IHE module 3

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Transient Groundwater Flow, Analytical Solutions

# Syllabus

The syllabus is a document that you may refer to at later stages in your career. We will not cover the entire syllabus. A list of covered subjects follows below.

# Exam

The exam will last one hour and consists of solving several tasks and providing answers to questions concerning the text. Required formulas will be given.

# Grading

Grading will be 70% exam, 30% assignments

Exam: Answers must show the motivation, that is, the rationale of your answer. I want to see what steps you make and why. **So motivate each step with some clarifying words**. Just numbers or incomprehensible formula derivations do not count!

# Assignment

An assignment will be provided. It can be partially made in class during the exercises in the afternoons. **But I must have the results latest when I judge your written exams, that is, by the end of the week in which the exam takes place, simply because I can't give marks without the assignments**. Any assignments handed in thereafter will not be graded, which implies that the entire mark will be defined only by the results of the written exam.

It is clear that I expect everyone to do his/her own assignments. It is generally easy for me to see who copied his or her work from someone else.

# What to learn/understand

Chapters 1 through 4.2. Check yourself by answering the questions on pages 37-39.

Chapter 4.3: Skip

Chapters 5.1 through 5.3, to the extent that you understand and can answer the questions on page 47-48.

Chapter 5.4.1-5.5.2. Understand how the *erfc* function works, understand that that the differential equation is a water balance, and understand what the parameters in the solution mean. Answer the questions on page 51-53

Chapter 5.4.3. and 5.4.4 Skip. It may be useful as a future reference.

Chapter 5.4.5. Understand how superposition in time works, and how to apply it when the analytic solution is provided.

Chapter 5.5.1-5.5.5 Understand how superposition in space works. Answer the questions of section 5.5.6.

Chapter 5.6.1-5.6.2 Understand what the formula means and how we cracked it down to a characteristic time for groundwater systems and to their halftime. Check if you can answer the questions in section 5.6.3.

Chapter 6: Flow to wells

Chapter 6.1, 6.2 Introduction to wells

Chapter 6.3. Theis: Relation between the transient and steady-state well solutions. The Theis solution and its approximation.

It's always a good exercise to derive the partial differential equation yourself. This is, in fact, a basic engineering skil as it specifies the physics of the problem.

Chapter 6.4 Understand the situation covered by the Theis and Hantush solutions. Understand the behavior of these solutions on double log and half log axes. Understand where the extracted water comes from in both cases. Understand that Theis is a special case of Hantush. Understand how the simplified Theis solution is derived and why its useful. Understand the radius of influence. Understand the discharge at distance in the Theis case and what it implies. What are type curves?

Chapter 6.5 Pumping tests. Understand the concept of a pumping test. The interpretation of a pumping test in the Theis situation using the simplified logarithmic approximation of the well function (the trick to always determined the transmissivity from the drawdown per log-cycle of time. The way to determine the storage coefficient using the simplified log-approximation of the Theis function and it is limitation (partial penetration, clogged pumping well when measuring when measuring level inside the pumping well).

Understand the principle of the classic analysis of pumping tests in the Theis and Hantush situation using graphs and type curves on double logarithmic scales (or paper).

Chapter 6.6 Partial penetration of the well screen in the aquifer. Just understand what it is and what effect it has on the drawdown near the well. You an always use this section as a reference in the future.

Chapter 6.7 skip.

It’s always good if you exercise to derive the basic differential equations (i.e. the physics). Realize that these partial differential equations are always water balances for an arbitrary, infinitesimally small portion of the aquifer.

The analytical solutions in chapter 6.5.1 and 6.5.2 do not have to be remembered. They serve as a reference so you can implement them in Excel or Python when needed.

Chapter 6.5.4: Answer the questions on page 109-110

Chapter 6.5.5: Skip, we will do the test in the exercises.

Chapter 6.6: Only understand the mechanism, as you are likely to encounter it in practice.

Chapter 6.7: Skip. As a reference. You may encounter it in practice. It is important to realize how it works because it can cause unexpected late drawdown not discovered during pumping tests of limited duration.

Chapter 7: Understand what convolution is. Convolution is extremely useful as it allows to simulate groundwater with simple formulas for arbitrarily varying input in an efficient and very general way. It can be seen as a smart form of superposition.

Chapter 8. Skip. May be for reference.