Chapter 12
Groundwater Drawdown by Pumping

Aquifers are a valuable source of water. Groundwater is available and used in many parts of the world for industrial and municipal purposes and for public water supply. In several regions and urban centers the percentage of groundwater on public water supply reaches 100%. Although the chemistry of subsurface water may be very different, groundwater quality can fulfill highest standards nevertheless.

Groundwater is pumped from single wells or galleries of several wells. In the vicinity of the wells the water table may decrease, depending on the type of the aquifer. In all cases the piezometric head decreases, which is explained in more details below.

Environmental studies in connection with groundwater withdrawal are necessary for several reasons. The maximum yield, which can be extracted on a sustainable basis, is of high concern for the well operating agency. The drawdown of the water table itself may also be of ecological importance, as eco-systems in the catchment of the well can be affected. Wetlands for example are vulnerable systems, which react quite sensitive to changes of the sub-surface or surface water table.

Water quality is another important topic for water withdrawal systems. If the quality of pumped water is not sufficient, knowledge about the well catchment and the flowpaths may enable counter-measures in order to avoid or reduce the migration of polluted water towards the pumping facilities. Recharge wells may prevent such migration if operated at an appropriate location and an appropriate recharge rate.

In this chapter we examine the change of piezometric head $h$ in the vicinity of a single pumping well. There are analytical solutions for $h$ as function of distance from the well centre $r$, which can be computed easily using MATLAB®. In all cases other causes for groundwater flow (for example base flow) are neglected. More complex situations are treated in the following two chapters.

12.1 Confined Aquifer

A confined aquifer is a permeable groundwater layer between two impermeable layers (aquitards), as shown in Fig. 12.1. In idealized situations, which are treated in this chapter, groundwater flows in a permeable layer, the aquifer, from all sides...
radially towards an installed pumping well. It is assumed that the situation is totally
equal in all radial directions, which allows the use of the radius \( r \) as the space
variable. It is also assumed that there are no differences in vertical direction: the
well is screened across the entire aquifer and there are no differences concerning the
hydraulic properties within the permeable layer. The aquifer remains water
saturated, i.e. there are no parts that fall dry due to pumping.

In the idealized situation shown in Fig. 12.1, the aquifer is characterized by
a thickness \( H \) [m] and a transmissivity \( T \) \([m^2/s]\). In the transmissivity parameter
the hydraulic conductivity \( K \) of the porous material and the thickness of the aquifer \( H \) are represented:

\[
T = K \cdot H
\]  

(12.1)

\( T \) increases with thickness; \( T \) is higher for more permeable aquifers. It is assumed
that the well withdraws water at a constant rate \( Q \) \([m^3/s]\), which allows the
description of the steady state groundwater flow. The relevant variable for the
analysis of groundwater flow is the piezometric head \( h \), which changes with
the distance \( r \) from the well position. Piezometric head is the key variable for
flow (see Darcy’s Law, Chap. 11), quantifying the height of the water table above
some reference level measured by a piezometer. A piezometer is a pipe that is open
at both ends, and reaches into the aquifer with the lower end). \( h \) decreases if the well
is approached and can be calculated by using the formula of Thiem (1906):

\[
h(r) = h_0 + \frac{Q}{2\pi T} \log \left( \frac{r}{r_0} \right)
\]  

(12.2)

with:

- \( h_0 \) piezometric head above base at radius \( r_0 \) [m]
- \( Q \) pumping rate \([m^3/s]\)
- \( T \) transmissivity of the aquifer \([m^2/s]\)
- \( r_0 \) radius [m]