TD 603
Water Resources

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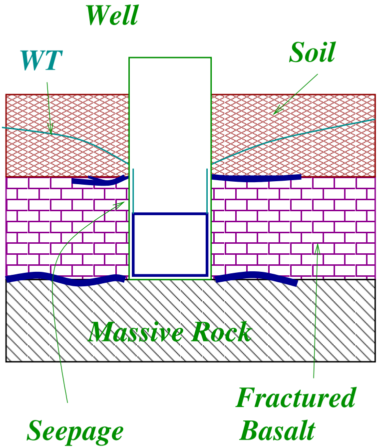
Lecture 8: Wells

Dug-wells



The Indian Work-Horse: 60 % of rural households and 25 % of irrigation in Maharashtra depend on it.

Wells in India

Open dug well

- Small diameter (3m-5m) for domestic use.
- Large diameter (5m-10m) for agricultural use.
- Typically shallow open aquifer wells.

- Depth 7m-15m, typically through soft layers down to consolidated rock.
- Here, through one layer of soil and then another of fractured basalt.
- Fractures and layer-junctions important for seepage. Note seepage face.
- Soil layers lined with masonry.

Agricultural wells

- Typically large-diameter, supplying about 30-100 cu.m. per day, irrigating about 1-2 hectares, largely rabbi.
- Frequently in command area of irrigation project, utilizing enhanced ground-water.
- Water lifted from storage, to accumulate overnight from aquifer.
- Water from shallow aquifer, of about 7-8m thickness.
- accounts for about 30% of irrigation
- Unique to developing world.

source: olofw, flickr

Borewells

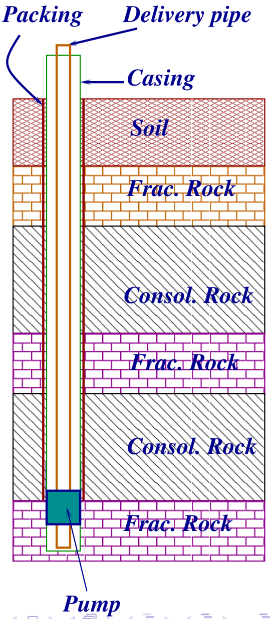
- Recent, roughly 1970 onwards.
- Began as *bore-wells in dug-wells*, to supplement agricultural use.
- High yield $>$ 1 liter/sec, for agricultural use. Low, used for hand-pumps (domestic use).

- Diameter about 6-22 inches, typical 8 inches, depth 50m-150m.
- Through various strata of consolidated and fractured rock.
- Water through active recharge from aquifer. Sometimes artesian!
- Hand-pump costs about Rs. 15,000 plus boring costs
- Borewells now exceed dug-wells in the ratio 8:1

Schema for a borewell-pump

- The hole is machine-bored, mounted on a truck.
- The casing is either PVC or steel and is perforated to allow seepage from the side into the main column.
- The packing is between the hole sides and the casing, and is typically pebbles.
- The water collects in the main column and is fed up through the delivery pipe by a submersible pump.

- Cost: about Rs. 1000 per meter



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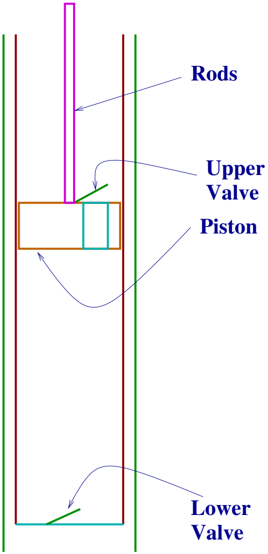
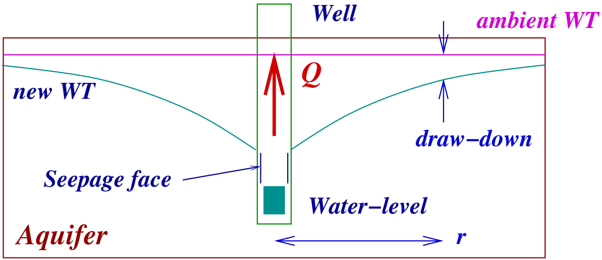


The hydrology of wells

- Well and Aquifer are deeply connected: well behaviour defines important aquifer parameters.
- Draw-down: drop in ambient head due to well water extraction.
- Draw-down cone: The area of influence of the well.



The radially symmetric GW problem:

- A constant discharge of Q (cu.m./s) is made from the well.
- Compute $h(r,t)$, the head at distance r at time t.
- Under what conditions is there a steady state?

The radial equation

Recall, the basic equation :

$$\frac{\partial}{\partial x}(\mathbb{K}\frac{\partial h}{\partial x}) + \frac{\partial}{\partial y}(\mathbb{K}\frac{\partial h}{\partial y}) + \frac{\partial}{\partial z}(\mathbb{K}\frac{\partial h}{\partial z}) = \mathbb{S}\frac{\partial h}{\partial t}$$

Assuming (i) no vertical flows, (ii) no external inflows, and selecting a cylindrical element between $r, r + dr$, we may write:

$$\frac{\partial}{\partial r}(\mathbb{K}2\pi rh\frac{\partial h}{\partial r}) = 2\pi r\mathbb{S}\frac{\partial h}{\partial t}$$

or simply:

$$\frac{\partial}{\partial r}(\mathbb{K}rh\frac{\partial h}{\partial r}) = r\mathbb{S}\frac{\partial h}{\partial t}$$

i.e.,

The Dupuit Radial Equation

$$\mathbb{K}h\frac{\partial h}{\partial r} + \mathbb{K}r\frac{\partial}{\partial r}(h\frac{\partial h}{\partial r}) = r\mathbb{S}\frac{\partial h}{\partial t}$$

The Dupuit Solution

- Lets first look at the steady state, i.e., with $\partial h/\partial t = 0$.
- Since the system is losing water, there must be some way of providing it. We put the constant head $h(R) = H$..
- Putting $g = h^2$ we get:

$$\mathbb{K}\partial g/\partial r + \mathbb{K} r \partial^2 g/\partial r^2 = 0$$

- This gives us:

$$h^2 = A \log r + B$$

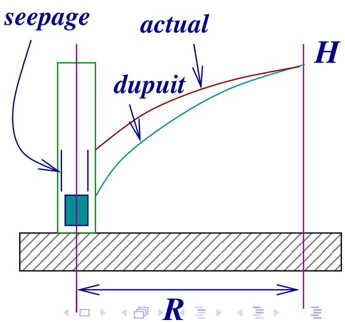
- Boundary Conditions: (i) $h^2(R) = H^2$ and (ii) $2\pi r K h dh/dr = Q$.

This gives us:

Final Form

$$h^2 = H^2 - \frac{Q}{\pi K} \log(R/r)$$

- Really about large diameter shallow aquifer wells.
- Has same drawback as earlier Dupuit.



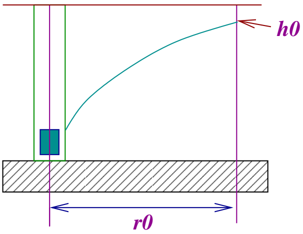
Another boundary condition

- We may also use (i) $2\pi rKdh/dr = Q$ and (ii) $h^2(r_w) = h_w$, where r_w is the well radius and h_w is the well water level. This gives us:

$$h^2 = h_w^2 + \frac{Q}{\pi K} \log r$$

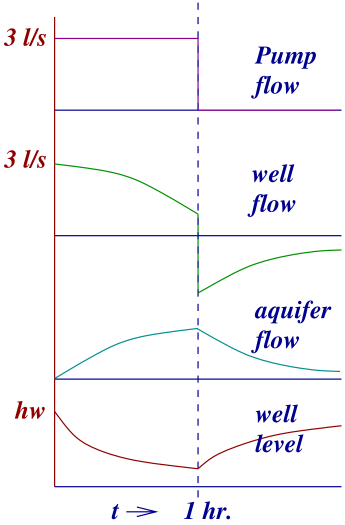
- This does not need the artificial condition about a distant H.
- However, it uses the near-well data which is likely to fail the Dupuit assumptions even more (called Well losses).

- Both boundary conditions do help in determining K if the well characteristics are known.
- One may either apply the equations to (i) r_w or (ii) a distant R when the ambient head H is known.
- OR one may actually measure head h_0 at distance r_0 and conclude K.



Transient response: Open wells

- Transient Response is far trickier to predict.
- Consider a pump operated at 3 liters/sec. for one hour from a well with steady state height h_w.
- Initially, most of the water comes from the well.
- As the height in the well drops, the aquifer starts seeping water into the well.
- Once the pump stops, the aquifer keeps seeping water.
- In the limit, the height in the well becomes h_w

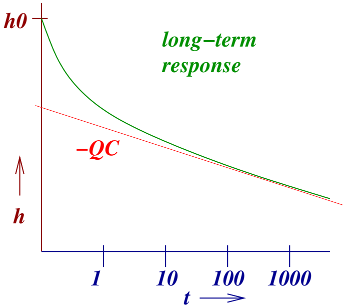


Long-term transient

- If the pumping rate is kept constant, say Q, and if the well doesnt dry up, the well height does keep dropping, albeit slowly.
- The long term relationship is given by:

$$h(t_2) - h(t_1) = Q \cdot C \cdot log(t_1/t_2)$$

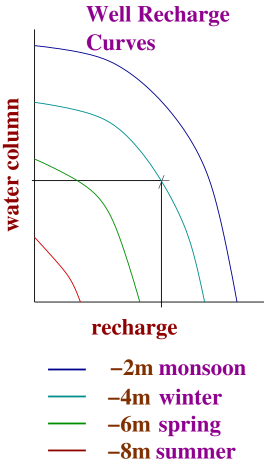
- The constant C *theoretically* on just the aquifer and the well dimensions. Practically, there is well-loss.
- This long-term relationship holds for bore-wells as well.



Yield tests

This is the basis of most Yield Tests for wells and even for borewells.

GP level reporting of water assets



- representation of data
- planning formats
- different yield tests
- small hydro-geological systems

Discussion

1. Irrigation department, Maharashtra, charges 50 % of regular tarrif for withdrawals from wells in the command area. Is this reasonable? How will you analyse this?
2. Elaborate on the working of a hand-pump.
3. What techniques exist to increase the yield from an existing well?
4. Not only Dupuit, but Darcy's assumptions also fail in near-well situations. Why do you think this happens.
5. Can you specialize the GW equation to radial symmtery but with vertical flows?
6. Comment on the use of bore-wells in locations on the Deccan Trap. Consult the data in the per-capita recharge and comment on the sustainable use of groundwater through bore-wells.