Chapter 4 – Flow to Wells

Example Problem Confined Aquifer

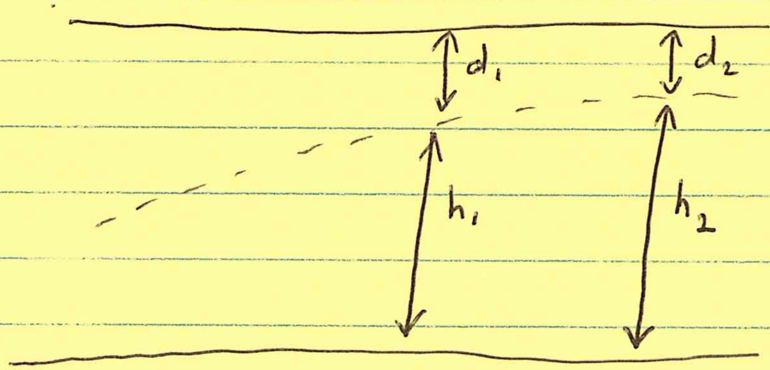
$$T = \frac{Q}{2\pi (h_2 - h_1)} \ln\left(\frac{r_2}{r_1}\right)$$

$$Q = 800 \ l/min = \frac{800}{1000} \ m^3/min$$

$$= \frac{0.8}{60} \ m^3/s$$

$$\left.\begin{array}{l} r_1 = 2m \\ r_2 = 10m \end{array}\right\} \frac{r_2}{r_1} = 5$$

$h_2 - h_1$ ~ all we are given is depths to water



$$h_1 + d_1 = h_2 + d_2$$

$$\therefore h_2 - h_1 = d_1 - d_2$$

$$\Rightarrow h_2 - h_1 = 15 - 12 = 3m$$

$$\therefore \quad T = \frac{0.8/60}{2\pi \; 3} \ln(5)$$

$$\boxed{T = 1.1 \times 10^{-3} \; m^2/s}$$

$$\boxed{K = \frac{T}{b} = \frac{T}{10} = 1.1 \times 10^{-4} \; m/s}$$

Example Problem Unconfined Aquifer

$$K = \frac{Q}{\pi (b_2^2 - b_1^2)} \ln\left(\frac{r_2}{r_1}\right)$$

$$Q = 500 \; l/min = \frac{0.5}{60} \; m^3/s$$

$r_2 = 8$

$r_1 = 3$ $\Rightarrow \frac{r_2}{r_1} = 8/3$

For unconfined aquifer $\Rightarrow$ b_1 = depth of aquifer − depth to water

$= 10 - 5 = 5 \; m$

$b_2 = 10 - 2 = 8 \; m$

$$\therefore \quad K = \frac{Q}{\pi (h_2^2 - h_1^2)} \ln \left(\frac{r_2}{r_1} \right)$$

$$= \frac{0.5/60}{\pi (8^2 - 5^2)} \ln \left(8/3 \right)$$

$$\boxed{K = 6.6 \times 10^{-5} \text{ m/s}}$$

For the Transient Pumping Tests please see the powerpoint called "Sample Transient Pump Test"

Also on following pages in pdf format

Theoretical Method $\Rightarrow$

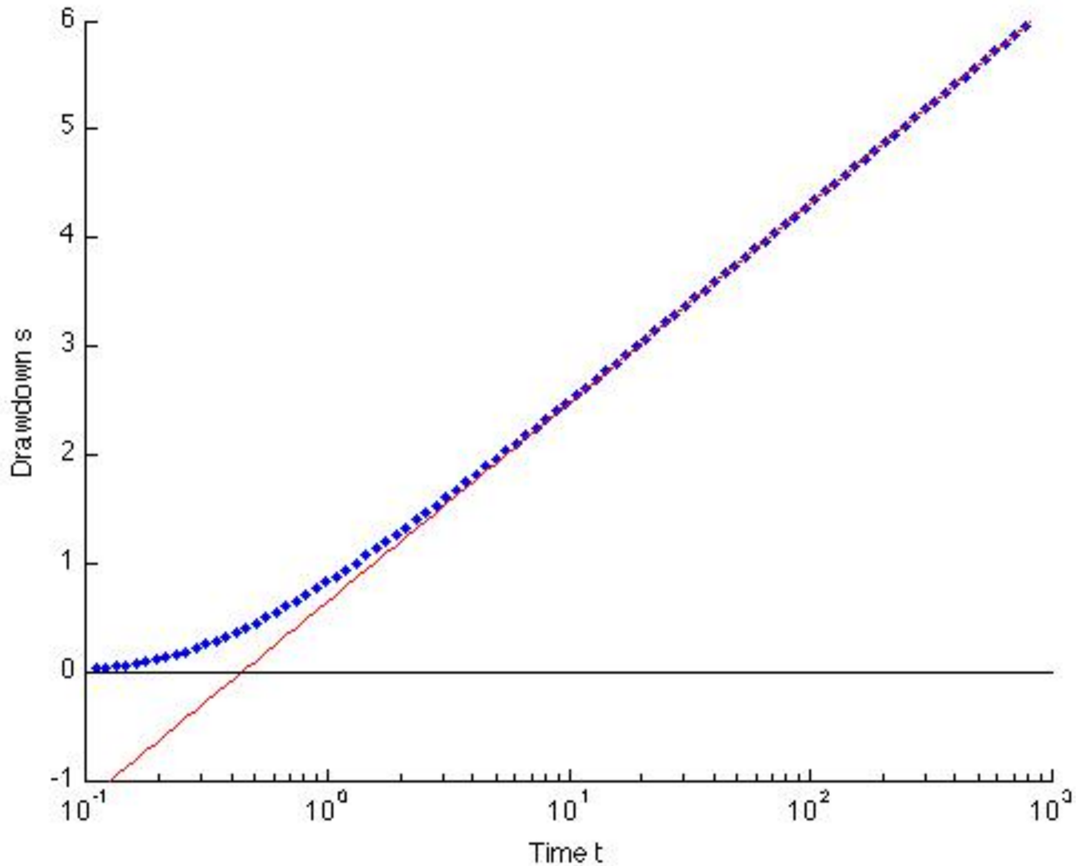
$$T = 0.1833 \frac{Q}{\Delta s_{10}} = 0.1833 \frac{10}{1.8} \approx 1 \text{ m}^2/\text{s}$$

$$S = 2.246 \frac{T t^{\iota}}{r^2} = 2.246 \frac{(1)(0.4)}{10^2} \approx 10^{-2}$$

Graphical Method $\quad T = \frac{Q}{4\pi (h - h_0)} W(u) = \frac{10}{4\pi (0.8)} (1) \approx 1 \text{ m}^2/\text{s}$

$$S = \frac{4 T u t}{r^2} = \frac{4 (1)(1)(0.3)}{10^2} \approx 1.2 \times 10^{-2}$$

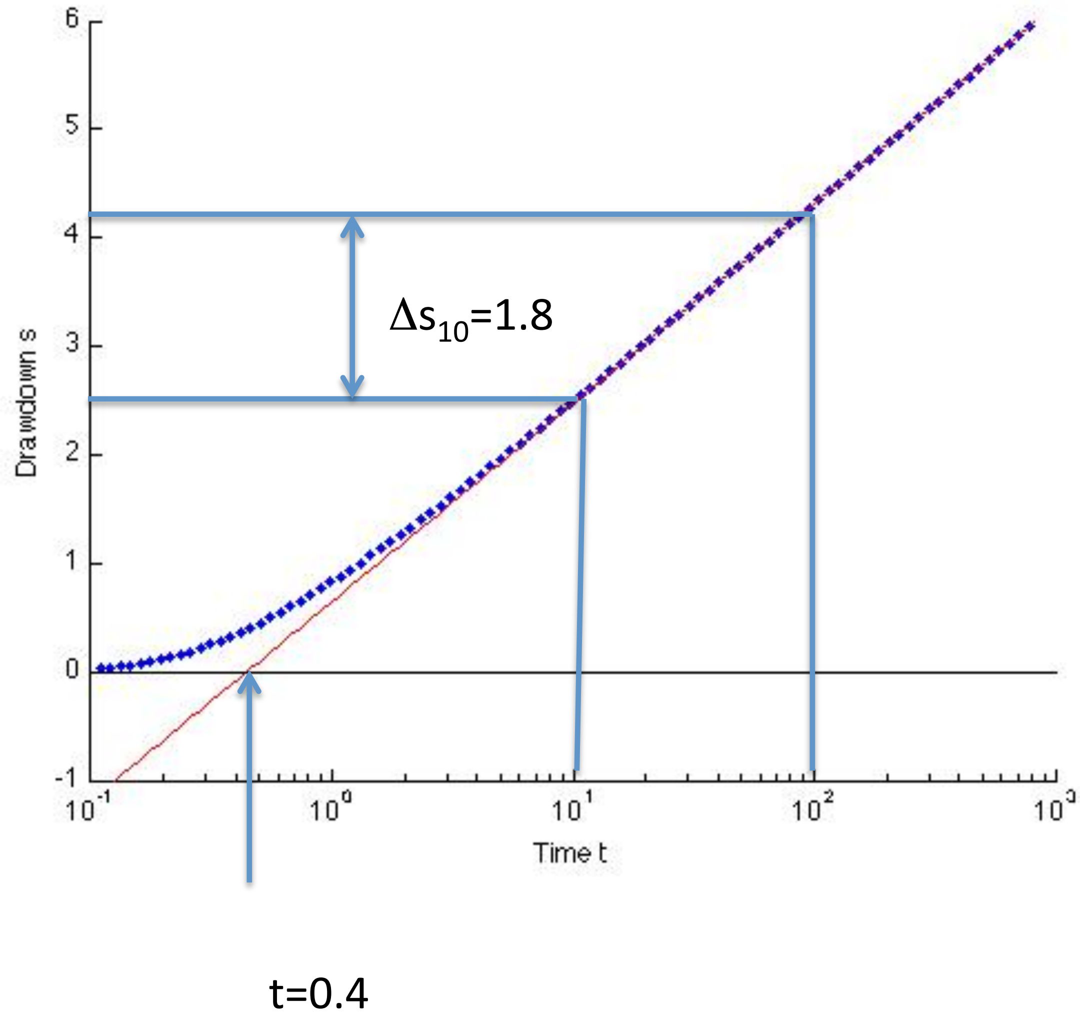
Theoretical Method



$$Kb = T = 0.1833\frac{Q}{\Delta s_{10}}$$

$$S = 2.246\frac{Tt^*}{r^2}$$

Theoretical Method

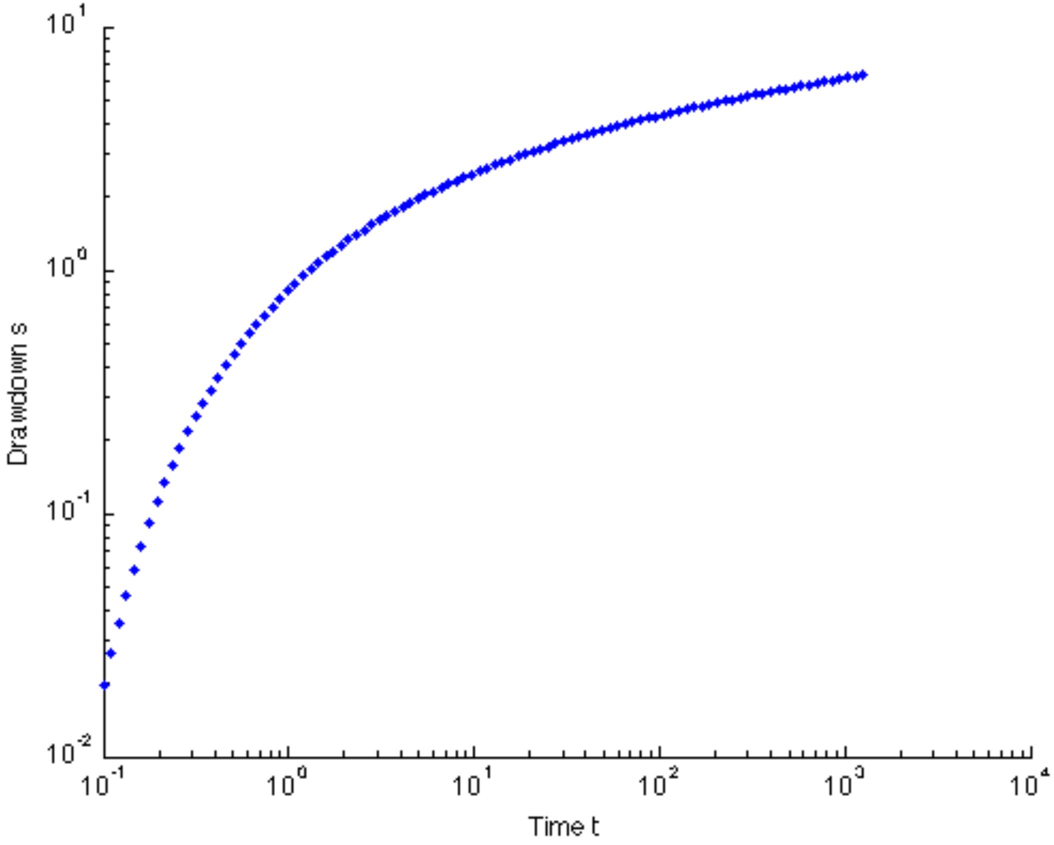


$$Kb = T = 0.1833\frac{Q}{\Delta s_{10}}$$

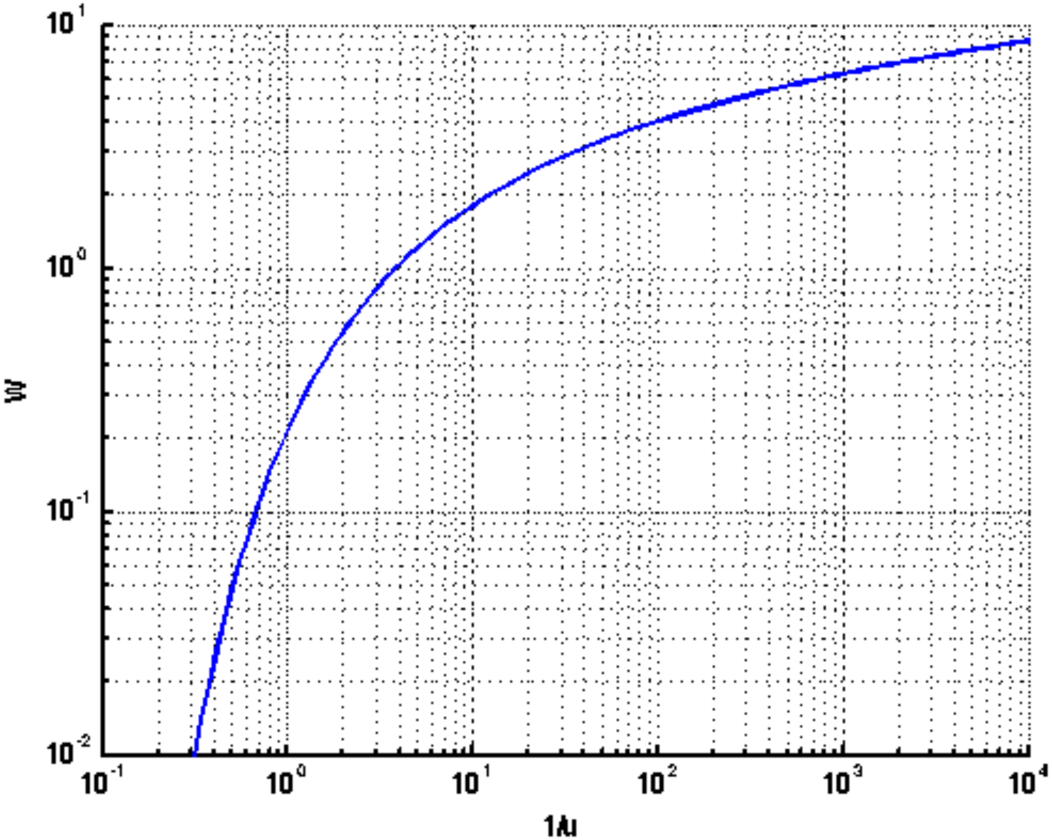
$$S = 2.246\frac{Tt^*}{r^2}$$

Graphical Method

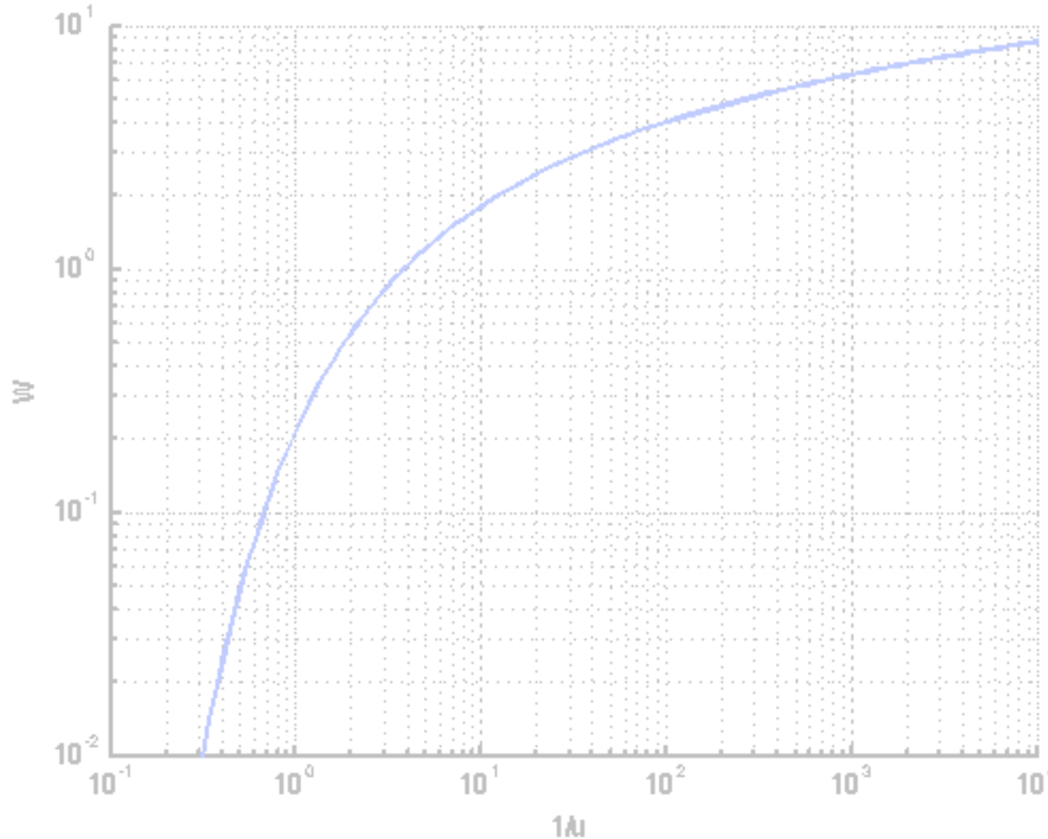
Drawdown Data



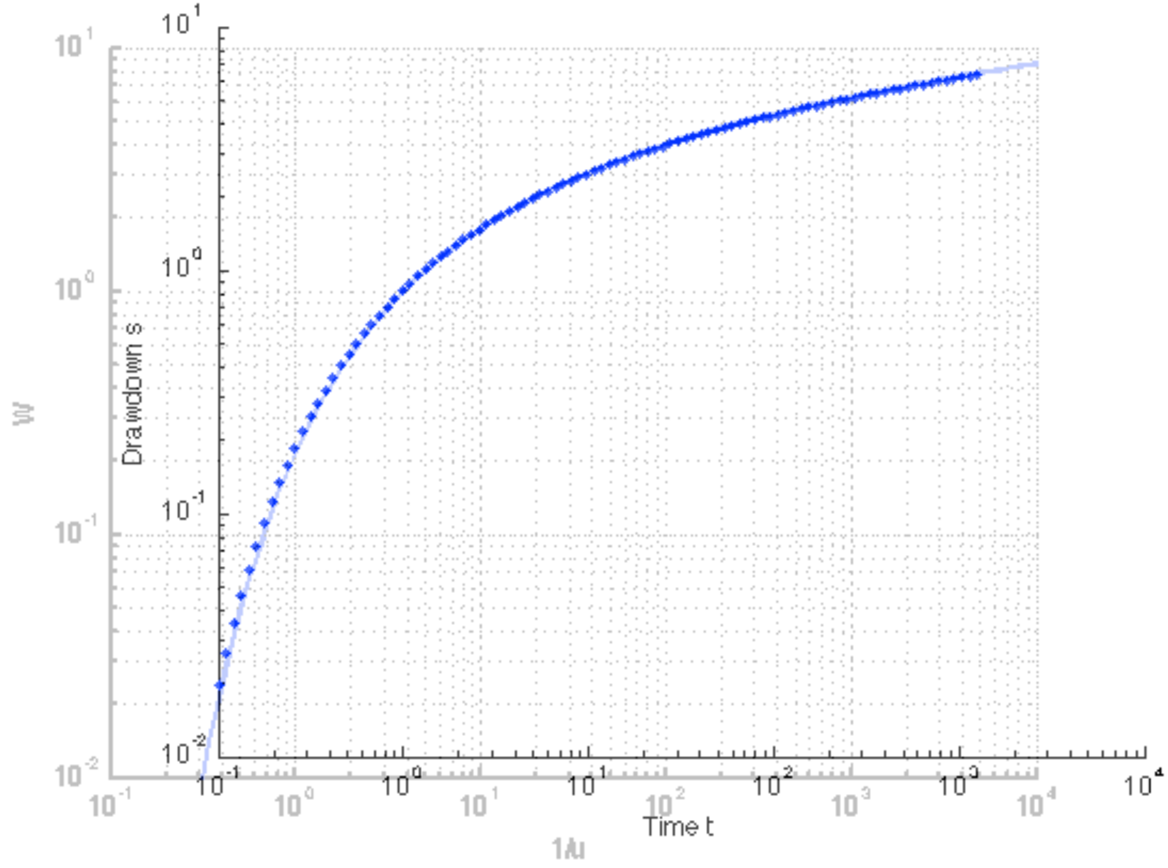
Well Function



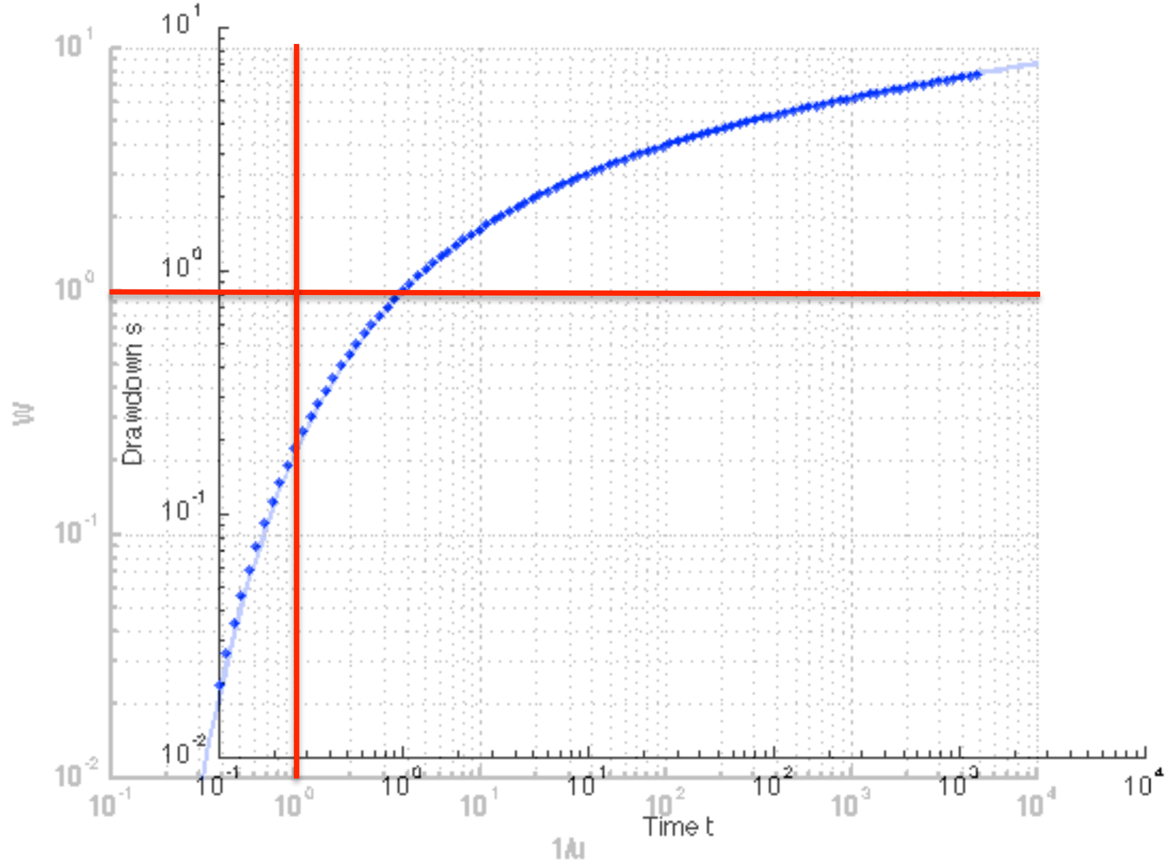
Let's make the well function 75% transparent



Overlay data on same graph



Locate Match Point on Well Function – (1,1)

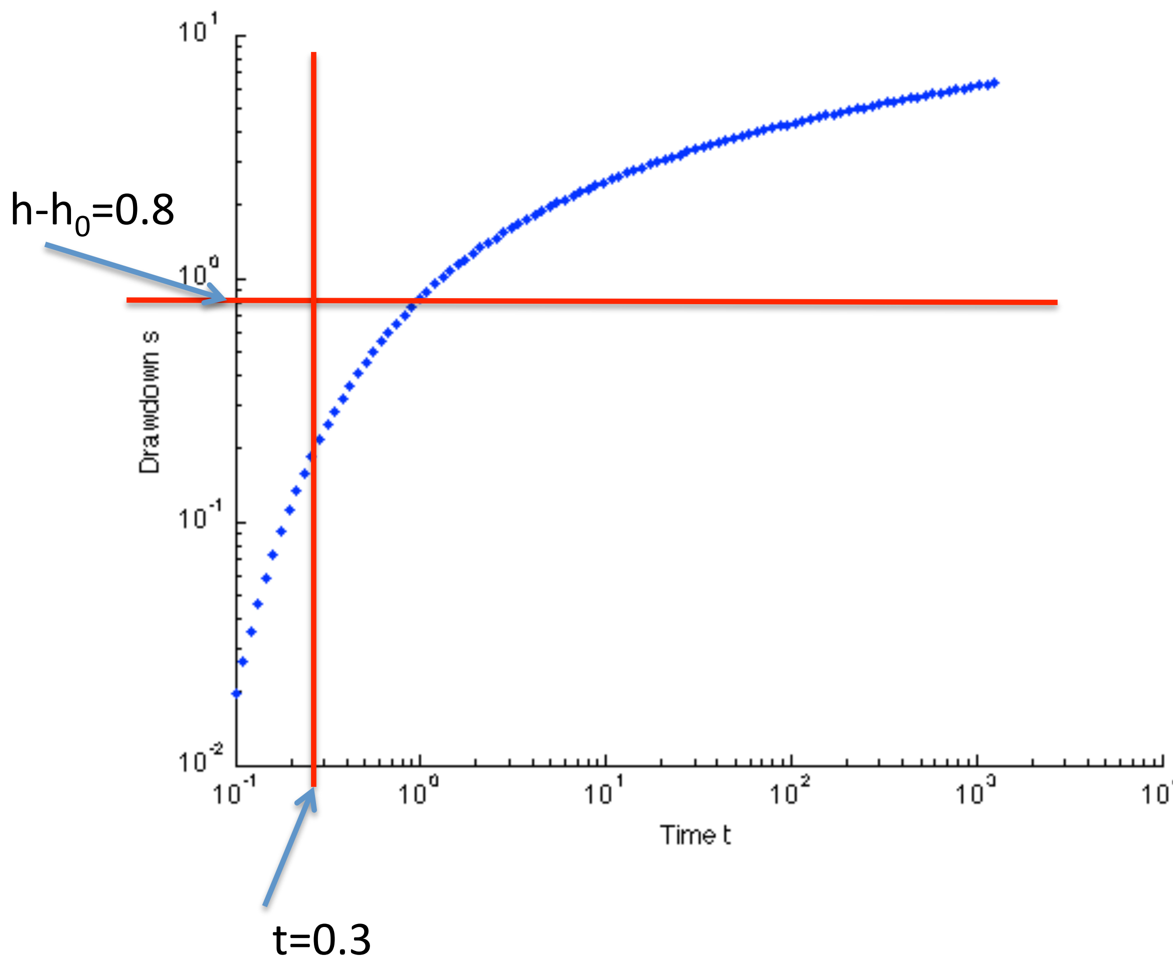


Delete Well Function and read off s and t from data

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

$$S = \frac{4Tut}{r^2}$$

W=1
u=1
$h-h_0=s$
t=t



Slug Tests

CBP Method

Equations $T = r_c^2 / t_1$ $\quad S = \mu \frac{r_c^2}{r_s^2}$

$r_c = r_s = 5\,cm$

Looking at data (following pages) it lines up best with curve for $\log_{10} \mu = -5$

$$\therefore \mu = 10^{-5}$$

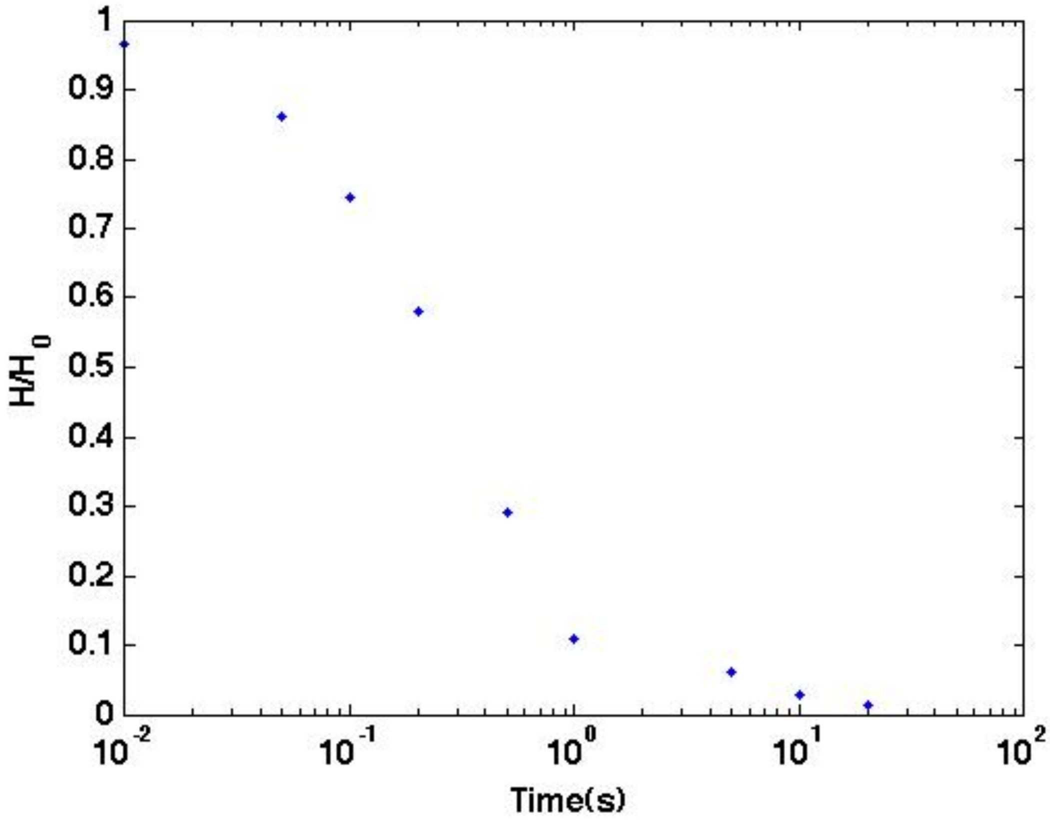
$$\therefore S = 10^{-5} \left(\frac{5^2}{5^2}\right) = 10^{-5} \text{ (Dimensionless)}$$

Point where $\frac{Tt}{r_c^2}$ on type curve $= 1$ is where

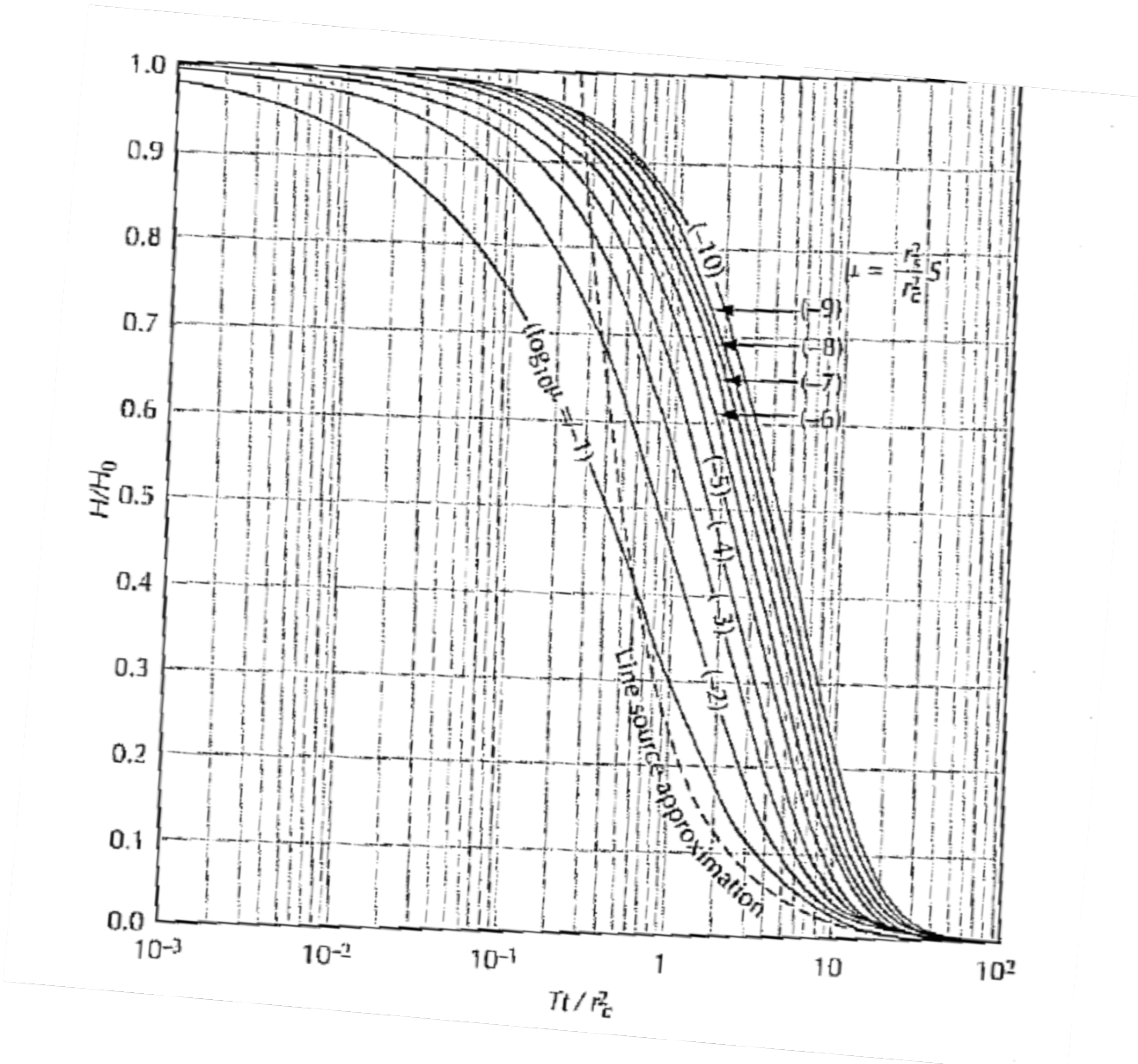
time on real data $t_1 = 0.1$

$$\therefore T = \frac{(5 \times 10^{-2})^2}{0.1} = \frac{25 \times 10^{-4}}{0.1} = 2.5 \times 10^{-2}\, m^2/s$$

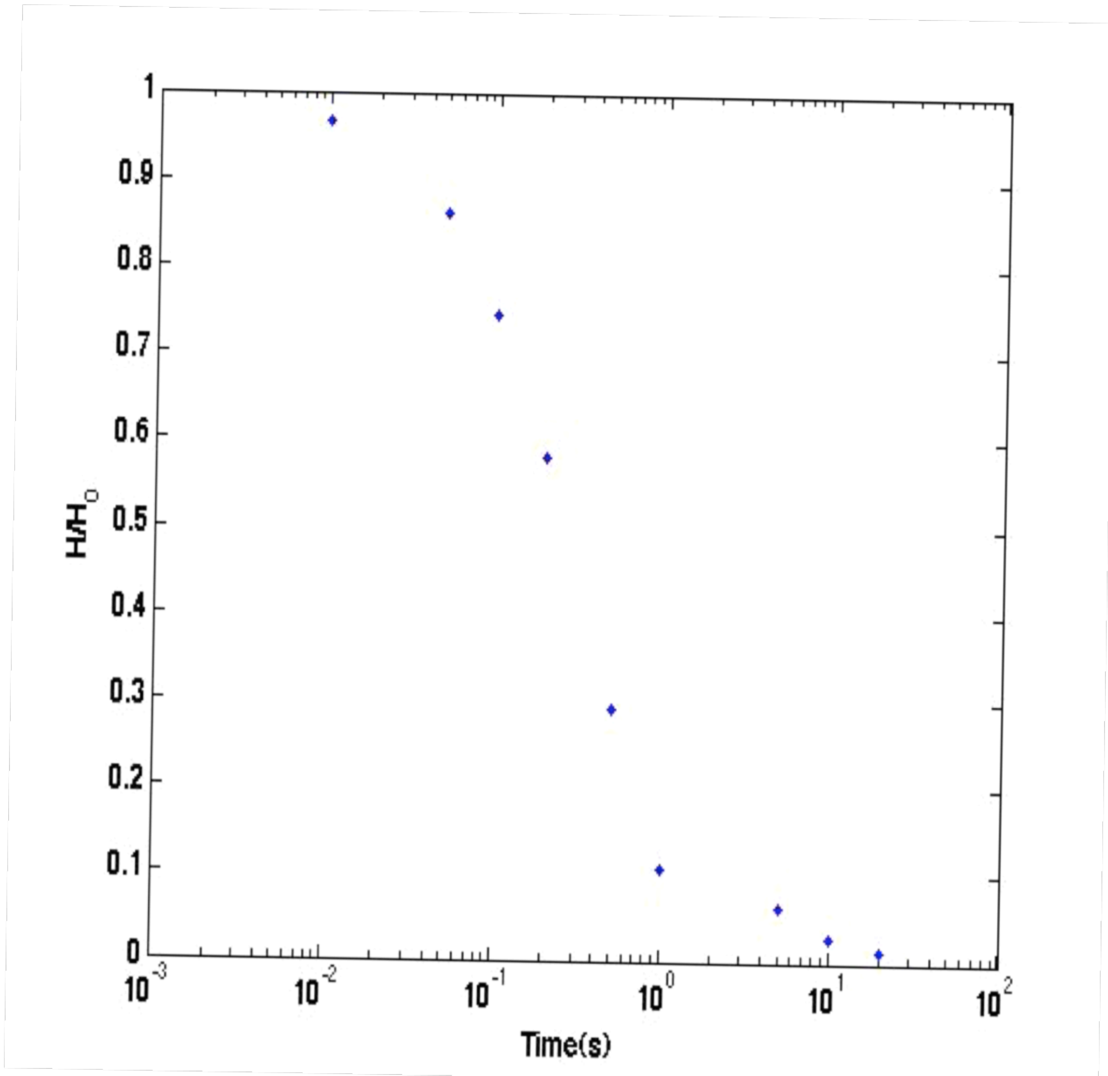
Data from Example



Overlay Graphics



Overlay Graphics



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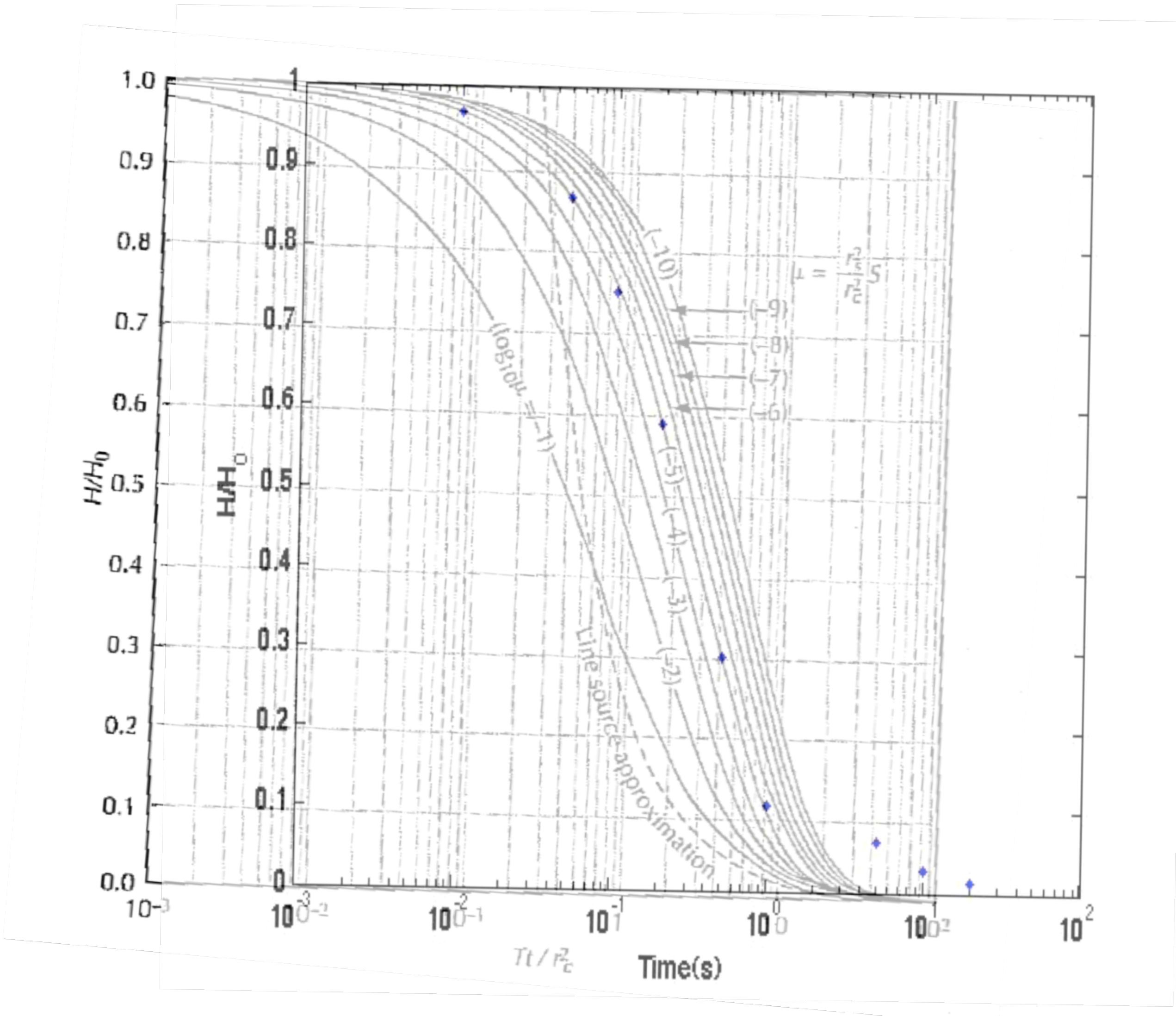

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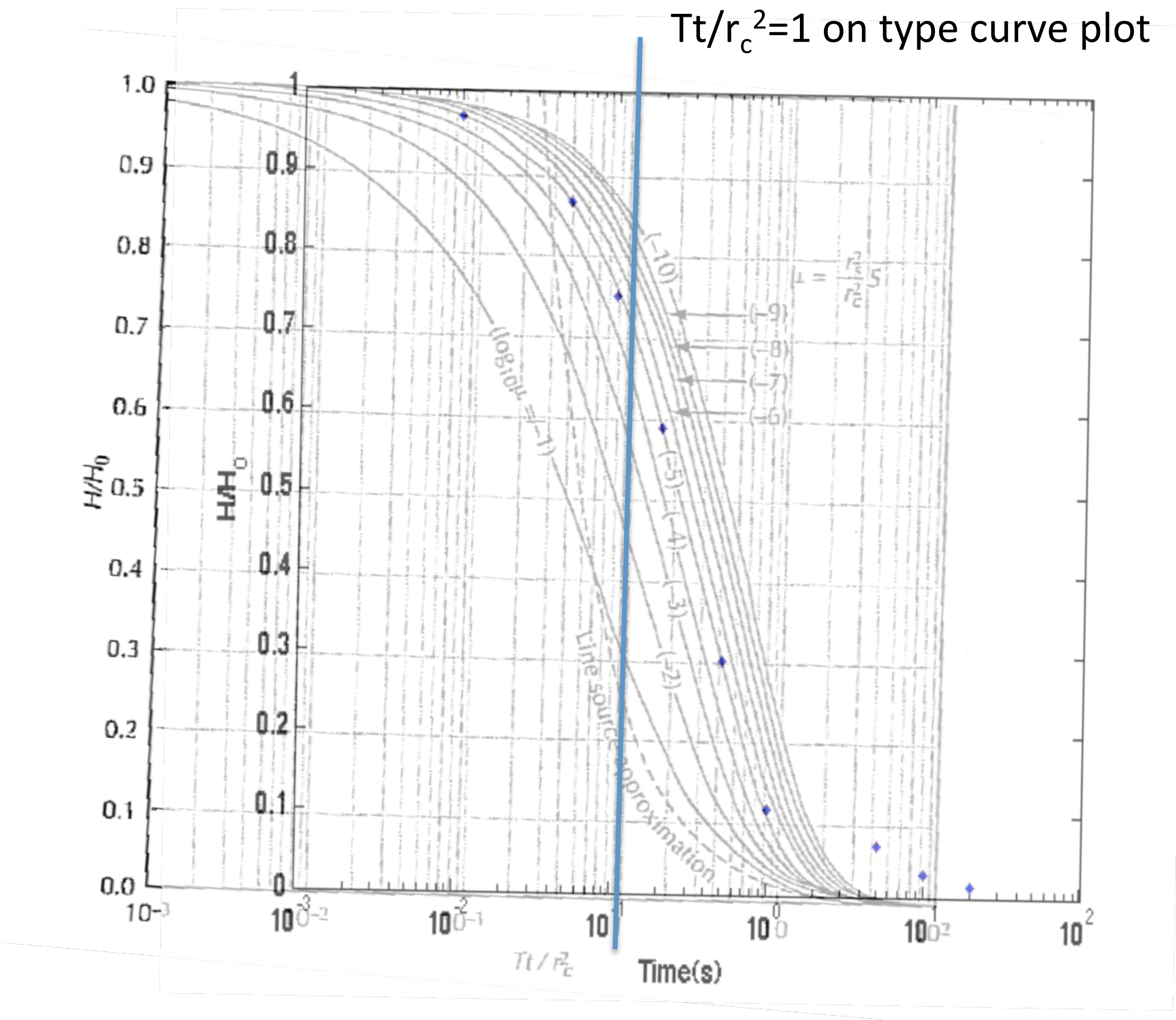
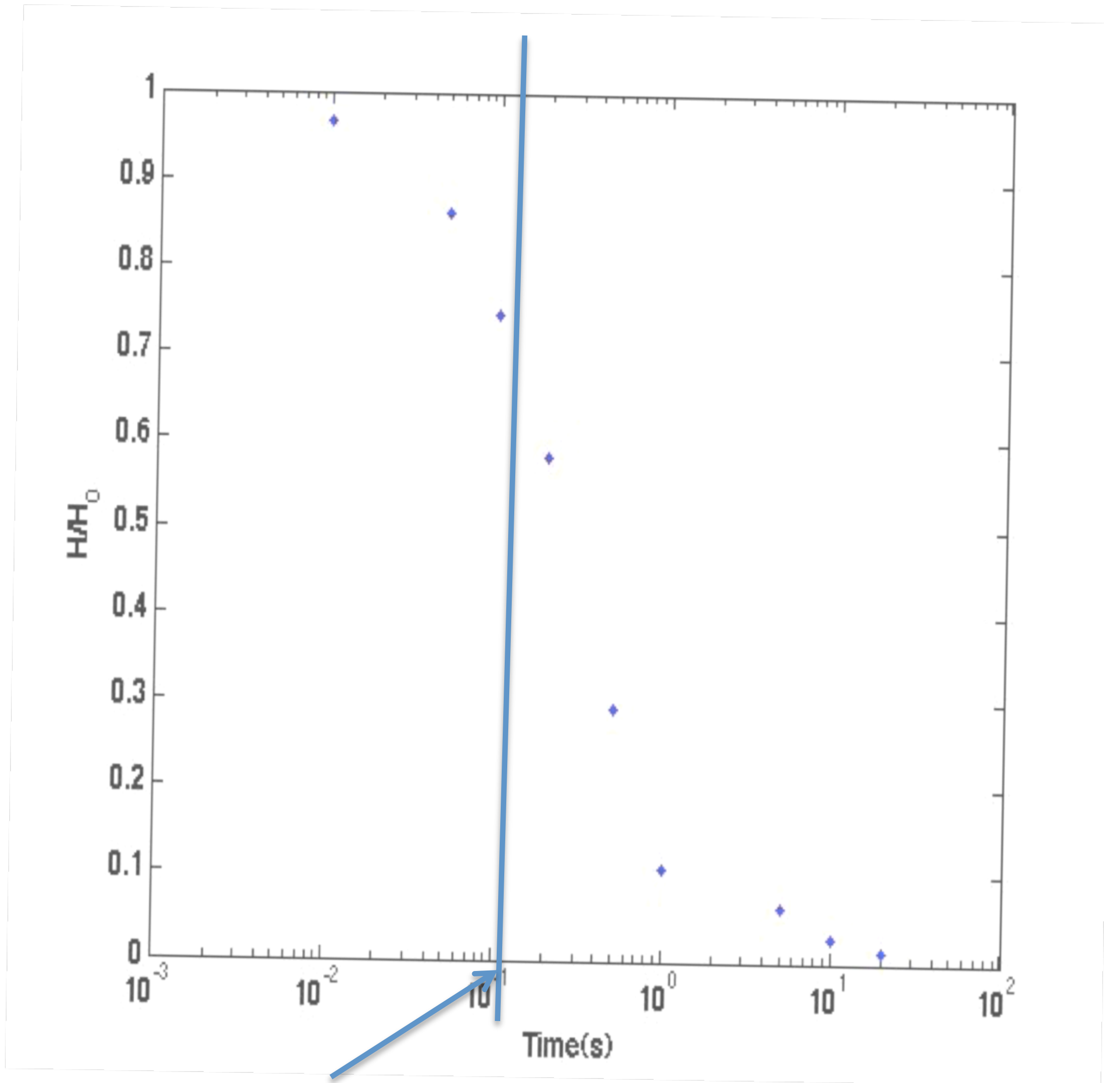


Remove the Type Curve, but keep vertical line

When overlaid on Figure 5.19
We identify mu=1e-6
(see figure below)
t_1=0.1



t_1=0.1

Hvorslev

$$K = \frac{r^2 \ln(L_e/R)}{2 L_e t_{37}}$$

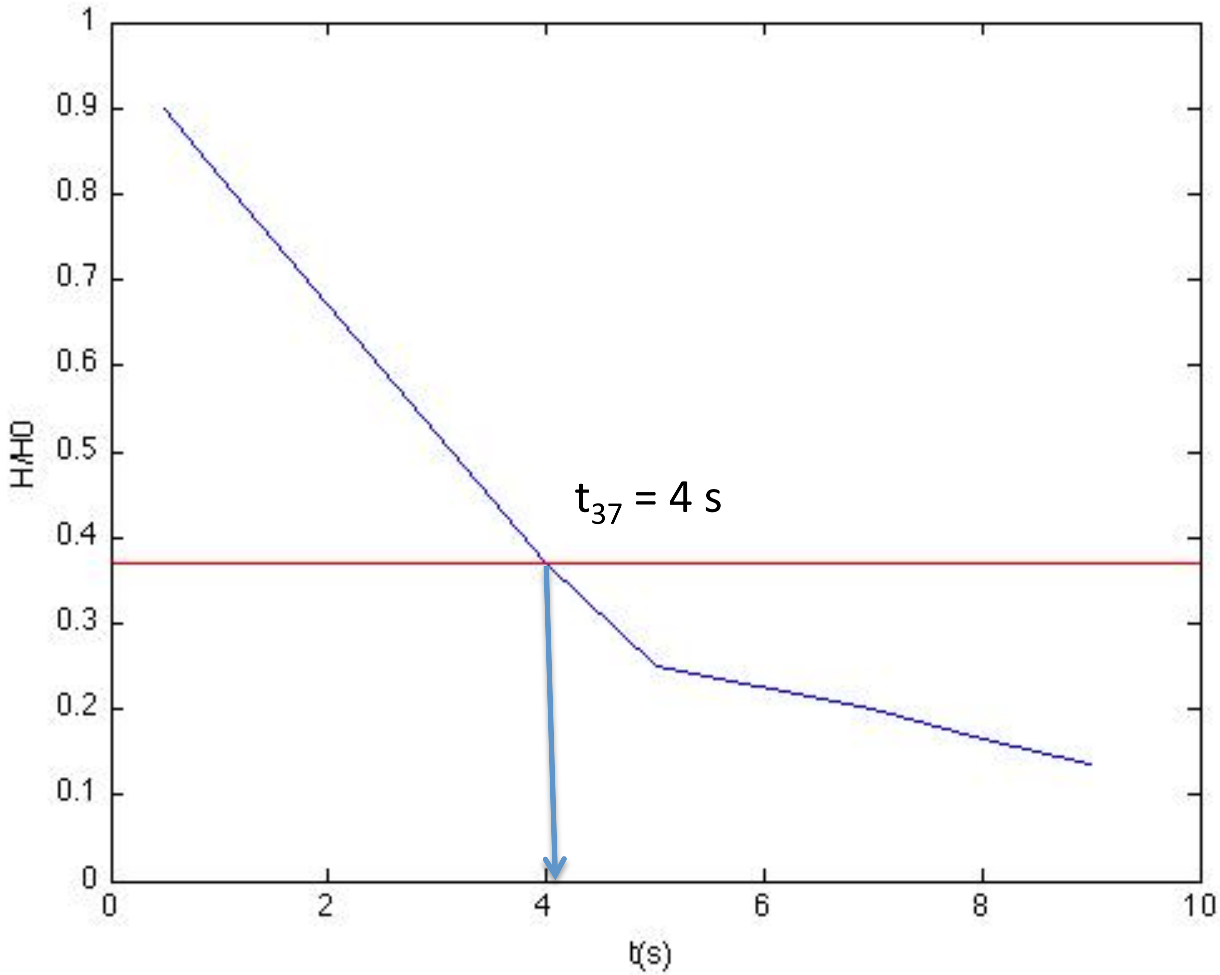
$R = 0.1\ m$

$r = 0.1\ m$

$L_e = 5\ m$

From data (see next page) $t_{37} = 4\ s$

$$\therefore\ K = \frac{(0.1)^2 \ln(5/0.1)}{2(5)(4)} = 9.8 \times 10^{-4}\ m/s$$



t₃₇ = 4 s
H/H0
t(s)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
2
4
6
8
10

van der Kamp

From data on following page

① $t_1 = 7.5\,s$ (trough 1 in the wave)

$t_2 = 22.5\,s$ (trough 2 in the wave)

$\therefore\ \tau = 15\ s \quad \Rightarrow \omega = \frac{2\pi}{\tau} = 0.4189\ s^{-1}$

② $$\left.\begin{array}{l} H(t_1) = -45\ cm \\ H(t_2) = -15\ cm \end{array}\right\} \gamma = \frac{\ln\left(\frac{H(t_1)}{H(t_2)}\right)}{\tau} = \frac{\ln(3)}{15} = 0.0732\ s^{-1}$$

③ $$L = \frac{g}{\omega^2+\gamma^2} = \frac{9.81}{(0.4189)^2+(0.0732)^2} = 54\ m$$

$$(g/L)^{1/2} = (\omega^2+\gamma^2)^{1/2} = 0.4255$$

④ $$d = \gamma/(g/L)^{1/2} = \frac{0.0732}{0.4255} = 0.1720$$

(5) $a = \dfrac{r_c^2 (g/L)^{1/2}}{8d} = \dfrac{(0.5)^2 (0.4255)}{8(0.172)}$

$= 0.0773 \ m^2/s$

(6) $c = -a \ln [0.79 \ r_s^2 \ S \ (g/L)^{1/2}]$

↑ note we do not know S

↳ based on geology assume $S = 10^{-3}$

$= (-0.0773) \ln [0.79 (0.5)^2 (0.4255)(10^{-3})]$

$= 0.7254 \ m^2/s$

$T_0 = c + a \ln(c) = 0.7254 + 0.0773 \ln(0.7254)$

$T_1 = c + a \ln(T_0) = 0.7006$

$T_2 = c + a \ln(T_1) = 0.6979$

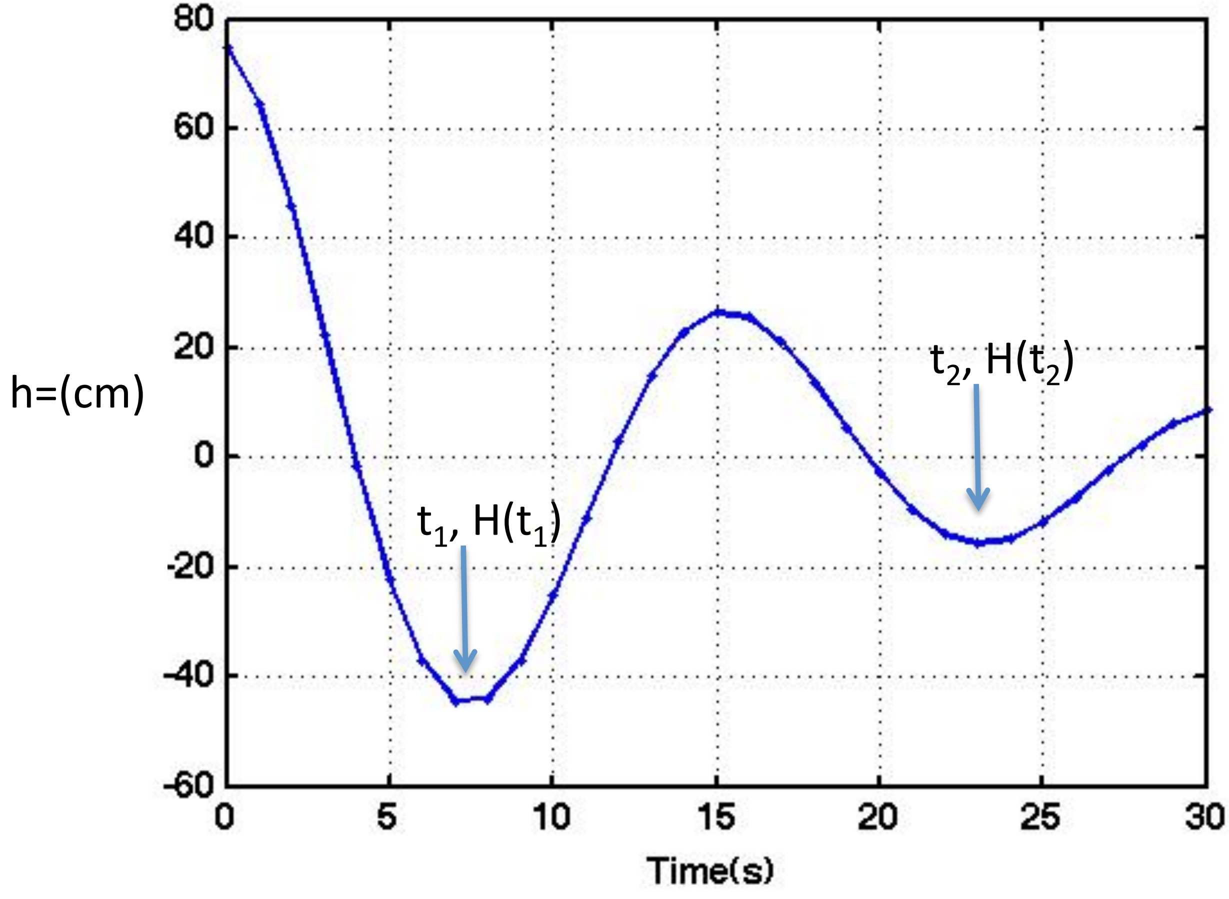
$T_3 = c + a \ln(T_2) = 0.6976$

$T_4 = c + a \ln(T_3) = 0.6976$

} converged $T = 0.6976 \ m^2 s^{-1}$

Example Problem

Interpret the following curve
rc=0.5 m and rs=0.5m



Note the x axis has been fixed relative to the notes