separately both for alluvial and hard rock area.



# ADVANTAGES AND DISADVANTAGES OF TUBE WELLS

SL NO	ADVANTAGES.	DISADVANTAGES.
1.	Do not require much space.	Requires costly & complicated drilling equipment & machinery.
2.	Can be constructed quickly- not time consuming.	Requires skilled workers & great care to drill & complete the tube well.
3.	Fairly sustained yield of water can be obtained even in years of drought.	Installation of costly turbine or submersible pumps is required.
4.	Economical when deep seated aquifers are encountered.	Possibility of missing the fractures, fissures & joints in hard rock areas resulting in many dry holes.
5.	Flowing artesian wells can some times be struck.	
6.	Generally good quality of water is tapped.	



# DOWN THE HOLE DRILLING- DTH



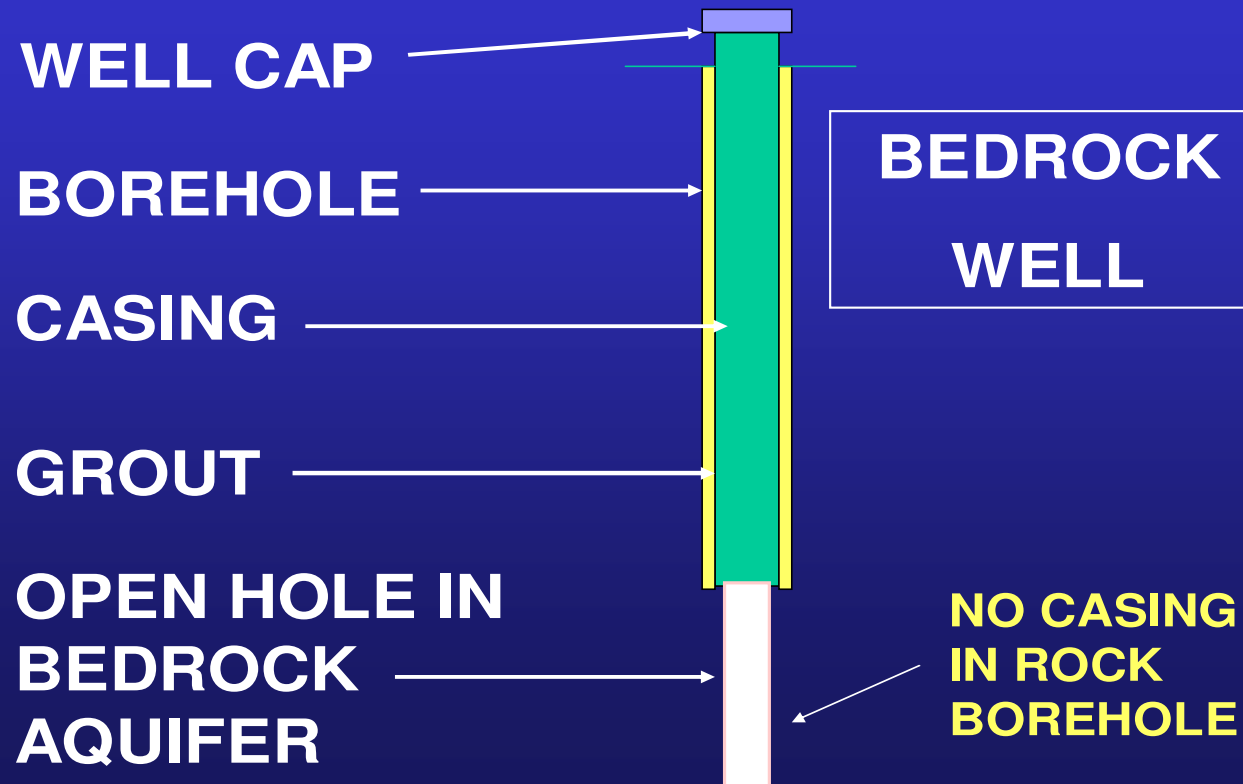
- This is a combination of rotary & percussion drilling. The cutting tool, besides a drill bit is a hammer which helps penetrate the rock by shattering. This method is very effective in drilling compact & consolidated rock with greater speed & thus very economical.





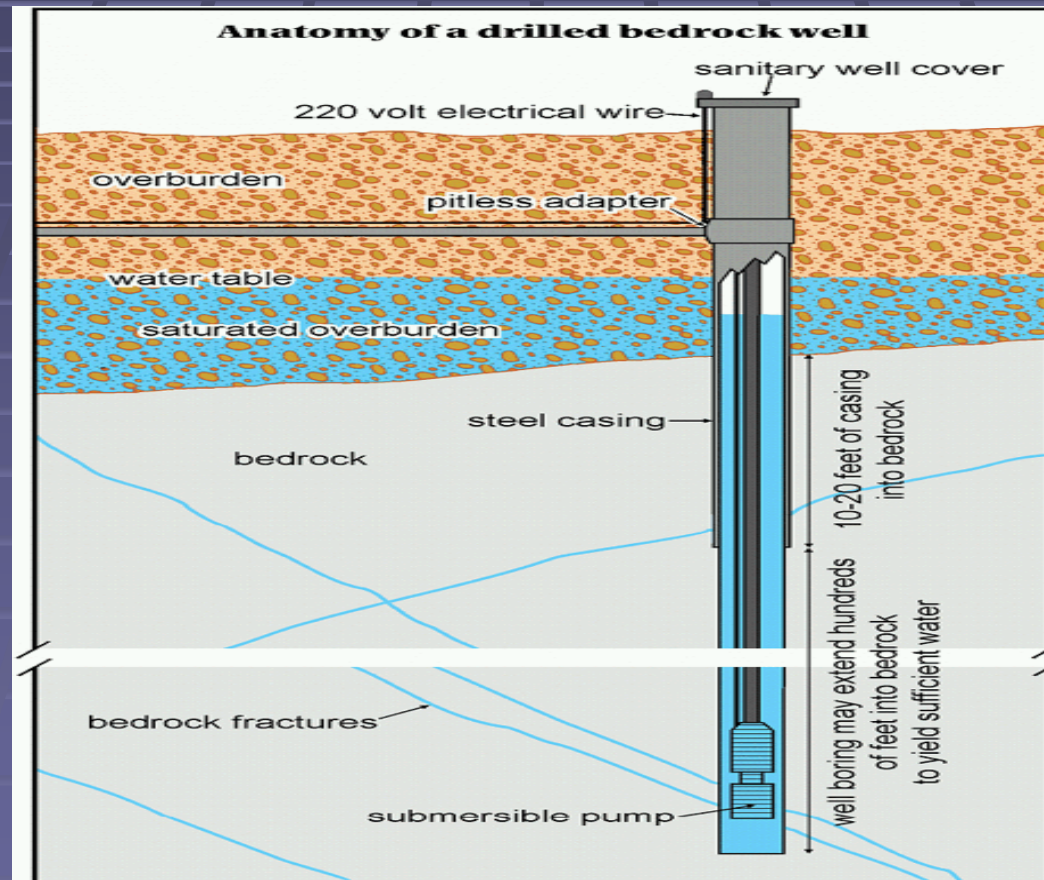
# BED ROCK WELL

## DRILLED WELL COMPONENTS





# ANATOMY OF A DRILLED BED ROCK WELL







# DRIVEN WELLS

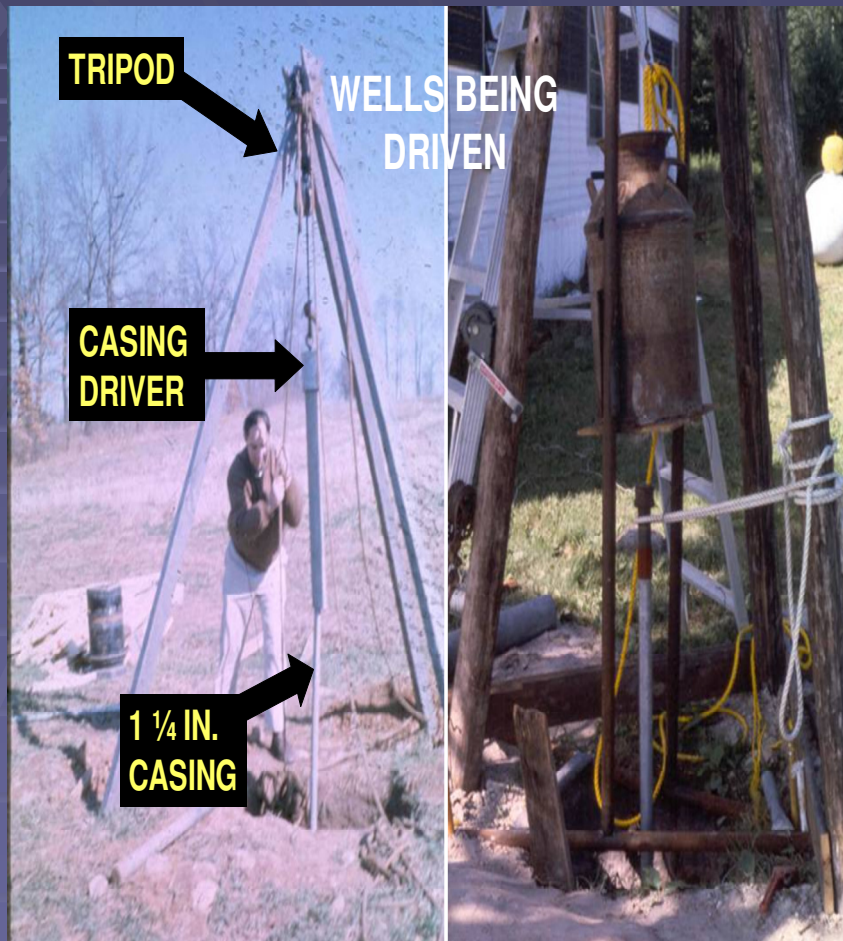
## DRIVEN WELLS

- Installed by property owners
- Common around lakes and high water table areas
- Most <35 ft. deep, limited yield (7 gpm or less)

***MORE SUSCEPTIBLE TO SURFACE  
CONTAMINATION THAN DRILLED WELLS***



# DRIVEN WELLS



- Well points fitted to the lower end of pipe are driven by hand method up to a depth of 10 to 15 meters in unconsolidated formations. Well points are usually driven in shallow coastal aquifers.



# DUG WELLS

- Dug wells have been popular from prehistoric times and provide an economical means of irrigation and water supply to small areas. They are feasible in porous or fissured rocks, where the water table is shallow.
- Dug wells are normally excavated by hand, the dry materials are hauled up baskets on ropes or cable.
- A good dug well can deliver from 100 to 300 m<sup>3</sup>/h of water, while small dug wells easily yield about 20 m<sup>3</sup>/h.
- In hard rock areas in well bores are drilled to rejuvenate the well. Both vertical bores of 4 1/2" to 6" dia and horizontal side bores of 2 to 6" dia are drilled, which is in practice for agricultural purpose.



# OPEN OR DUG WELLS

- Shallow open wells are dug out with large diameter to store water in the well itself. These wells are low discharge wells extending below the water table ideally suited for domestic and agricultural use.
- These wells are more common in alluvial formations and to some extent in weathered hard rock.
- Where the subsurface is unconsolidated the wells are lined with masonry bricks to prevent caving in.
- In some areas with alluviums and sand, where the water table is shallow, dug wells of very smaller dia about 0.5 to 1 m ie precast cement rings are erected, popularly known as ring well. These ring wells are suitable for domestic purposes.
- In some sedimentary areas with unconsolidated formations, dug well is excavated to certain depth of about 5 to 10 m and below which bore wells are drilled and such wells are known as dug cum bore wells.



# COLLECTOR WELLS

- To get high yield in permeable alluvial aquifers with permanent source for continuous recharge radial collector wells are dug.
- A radial collector well is essentially a large diameter, normally 4 to 6 meters, shallow well from which horizontal strainers protrude, radially near the bottom, into the permeable aquifers.
- The screens are not installed in trenches but are jacked out horizontally in sections from the caisson [water tight chamber].
- The strainers or steel perforated screens of 16 to 48 inches in dia can be jacked out to a distance of 2,000 feet beneath the water source.
- Plastic screens also have been installed successfully by telescopic method. After the screened areas are developed, water infiltrates into caisson eventually raising the water level. Thus the caisson can serve as a large storage tank.
- A second type of collector system called a radial collector uses multiple screens extended horizontally outward from a caisson. This type of system is suitable for flood plain installation and can yield millions of gallons per day.
- The cost of collector well is substantial in comparison with vertical wells.





# INFILTRATION WELLS

- In some geologic environments like a river valley where thin alluvial deposits overlie bedrock and even though the hydraulic conductivity of the sediment is excellent, the transmissivity is limited because of the thin deposits. Under this hydrogeological conditions infiltration galleries are favorable.
- Infiltration galleries consist of one or more horizontally laid screens placed in permeable alluvial materials either adjacent or beneath water body.
- A significant quantity of water may be pumped from an infiltration gallery because the hydraulic conductivity of natural material and the filter pack surrounding the screens is high that recharge is sufficient to meet the pumping rate.
- The usual practical depth limitation is about 25 feet [7.6 m]. The water entering the screen is collected in sump constructed beneath the end of the screens.
- A major design principle for galleries involves the orientation of the screen relative to the surface water or ground water flow directions.

# OPEN WELL- ADVANTAGES & DISADVANTAGES

SL NO	ADVANTAGES.	DISADVANTAGES.
1	Storage capacity of water is available in the well itself.	Large space is required for the well and for the excavated materials.
2.	Does not require sophisticated equipment & skilled personnel for construction.	Construction is slow and laborious.
3.	Can be easily operated by installing a centrifugal pump.	Subject to high fluctuations of water table during different seasons.
4.	Can be revitalized by deepening by blasting or drilling vertical or side bores.	Susceptibility to dry up in years of drought.
		5. High cost of construction as the depth increases in hard rock areas. 6. Deep seated aquifers cannot be economically tapped. 7. Uncertainty of tapping good quality water. 8. Susceptibility for contamination unless sealed from surface water ingress.





# WELL DEVELOPMENT

- Well development is the process which causes reversals of flow through the screen openings so as to washout the fines & rearrange the formation particles to form a graded filter, ultimately to yield clear sand free water.
- Proper development increases the well efficiency & the well loss coefficient.

# WELL DEVELOPMENT METHODS

Some of the methods in vogue are,

1. Mechanical surging- In this method solid pipe or surge plungers are used & the plunger is operated up and down in the casing like piston in cylinder, which produces the required alternate reversal of flow.
2. Using compressed air- This method proved to be rapid & effective when properly used. The process involves in combination of surging & pumping. By means of sudden release of large volume of air, a strong surge is produced.
  - For this purpose air compressor is used capable of developing 200 to 600 CFM of pressure.







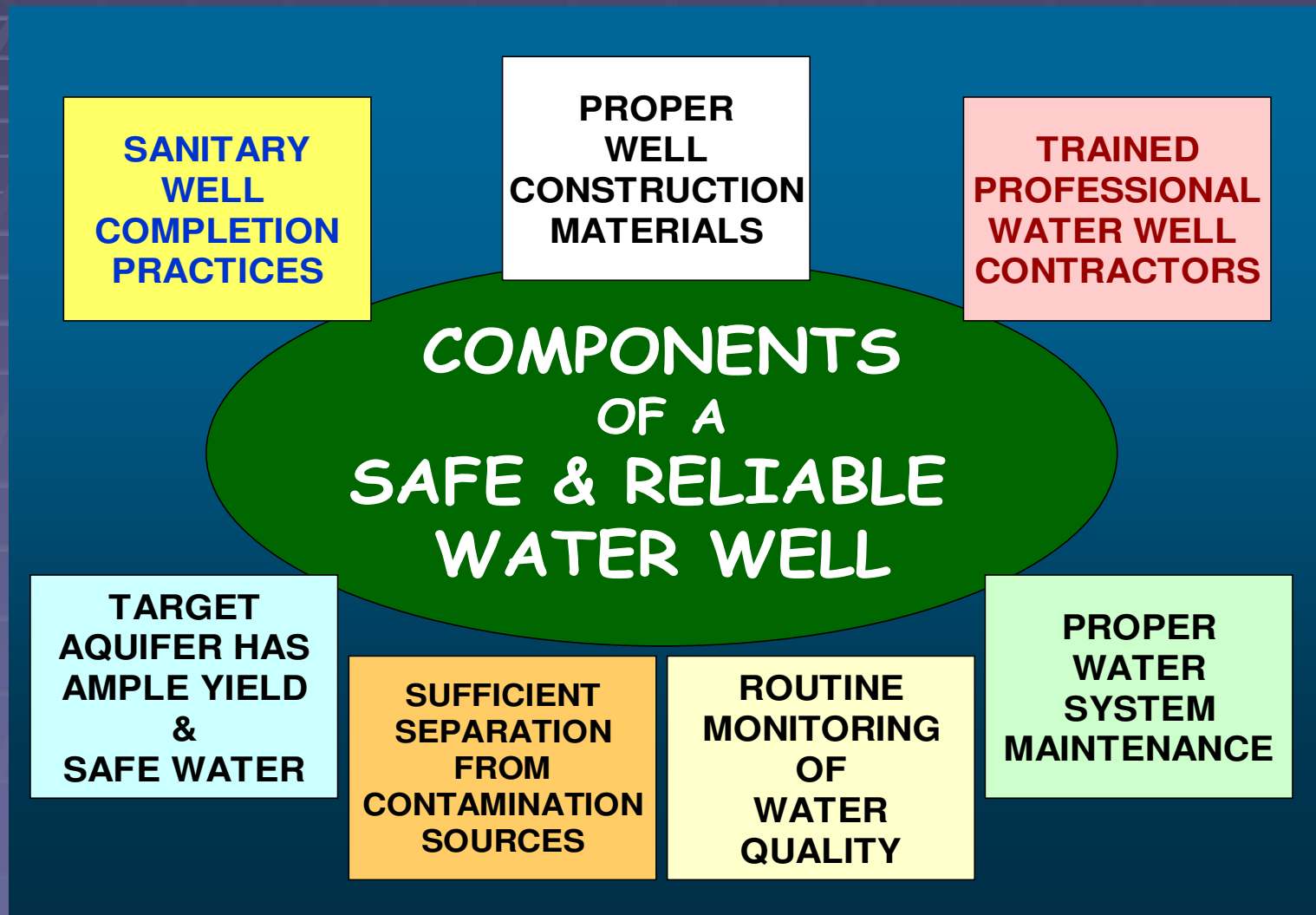
# WELL DEVELOPEPMENT BY COMPRESSOR







# COMPONENTS OF A SAFE & RELIABLE WATER WELL





# WELL COMPLETION

- After a well has been constructed, proper sanitary completion is necessary to produce safe public health standard quality of water.
- Well completion involves the operation of,
  1. Grouting & sealing the casing.
  2. Completion of the top of the well.
  3. Disinfection of the well.

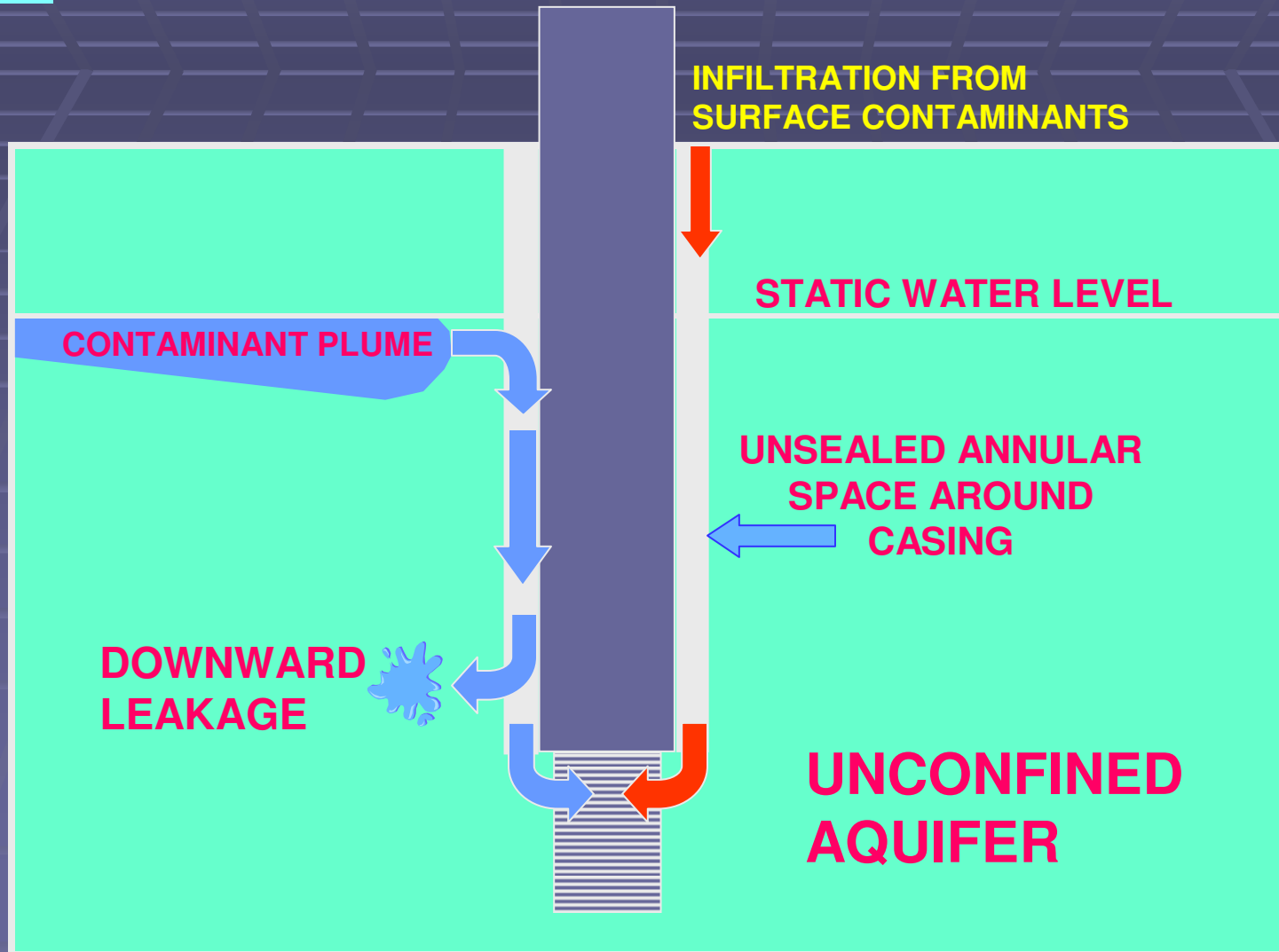


# GROUTING & SEALING

- Grouting the casing means, the filling the annular space between the outside of the casing & inside of the drilled hole with a cement grout.
- Grouting & sealing the casing serves to prevent the downward seepage of polluted surface water.
- The top of the casing should normally extend as least 50 cm above the ground level to avoid direct contact with accumulating drainage water.
- The top of the casing should be provided with a water tight sanitary seal ie a well cap.



# DOWNWARD LEAKAGE AROUND UNGROUTED CASING



# WELL GROUTING BENEFITS

## BENEFITS OF WELL GROUTING

- ***PREVENT CONTAMINANT MIGRATION FROM SURFACE (Keeps surface runoff from moving downward along well casing)***
- ***SEAL OFF POOR QUALITY AQUIFERS (Prevents mixing of water from different aquifers)***
- ***PRESERVE ARTESIAN AQUIFER PROPERTIES***
- ***ADDED SEALING OF CASING JOINTS***







# WELL DISINFECTION

- After completion of construction, the well, casing, pump & pipe systems have to be disinfected or sterilized promptly, for which chlorine solution is the simplest & most effective method.
- Highly chlorinated water can be prepared by dissolving dry calcium hypochlorite, liquid sodium hypochlorite or gaseous chlorine in water.
- This solution is poured into the well through the top of the casing before it is sealed.



**THANK YOU**