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NORTH WES TERN HIMALAYAN REGION
JAMMU

Water Well Construction, Development & Testing

Activities During Tubewell Construction

1. Site location
2. Drilling of borehole
3. Collection of data during drilling –
    1. Sampling of geological strata
    2. Water level data
    3. Drill time log
4. Analysis of sand samples
5. Borehole (Geophysical)logging
6. Preparation of lithological logs (Composite)
7. Tubewell designing
8. Tubewell installation

Activities During Tubewell Construction

9. Gravel Packing
10. Cement seal/packer
11. Plumbness and alignment
12. Protecting tube well against local contamination
13. Tubewell Sterilisation
14. Tubewell development
15. Testing of tube well for
    1. Safe yield and efficiency &
    2. Aquifer Parameters
    3. Water Quality

Site Selection

- Physiographic studies
- Hydrogeological surveys
- Geophysical surveys

Physiographic Studies

- Hilly tract – these have low potential as these are comprised of consolidated sediments
- Piedmont or kandi or bhabar area – good ground water potential but boulder strata and difficult drilling, etc.
- Tarai or Sirowal area – good ground water potential, shallow water levels
- Alluvial plain – post prolific aquifers exist in these formations all over Punjab.
- Inter-mountain valley- low to moderate ground water potential, difficult drilling process.
- Close to or away from river/stream
- Closeness to contamination generating source – ground water may be contaminated at shallow depths, protection of source essential.
- Topographic depression or high – scheme may get flooded in topographic lows

Hydrogeological Surveys

It comprises understanding of

- Geological frame work in the area including lithological sequence
- Ground water occurrence
- Ground water quality
- Sources of contamination and plausibility of pollution.
- Geological maps and sections
- Records of existing tubewells in the area.

Geophysical Surveys/Investigations

Four basic methods of geophysical surveys are available

- Seismic
- Electrical resistivity (Vertical Resistivity Sounding)
- Gravimetric
- Electro-Magnetic

Commonly applied in J &K is

Vertical Electrical Sounding

DRILLING METHODS

DRILLING TECHNIQUES	BASIC TYPE OF RIGS	REMOVAL OF CUTTINGS
PERCUSSIVE	CABLE TOOL DRILLING	By BAILING By SAND PUMP
	DTH DRILLING	By AIR
	AIR ROTARY DRILLING	By AIR
ROTARY	DIRECT CIRCULATION ROTARY DRILLING	By DRILLING FLUID
	REVERSE CIRCULATION ROTARY DRILLING	

Selection of Rigs

It is made after careful study of following factors.

- ***Formation to be drilled,***
- ***Size and depth of holes***
- ***Drilling difficulties that may be encountered,***
- ***Casing policy***
- ***Mobility of the Rigs in the area of operation.***

Having determined these factors, it will be possible to select a Rigs that will produce the best possible performance.

Well Drilling Methods

- Cable Tool Drilling (Percussio):
- Suitable to drilling in Boulders, slanted and fissured formations
- Drilling rate in unconsolidated formation is much slower compared to other methods.

Advantages

- More precise sample data are collected.
- Detection of thin sections and weak zones,
- Facility of testing quality and quantity of water in different formations during drilling.
- This method requires much less water for drilling

Rotary Air Drilling

1. Suitable to drilling in dry formations and Arid regions where drilling water is difficult to obtain.
2. Suitable to drilling through lost circulation zones.
3. High rate of drilling in semi- consolidated rocks.
4. Progress in hard rock drilling is better than with mud drilling.

Advantages

1. Compressed air is used in this method to clean the hole of drill cuttings for this purpose a minimum of 3000 feet per minute up stream velocity of air is required.

DTH DRILLING

Involves a pneumatically operated bottom-hole drill that efficiently combines

1. Percussion action of cable tool drilling
2. Turning action of rotary drilling
3. Suitable to drilling in hard rock formations.
4. It is the fastest method of penetration in hard rock.

DTH DRILLING

Advantages

- Continuous hole cleaning exposes new formation to the bit
- No energy is wasted in re-drilling old cuttings.
- Facility of testing quality and
- Quantity of water in different formations during drilling.

Odex Drilling

It is similar to DTH drilling with additional feature that:

- Casing and drilling are operated simultaneously to save time and complications

- Enlargement of borehole is not possible both DTH and Odex methods

- It has got very effective results in overburdened and loose formation

Borehole Diameter

- Dependent on diameter of the well assembly pipes and screen
- 50 mm larger than well assembly pipes in percussion and hand boring methods
- 200 – 300 mm more than the screen diameter in case of gravel packed wells
- Larger diameter may restrict impact of well development
- Add to extra gravel cost with no inherent benefit

Practice of drilling larger diameter boreholes for 200 mm diameter screen wells should be dispensed with immediately as it causes more harm than benefit.

Data Collection during Drilling

Sampling of geological strata

- Samples of the strata drilled through are of utmost importance in success of the tube well.
- Make it mandatory to collect strata samples at an interval of 3 m and at change of strata in case of rotary drilling methods
- The interval could be 1 m in case of percussion method of drilling.
- Always wash samples free of drilling mud and keep them in sample box designed for this purpose with depth range marked on each sample.

Water Level and Water Quality Record

- Feasible only in **percussion and hand boring** methods.
- Record Water level at the beginning and end of drilling each day.
- Collect water samples from each aquifer zone and get it tested as per requirement.

Borehole (Geophysical) Logging

- Electrical logs (both resistivity and self potential)
- Caliper
- Temperature and
- Radiation
- The caliper and temperature logs have little use in production well programme

Electrical logs

- Spontaneous Potential
- Resistivity Logs, Short Normals - N16”, N64’ and Laterals 18’8”

Lithological log / Strata Chart

- Prepare composite log based on
  - Drill cuttings samples and
  - Borehole logs
- Give due consideration to all logs
  - Drill-Time Log
  - Mud Thickness Records
- Include granularity and water quality in the final composite log

Tubewell Designing

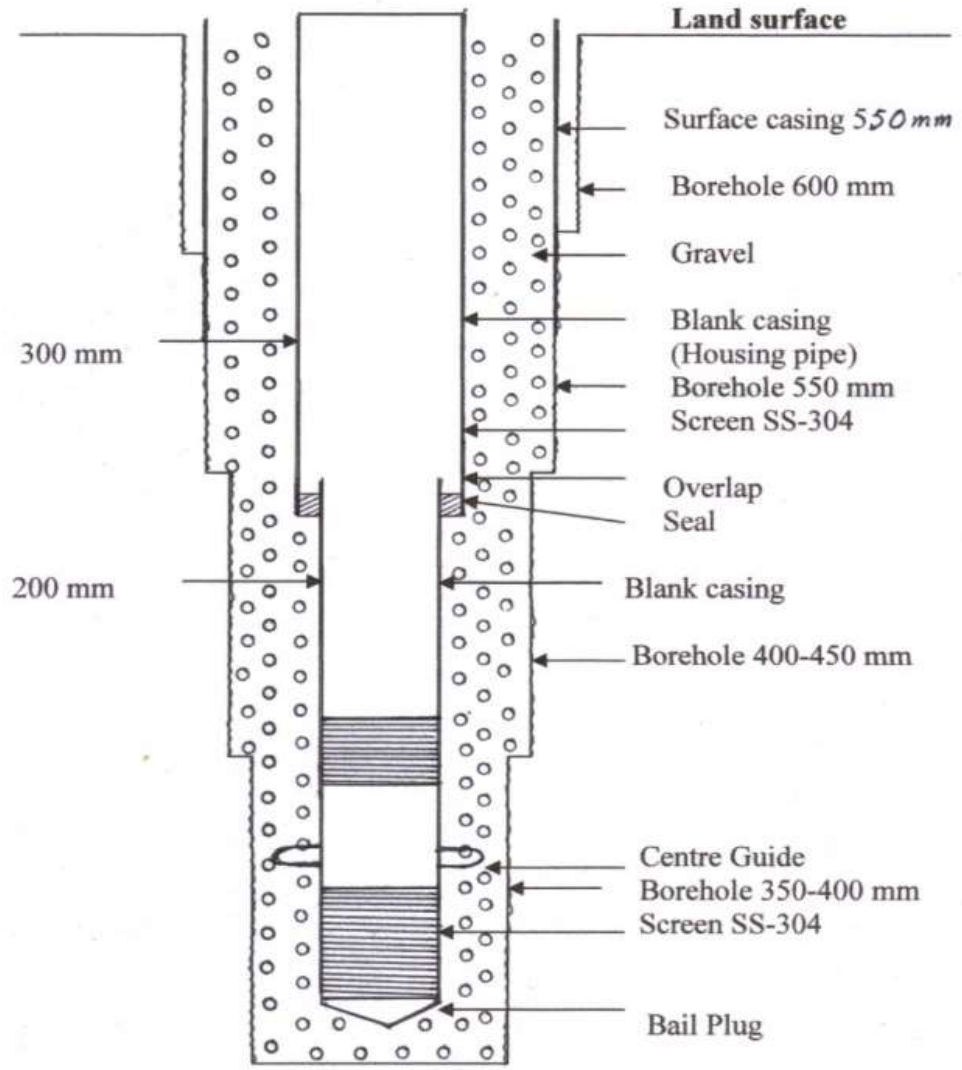
Basic information desired for designing of a tube well

- Thickness, character and sequence of coarse granular zones below the water level
- Thickness, character and sequence of aquifers identified, nature of the permeability, degree of confinement
- Size and gradation of aquifer material
- Transmissivity and storativity (If already known)
- Water level conditions and trends
- Water quality
- Experience of
  - Design and construction of earlier constructed tubewells
  - Operation and maintenance of earlier constructed tubewells
- Purpose and desired yield of the proposed tube well.

Components of a Tube well

- Surface casing
- Pump chamber casing or housing pipe
- Screen
- Gravel packs
- Reducers and overlaps
- Seals and grouts
- Tremie pipes or gravel feeders
- Centring guides
- Pump foundations

Components of a Tubewell-Percussion Drilling



Surface Casing

- Surface casing is an essential component of all water supply wells to protect against contamination.
- Minimum of 30 m or down to good clay strata whichever is later
- Larger diameter casing with a sharp lower end embedded in clay
- Outer annular space grouted with cement
- Further drilling of the borehole for tubewell is then done through this pipe with a smaller diameter bit.

R**ecommended for all wells constructed by rotary and percussion methods**

Pump Chamber Casing or Housing Pipe

Diameter - Depends on the size of the pump motor to be put in. It should be 50mm larger than pump bowl diameter.

Depth or length – depends on

- Present water level
- Minimum water level recorded
- Long term water level trend
- Probable draw down at desired yield
- Interference due to other wells
- Required pump submergence
- The pipe diameters between pump and the reducer
- Presence of any overlap
- Sanitation and stability
- Life of well expected

All these factors are added to decide the length of housing pipe.

Screens

Purpose

- Stabilize the sides of the bore
- Keep sand out of the well
- Facilitate flow into and within the well

It may be in one or more sections in the intake assembly

Type

- Slotted
- Wire wound
- V- wire V- slot
- Gravel pre- packed

Screen Material

- **Mild Steel**
- **Brass**
- **Stainless Steel**
- Alloys
- **PVC**
- Fiber glass
- Wood/bamboo
- Concrete pipe
- Vitreous clay

Screen Length

- Within limitations, use as much screen as possible.
- Tap 40 % in unconfined aquifer in lower part
- Tap 80 % confined aquifer in middle part

Designed Discharge

- Required yield (Q) m^3/sec
- Entrance velocity (V) 0.015 – 0.03 m/sec
- % effective open area (A) 20 % in slotted pipe
- diameter of screen (D) m

Length = Q / (DVA)

Slot opening

- 60 – 70 % size of aquifer material in natural pack well
- 90 % size of gravel material

Gravel Pack

Purpose

- Stabilizes aquifer
- Minimizes sand pumping
- Permit using largest slot opening with resultant maximum open area
- Provide high permeability annular zone increasing effective radii of well and yield

When must be used

- Presence of fine uniform sand aquifer
- Presence of layered aquifer - sand clay layers
- Requirement of maximum yield from the well

Gravel Pack

Gravel characteristics

- Clean – little loss of material during development
- Well rounded grains – high hydraulic conductivity, higher yield
- Inert material: 90–95% quartz grain – no loss of volume by dissolution
- Uniformity co-ef. 2.5 or less matching with formation – less segregation during installation & lower head loss through pack

Thickness of pack – a pack thickness of only three to four grain diameters is sufficient to retain and control formation, 12mm packs are good.

Seals and Grouts

Seals and grouts are of two purposes

- That are used in joining pipes of different diameters in well assembly in percussion method of drilling and
- To prevent unwanted water from shallow aquifers to reach screen to contaminate well water through gravel pack – seals in gravel pack.

Seals in Gravel pack

- Essential in gravel packed wells constructed by rotary method of drilling.
- Required only if the surface casing has not been provided in the well design
- It is put in the gravel pack at a depth that would prevent downward vertical movement of unwanted water from shallow aquifers or known sources of pollutant through gravel pack.
- The thickness and precise location is determined from the study of geophysical and lithological logs. Should be against clay stratum.

Seals in Gravel pack

Cement grout seal

- Place the gravel to the desired depth and confirm by actual measurement.
- Calculate the amount of slurry required for the seal
- Place some fine sand and bentonite balls on top of filter pack
- Lower tremie pipes to top of above layer. Prepare cement slurry and Mix some bentonite in the grout to help reduce chances of shrinkage.
- Install the grout by pouring the slurry through in the annulus to the surface or desired depth. Raise the tremie pipe as grouting proceeds.

The clay seal is preferred as it is easy to install and equally effective. It is able to move along with any settlement in gravel pack

Well Development

Purpose

- **Primary** - Obtain maximum production efficiency
- **Incidental** - Stabilization of the well structure
  - Minimization of sand pumping
  - Removal of mud cake
  - Compacted borehole wall breakings
  - Removal of fines from gravel and formation
  - Increasing the porosity and permeability
  - Breaking bridging if any
  - Improvement of corrosion and incrustation conditions
- **Process of development**

  Surge water back and forth through the screen, pack and aquifer at higher velocities than during final pumping (operational) rates

Well Development

Acceptable sand content –

- As per BIS less than 20 ppm after 20 min of pumping.
- **Ideally the water should be silt free**

Methods of Development

- Compressed air - very effective
- Over pumping - final stabilization of well
- Raw hiding - good
- Surging - not in practice
- Jetting - very effective in mud filled wells
- Chemicals - very useful in some conditions

Tubewell Sterilization

Why - To prevent or retard the growth of corrosion and incrustation

fostering organism that may reduce the life of the well.

Procedure

- Estimate the volume of water in the casing and the gravel
- Add sufficient chlorine to yield a concentration of 1000 mg/l in well water.
- Mix the solution thoroughly in the well by surging from the bottom of the well to the water surface.
- Allow 6 hours contact time for the solution in the well, during which the well should be surged every 2 hours interval.
- At the end pump the well and pumped discharge to flow back into the well to thoroughly flush the inside of the casing and the pump column pipe and the gravel pack if present, for at least 30 minutes.
- Pump the well to waste until there is little or no odour or taste of chlorine in the discharge.

PUMPING TEST

Pumping test is a field experiment in which

- Well is pumped at a controlled rate and
- water-level response (drawdown) is measured in pumped well itself and one or more surrounding observation wells

Common types of pumping tests

1- **Constant discharge Test (Aquifer test)**- maintain pumping at the control well at a constant rate. This is the most commonly used pumping test method for obtaining estimates of aquifer properties.

2-**Step Drawdown Test (Well Test)** proceed through a sequence of constant-rate steps at the control well to determine well performance characteristics such as well loss and well efficiency.

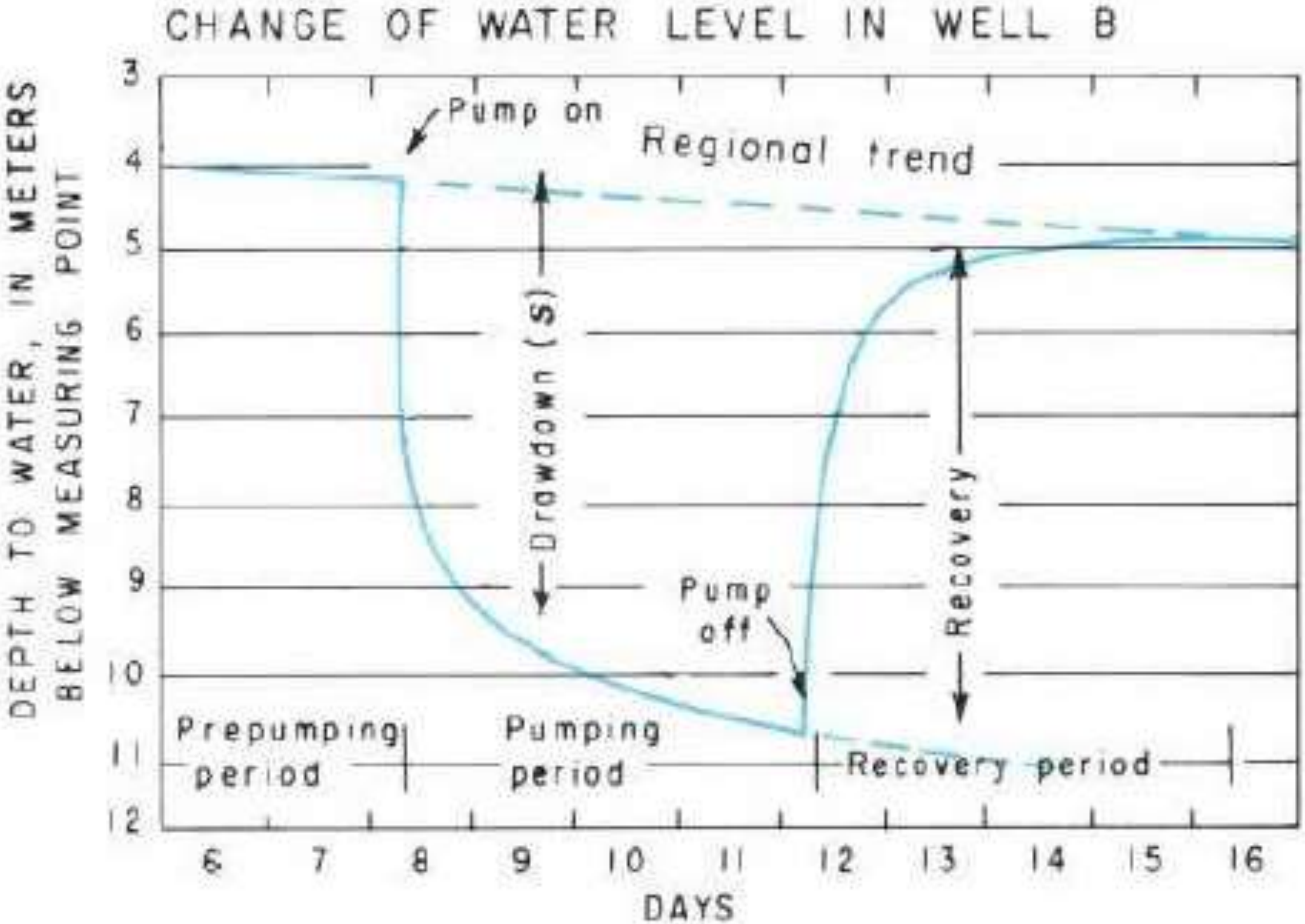
3- **Recovery Tests** use water-level (residual drawdown) measurements after the termination of pumping.

Although often interpreted separately, a recovery test is an integral part of any pumping test.

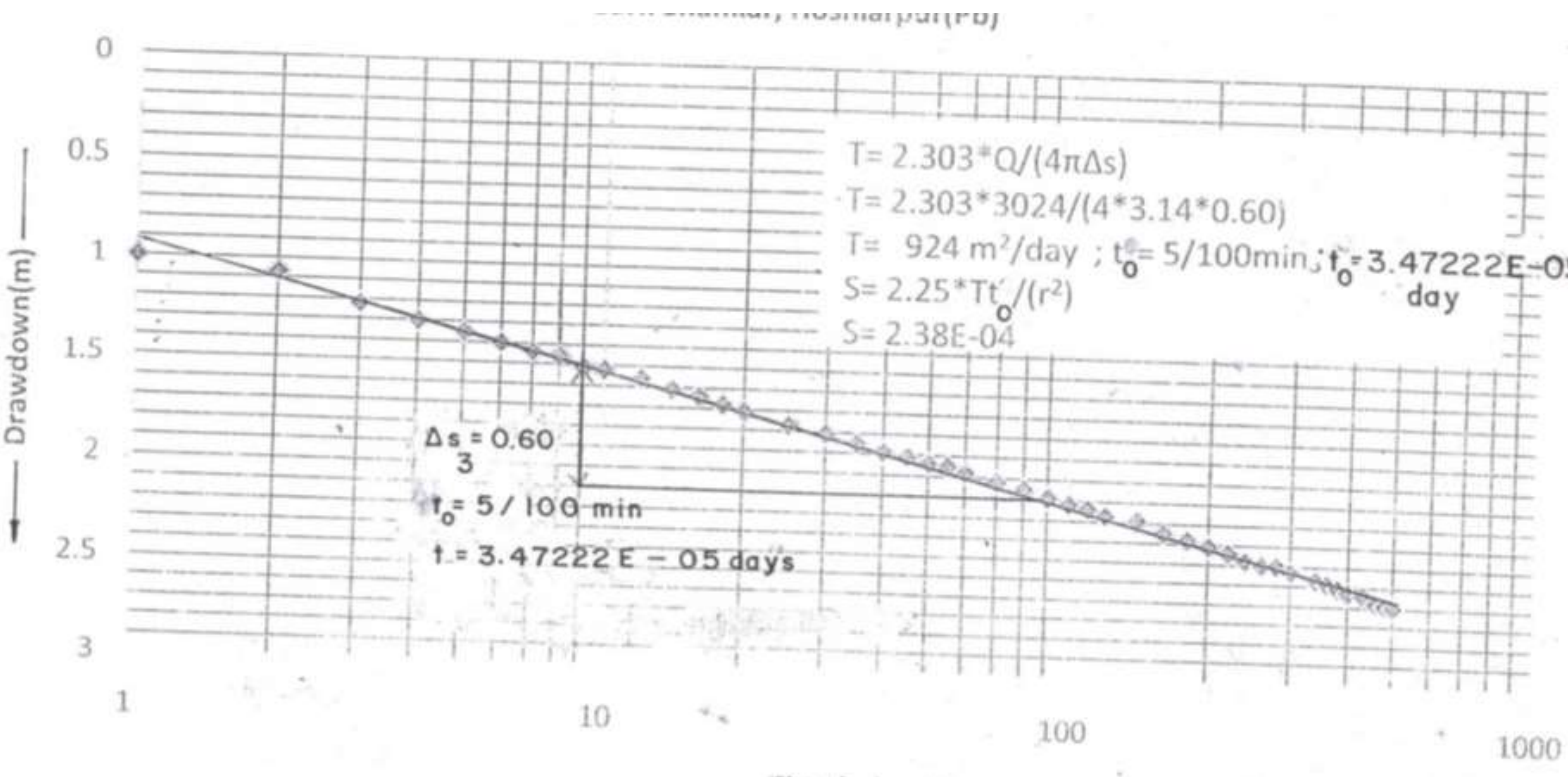
AQUIFER TEST TO ESTIMATE AQUIFER PROPERTIES

The goal of aquifer test is to estimate

1. Hydraulic properties of an aquifer system
2. Transmissivity
3. Hydraulic Conductivity (horizontal and vertical)
4. Storativity (storage coefficient).
5. Also used to estimate the properties of aquitards
6. Pumping tests can identify and locate recharge and no-flow boundaries that may limit the lateral extent of aquifers as well.


CHANGE OF WATER LEVEL IN WELL B
DEPTH TO WATER, IN METERS BELOW MEASURING POINT
3
4
5
6
7
8
9
10
11
12
Pump on
Regional trend
Drawdown (S)
Pump off
Recovery
Prepumping period
Pumping period
Recovery period
6
7
8
9
10
11
12
13
14
15
16
DAYS

Aquifer Performance Test



Well Test for Safe Yield and well Efficiency

Procedure

- Pump the tube well at three or more discharge heads and note the draw down for at the end of same period of pumping say one hour.
- Determine specific capacity using eqn 1 for the three discharges
- Determine also s/Q for the three steps of discharges
- Using eqn 2 determine values of B and C

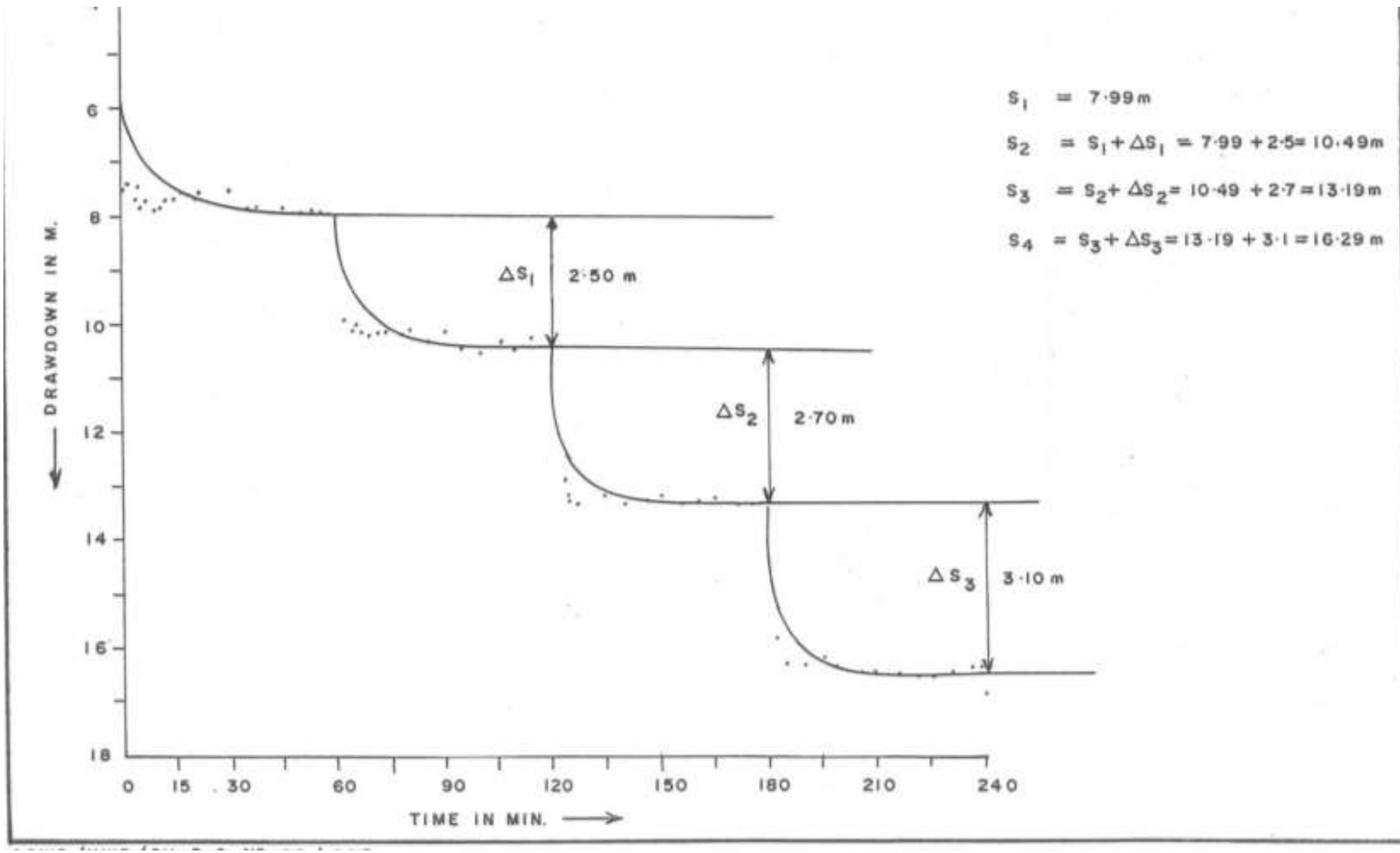
$$\text{Well efficiency} = (BQ/ (BQ + CQ^2) \times 100$$

- The efforts of the engineers must be to obtain highest well efficiency. In a 100 % efficient well, the draw down just outside borehole is equal to the draw down inside the well.

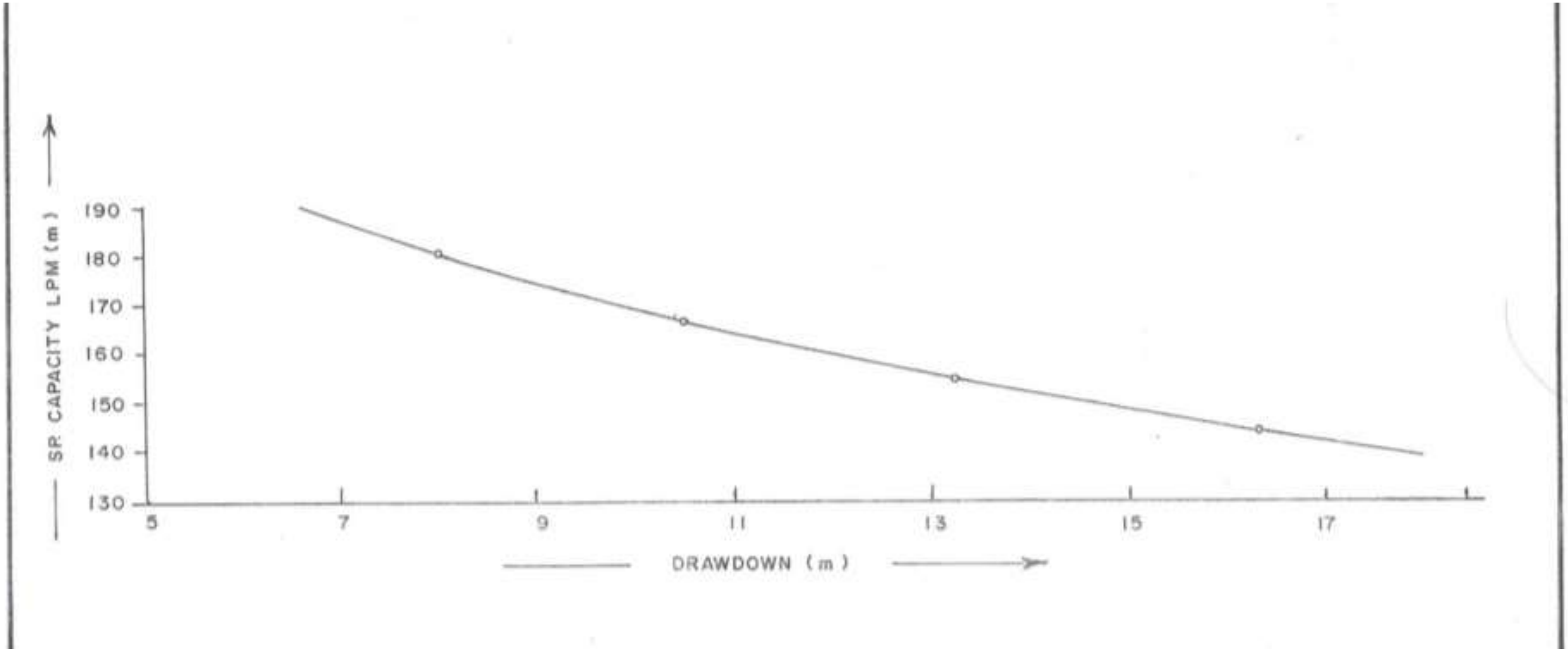
Specific capacity of well

Step No.	Duration (min)	Discharge (lpm)	Draw down (m)	Specific capacity (lpm/m)
I	60	1440	7.99	180.22
II	60	1740	10.48	160.03
III	60	2040	13.33	153.03
IV	60	2340	16.75	139.70

Step Draw down Test



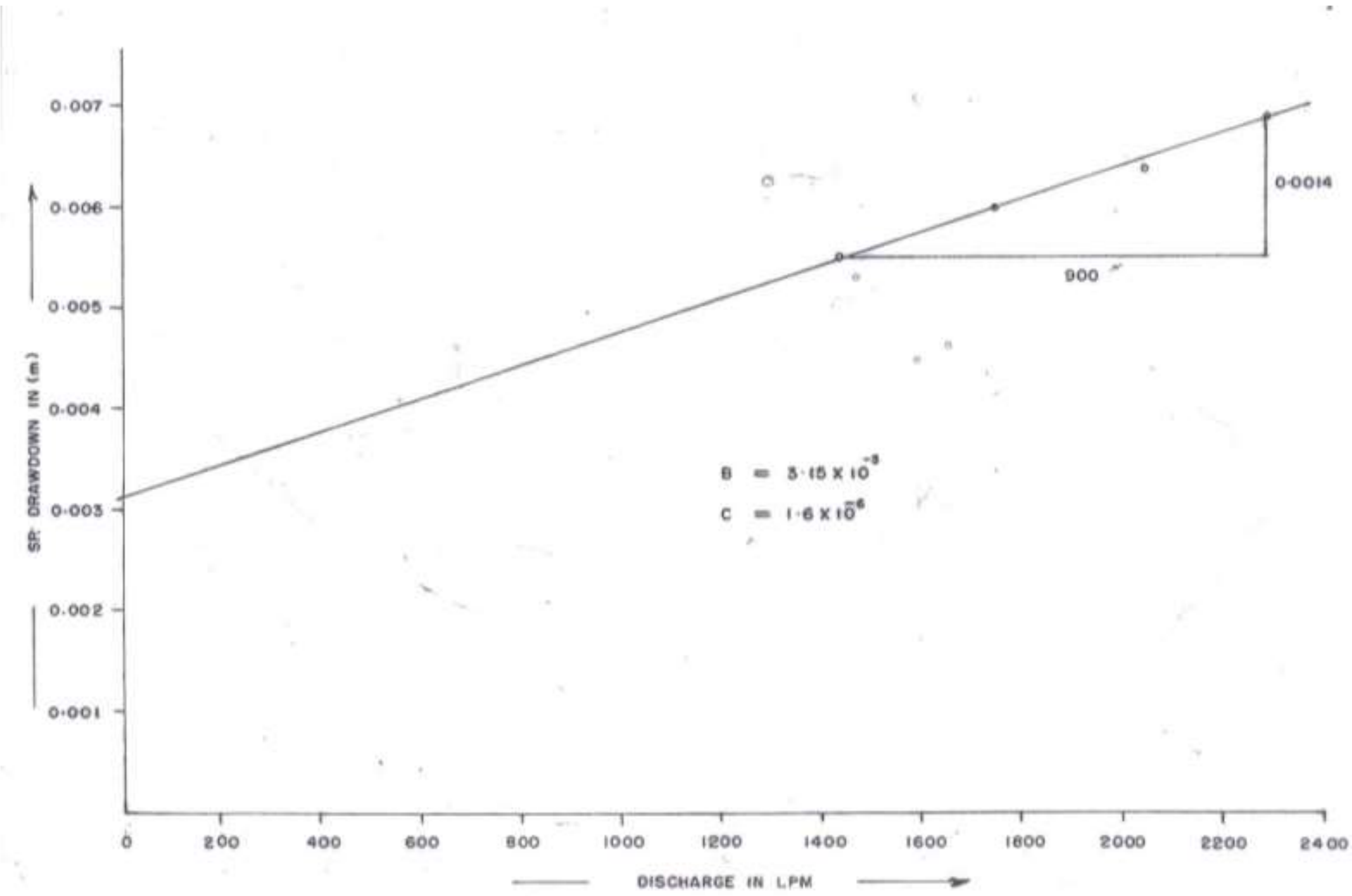
Step Draw down Test
Sp. Capacity



Step Draw down Test

Step	Q (lpm)	Graphically corrected draw down (m)	Sp.ddn (m/lpm)	Formation loss (BQ) (m)	Well loss (CQ^2) (m)	Calculated drawdown ($BQ+CQ^2$) (m)	Well efficiency
I	1440	7.99	0.00555	4.536	3.23	7.76	58.44%
II	1740	10.49	0.00603	5.481	4.71	10.19	53.78%
III	2040	13.19	0.00647	6.426	6.47	12.90	49.82%
IV	2340	16.29	0.00696	7.371	8.52	15.89	46.39%

Step Draw down Test



Drawdown

- When water is pumped out from a tube well, the water level in the well as well as in the vicinity of the pumped well is lowered.

  The lowering of the water level at any point as a result of groundwater pumping is called drawdown at that point.
  The drawdown is maximum at the well and goes on reducing away from the well till at some distance the drawdown is zero.

Cone of Depression:

The existence of hydraulic gradient induces flow of water into the well from the surrounding aquifer. Since the water moves towards the well from all directions it forms successive cylindrical sections. As the water approaches the well the surface area of each cylindrical section goes on reducing. Although the surface area of cylindrical rings reduces the rate of flow is same through all cylindrical sections.

Radius of Influence:

-It is distance from the centre of the well to the point at which the drawdown is zero.

-The point at which drawdown is zero indicates the outer limit of the cone of depression.

-The cones of depression are larger for wells sunk in the confined aquifer.

-Radius of influence is also greater in confined aquifer than in the unconfined aquifer.

-Drawdown, cone of depression and radius of influence are the three parameters of the same phenomenon, are closely inter-related and are characteristic features of every pumped well.

Well interference

Many times two or more wells are located in the same aquifer and are close to each other.

1. It is possible that their cones of depression may intersect each other.
2. When such a situation exists,
    1. wells are said to interfere with each other because the Radius of influence of one well then overlaps the Radius of influence of the other well.

Interference of wells

Impact:

1. Total groundwater contribution is less than the sum of the discharging capacity of wells.
2. The efficiency of each well is decreased.
3. With increased drawdown pumping lift becomes higher.
4. The pumping cost increases due to decreased efficiency and increased pumping lift.
5. Pumps may temporarily stops giving water.

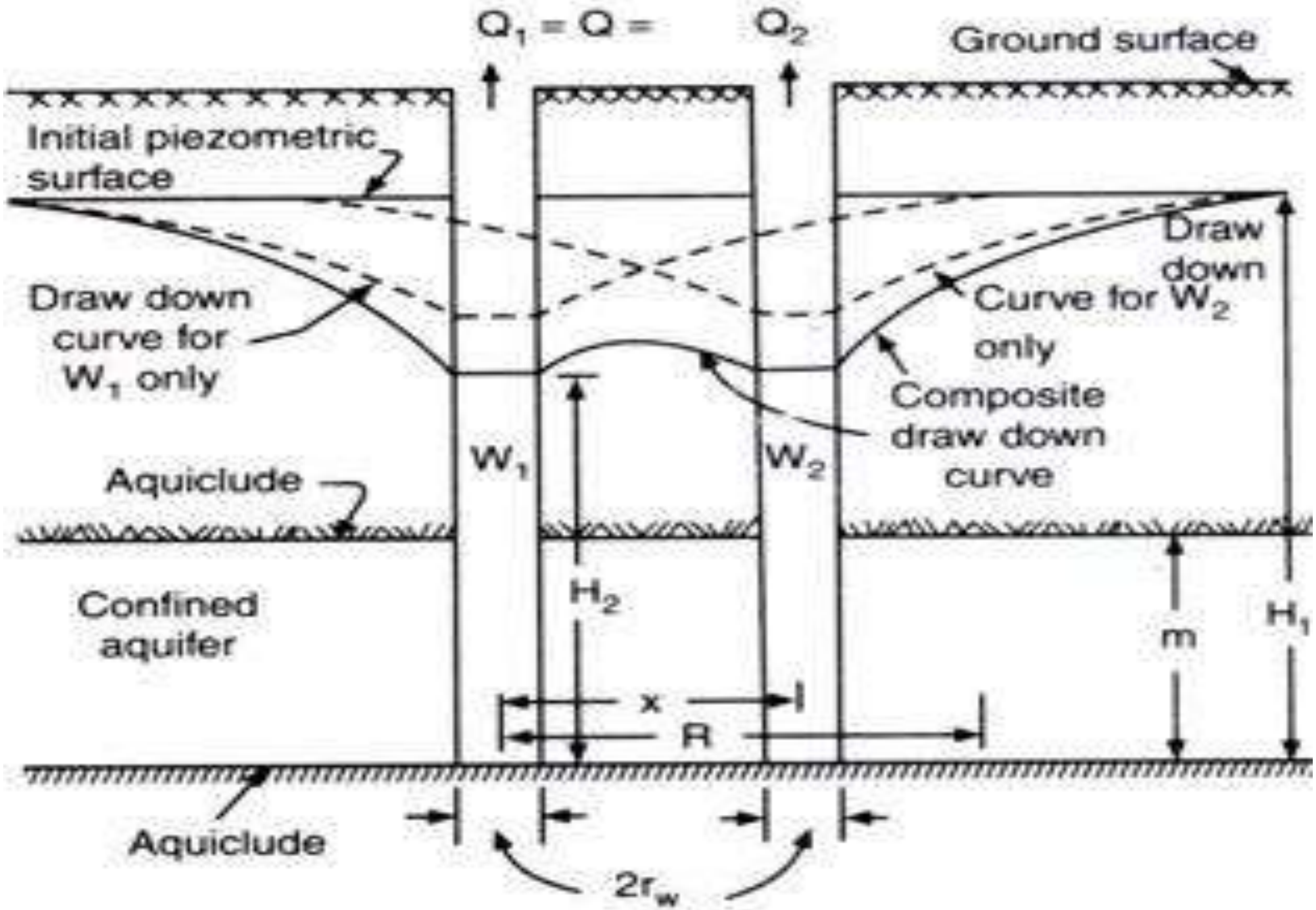
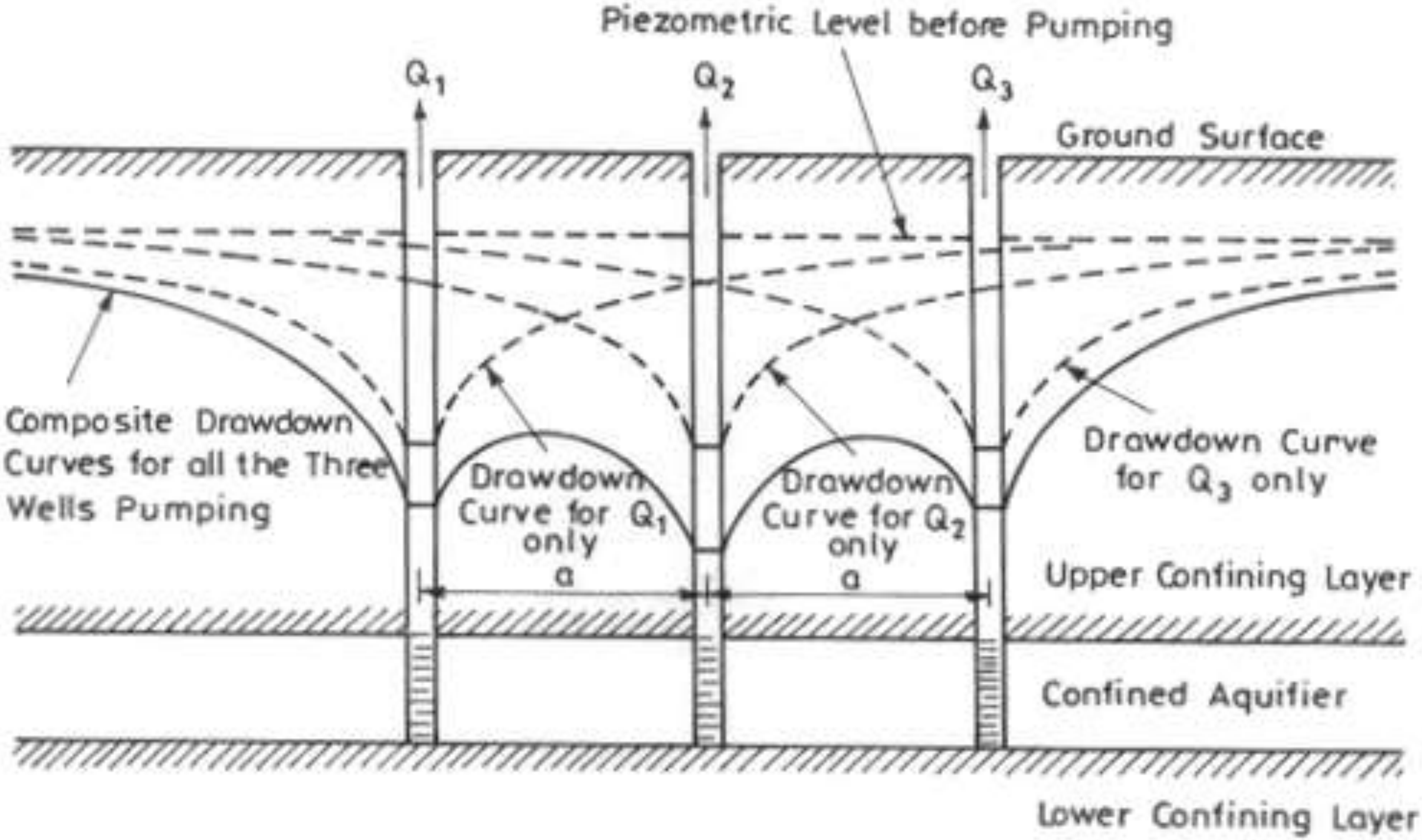


Fig. 16.7. Interference of wells



Piezometric Level before Pumping
Q_1
Q_2
Q_3
Ground Surface
Composite Drawdown Curves for all the Three Wells Pumping
Drawdown Curve for Q_1 only
Drawdown Curve for Q_2 only
Drawdown Curve for Q_3 only
a
a
Upper Confining Layer
Confined Aquifier
Lower Confining Layer

THANKS