Theis Equation

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1 Theis Solution

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The Theis (1935) equation is used to calculate drawdown for two-dimensional radial groundwater flow to a point source in an infinite, homogeneous aquifer. The Theis equation was derived from heat transfer literature (with the mathematical help of C.I. Lubin) and is defined as:

$$s = \frac{Q}{4\pi T} W(u) \tag{1}$$

where s is drawdown [L], Q is the pumping rate [L^3/T], T is the aquifer transmissivity [L^2/T], u is a dimensionless time parameter [unitless], and $W(u)$ is the Well function (exponential integral E_1) [unitless]. The exponential integral is available in `scipy.special` as the `exp1()` function.

The dimensionless time parameter is defined as:

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

where r is the distance from the pumping well to a point where drawdown is observed [L], S is storativity [unitless], and t is the time since pumping began. Storativity is defined as:

$$S = S_s b \tag{3}$$

where S_s is specific storage [1/L] and b is the thickness of the aquifer.

1.1 Drawdown from a pumping well

First we will plot drawdown with time at a arbitrary distance from a pumping well. The relevant parameters are:

Table 1: Aquifer and well parameters

Parameter	Value	Units
x_{well}	0.	m
y_{well}	0.	m
x_{obs}	1000.	m
y_{obs}	1000.	m
T	0.30	m^2/s
S	0.0008	unitless
Q	1.16	m^3/s

1.1.1 Exercise 1

Create a function that calculates the drawdown at a monitor well location. You will also need a function to calculate the distance from the monitor well to the pumping well. Plot drawdown versus time using `matplotlib`.

1.1.2 Exercise 2

Make new functions from your existing drawdown and distance functions to calculate the drawdown for a square area with a fixed cell size ($\Delta x = \Delta y$) and a pumping well in the center of the area. Your functions should be able to work with two-dimensional `numpy` arrays and return a `numpy` drawdown array that can be plotted with `matplotlib`. Use an odd number of rows and columns (rows = columns) so that the pumping well is located in center of the area.