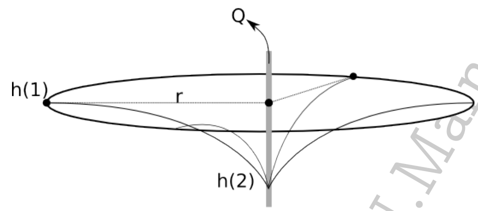
1 Pumping Tests

Pumping Tests

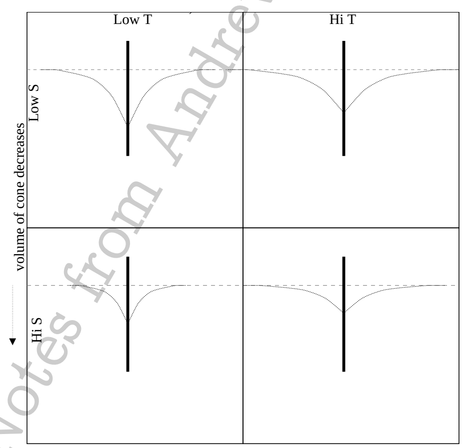
- Large scale tests
  - Single well is pumped
  - one (or more) observation wells used to measure aquifer response
  - shape of cone of depression used to determine K and S_s
- time-drawdown tests
- distance-drawdown tests



Cone of Depression

Question?
How will the shape of a cone of depression change in response to different values of T and S?

Cone of Depression



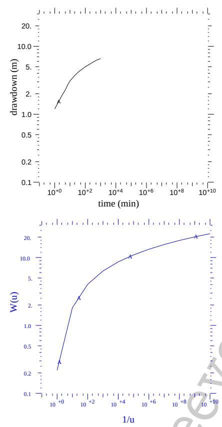
Type-Curve Matching

- Use Theis solution to flow equation

$$h_0 - h_{r,t} = \frac{Q}{4\pi T}\int_u^\infty \frac{e^{-u}}{u}\,du$$
$$u = \frac{r^2 S}{4Tt}$$

- make log-log plot of (1/u) vs W(u)
- make log-log plot of time vs drawdown
- match data to type curve
- pick common point, find (1/u),W(u),t, and $h - h_0$ at point
- solve above equations for T and S

Type-Curve Matching



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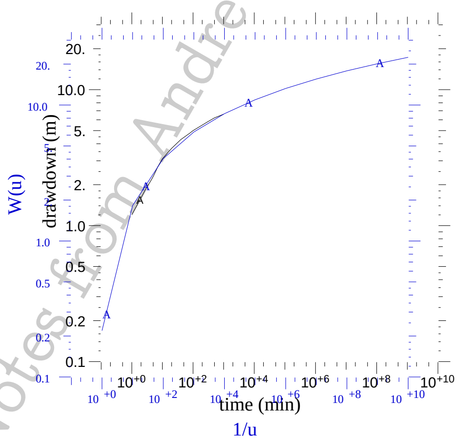

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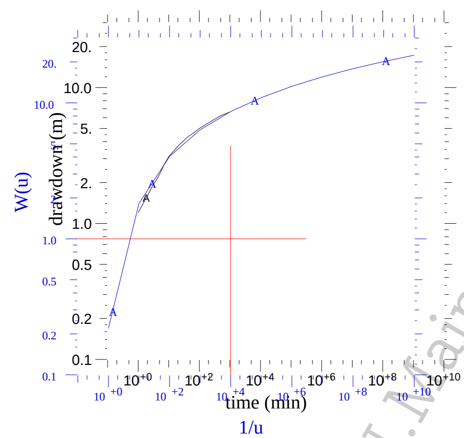
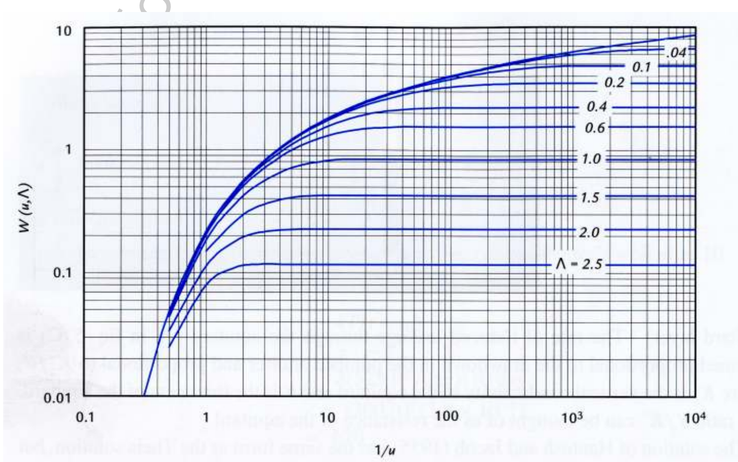


Type-Curve Matching

- Scales on data graph and type-curve graph must be identical
- When matching graphs, axes must be kept parallel
- Different type-curves available for different assumed conditions
  - leaky confining unit
  - unconfined flow

Type-Curve Matching



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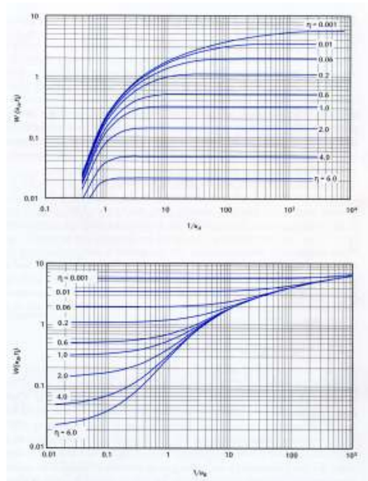


Cooper-Jacob Straight-Line Method

$$h_0 - h = \frac{Q}{4\pi T} W(u)$$

$$W(u) = -.5772 - \ln(u) + u - \frac{u^2}{2 \cdot 2} + \cdots$$

$$h_0 - h = \frac{Q}{4\pi T}(-.5772 - \ln(u))$$

$$h_0 - h = \frac{Q}{4\pi T}(\ln(\frac{1}{u}) - .5772)$$

$$h_0 - h = \frac{Q}{4\pi T}(\ln(\frac{1}{u}) - \ln(1.781)$$

$$h_0 - h = \frac{Q}{4\pi T}(\ln(\frac{1}{1.781u})$$

$$\ln(u) = 2.3\log(u)$$

$$u = \frac{r^2 S}{4Tt}$$

$$h_0 - h = \frac{2.3Q}{4\pi T}\log(\frac{1}{1.781u})$$

$$h_0 - h = \frac{2.3Q}{4\pi T}\log(\frac{4Tt}{1.781r^2 S})$$

$$h_0 - h = \frac{2.3Q}{4\pi T}\log(\frac{2.25Tt}{r^2 S})$$

Cooper-Jacob Straight-Line Method

- 10-fold reduction in t (or $\frac{1}{r^2}$) = change in drawdown over 1 log cycle.

$$\Delta h_{log\ cycle} = \frac{2.3Q}{4\pi T}$$

- when drawdown equals zero.

$$0 = \log(\frac{2.25Tt_0}{r^2 S})$$

$$1 = \frac{2.25Tt_0}{r^2 S}$$

Partially Penetrating Wells

- Assumed fully penetrating pumping well (horizontal flow)
- Partial penetration induces vertical flow
  - reduced influence in stratified systems ($K_H > K_V$)
  - decreases with distance from pumping well
  - negligible when:

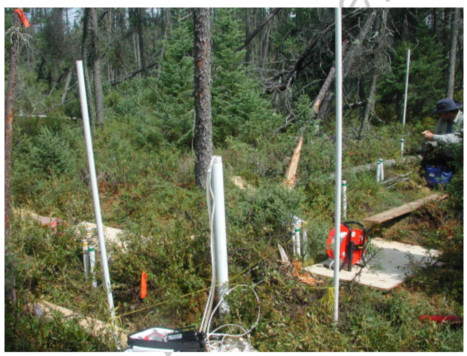
$$r > 1.5 \cdot b \cdot \sqrt{\frac{K_H}{K_V}}$$

- Addition drawdown (Δs)occurs near pumping well (p=$\frac{l}{b}$, b=thickness, l=screen length, a=1(screen at top of aquifer) or 2 (screen cnetered in aquifer)).

$$\Delta s = \frac{Q}{2\pi T}\frac{1-p}{p}\ln\left(\frac{(1-p)\cdot l}{a \cdot r_s}\right)$$

Planning a Pumping Test

- Need estimate of drawdown vs. Q in pumping well
- Measurement of observation wells
- Monitoring method for pumping rate



Planning a Pumping Test

Discharge Rates:

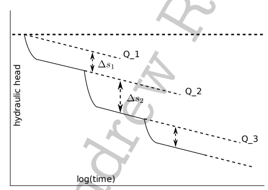
- Orifice weir
- Orifice bucket
- Open channel Weir or flume

Planning a Pumping Test

- Step drawdown pumping tests
  - estimate T and S
  - estimate drawdown due to different pumping rates
  - determine well loss constant
    - wells not 100% efficient
    - more drawdown in well: $s_{real} = s_{theory} + s_{well_loss}$
- increase Q in increments and measure response

Analysis of step drawdown pumping test

- $s_{wellloss} = CQ^2$
- well loss increases disproportionately with Q
- C is a constant determined from step drawdown test
- $C = \frac{\frac{\Delta s_2}{\Delta Q_2} - \frac{\Delta s_1}{\Delta Q_1}}{\Delta Q_2 + \Delta Q_1}$
- $\frac{s_w}{Q} = B + CQ$, B is coef. of loss due to aquifer, C is coef. of loss due to well inefficiency. A linear equation with B as the intercept and C as the slope.



Other Well Jargon

- well efficiency - ratio of theoretical to observed drawdown
- $W.E. = \frac{s_{theory}}{s_{well}}$
- specific capacity - ability of well to deliver water
- $S.C. = \frac{Q}{s_{well}}$
- specific capacity constant if well 100% efficient

Boundaries and Pumping Tests

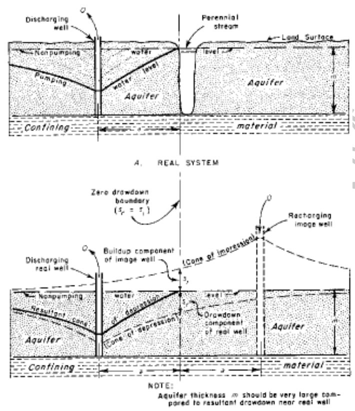
- Assumed aquifers extend to infinity

Question?
How will constant hydraulic head and no flow boundaries influence the cone of depression during a pumping test?

Boundaries and Pumping Tests

- No flow boundaries
  - increased drawdown
  - must be zero hydraulic gradient oriented normal to the boundary
- Constant head boundaries
  - decreased drawdown
  - head nust be unchanged at the bounary
- Image wells used to enforce boundary conditions

Boundaries and Pumping Tests



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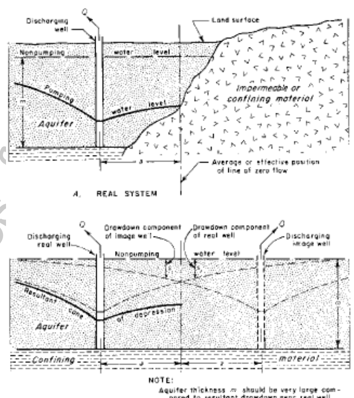
Boundaries and Pumping Tests



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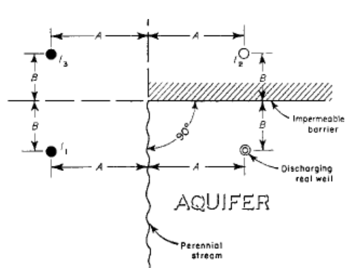

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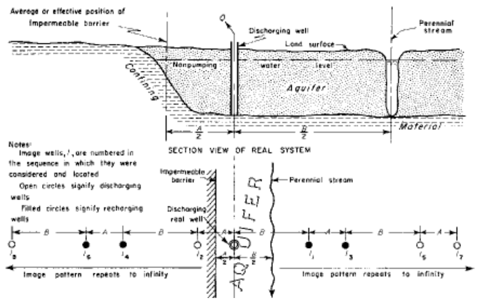

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Tracer testing

- velocity from travel time
- point dilution method
  - instantaneously completely mix tracer in well
  - measure conc. change with time
  - groundwater flux dilutes tracer in well

$$\frac{dC}{dt} = \frac{-A \cdot v_{bore} \cdot C}{V_{well}}$$

$$v_{bore} = \frac{-V_{well}}{A \cdot t} \ln\left(\frac{C}{C_0}\right)$$

$$v_{gw} = \frac{v_{bore}}{n_e \cdot \alpha}$$

α is geometry factor that accounts for convergence and divergence of flow lines near well screen, from .5 to 4 in sand