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 rabi.
- 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:

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

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

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

or simply:

\[ \frac{\partial}{\partial r}(Kr h \frac{\partial h}{\partial r}) = r S \frac{\partial h}{\partial t} \]

i.e.,

The Dupuit Radial Equation

\[ Kh \frac{\partial h}{\partial r} + Kr \frac{\partial}{\partial r}(h \frac{\partial h}{\partial r}) = rS \frac{\partial h}{\partial t} \]
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:

$$K \frac{\partial g}{\partial r} + Kr \frac{\partial^2 g}{\partial r^2} = 0$$

- This gives us:

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

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

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.

![Diagram of seepage and actual flow](image)
Another boundary condition

- We may also use (i)
  \[ 2\pi rKdh/dr = Q \]
  and (ii)
  \[ h^2(r_w) = h_w, \text{ where } r_w \text{ is the well radius and } h_w \text{ is the well water level.} \]
  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 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 doesn't dry up, the well height does keep dropping, albeit slowly.
- The long term relationship is given by:

$$h(t_2) - h(t_1) = Q \cdot C \cdot \log\left(\frac{t_1}{t_2}\right)$$

- 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 tariff 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 symmetry 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.