ENVR 453
Groundwater Hydrology
Fall

1 General Information

Instructor:	C.T. Miller
Office:	3201 McGavran-Greenberg Hall
Office Hours:	By Appointment
Office Phone:	919-966-2643
E-mail:	casey_miller@unc.edu

2 Grading Bases

The bases for assigning grades are as described in the following table; additional detail about these components is given in sections that follow.

Problem Sets:	25%
In-Class Participation:	25%
Mid-Term Exam:	25%
Final Exam:	25%

3 Course Policies

Attendance of lectures is an essential part of this course due to the Socratic methods used in this course. For this reason, in-class participation is an important part of the grading evaluation. Late assignments and exams will not be accepted. The final exam plan for this course has been approved by the administration.

4 Course Objectives

Objectives of the course are for students to accomplish the following:

- to understand the set of fundamental physical, chemical, and biological processes operative in porous medium systems;
- to develop the ability to translate a physical system into an appropriate mathematical model that describes the system;
- to develop the ability to apply existing solutions to porous medium models;
- to develop an understanding of some common methods for deriving solutions to models used to describe porous medium systems; and
- to develop a physical intuition for how natural systems behave and the relative importance of competing phenomena.

5 Background Required

This course is intended as an advanced undergraduate course or first graduate-level course in fluid flow and contaminant transport in porous medium systems. Fundamental, well-established principles and evolving theories alike will be covered. However, many details associated with the more advanced topics will not be covered due to the level of this course and the expected lack of background of some students in some essential areas needed to grasp fully state-of-the-art methods. Many references and sources of information exist, and these will be passed on to the students so that they can independently learn more in their areas of deficiency and interest.

However, the subject matter itself presents somewhat of a problem because it is interdisciplinary in nature. Aspects of engineering, physics, chemistry, biology, and mathematics are often needed to fully understand a single typical problem. Past experience has shown that students are often deficient in one or more of these areas. This is expected from my perspective and should be from yours. Few people at the advanced undergraduate or beginning graduate level have a solid background in each of these fundamental areas. Depending upon your background, different aspects of this course may be familiar or entirely new. New aspects may require reading in undergraduate or lower-level graduate references from subjects outside of groundwater hydrology to fully ground yourself in the fundamentals of a given problem. Outside reading will be suggested to help those dealing with new concepts.

The essential pre- or co-requisites for this course are the following:

- calculus through ordinary differential equations;
- partial differential equations;
- calculus-based physics;
- fluid mechanics;
- general chemistry;
- general biology;
- computer literacy (e.g., programming in one or more languages, such as Matlab, Mathematica, C++, or FORTRAN); and
- environmental physics.

If you are deficient in one or more of these areas, it doesn't mean you shouldn't take the course or won't be able to successfully complete the course with a good grade; it is an indication of how much time and work may be required to do so though. You should expect to do outside study in any areas where your background is deficient.

Because this is an advanced-undergraduate or beginning graduate-level course, it is expected that significant time will be required outside of lecture to master the material covered in the lectures and to complete the problem sets. If your background is average, you should plan on about three hours outside of class for each hour of class time. If your background is deficient, then more time will be required. Conversely, if your background is excellent, then you may need less time than average to master the material.

6 Problem Sets

Problem sets will be given during the course to expose students to problem solving for a range of common topics. At least one week will be allowed to complete all problem sets and usually more than a week will be allowed. Any reference materials or software available to the student can be used to complete these problem sets. General group discussions are encouraged to discuss concepts and approaches—this is an efficient way to aid learning—but each write-up must be the sole product of the student submitting the work. Key ideas contributed by others should be acknowledged in the write-up and

referenced. Students may be asked to present their solution to a problem to the class during lecture.

7 Exams

A mid-term and final exam will be given in this course. Both of these exams will be given in take-home form to allow stimulating questions to be posed without unreasonable time constraints. These exams must be individual work and should not be discussed with anyone else before turning the exam in to the instructor. You will be asked to write and sign the honor pledge to affirm that you have neither given nor received aid on the exam.

8 Course Text and References

The material covered in this course does not map to any available book, so no book is required. This statement requires some explanation and elaboration. First, our approach will be more fundamental than that taken in most text books. We will focus on the physical and mathematical foundation of mechanistic descriptions of porous medium systems. By understanding the fundamentals, a more mature understanding can be developed as opposed to focusing on the application of some set of approaches. There are also fundamental lessons that emerge from such an approach that are important across the sciences in general. So while you think you are learning groundwater hydrology, you will really be learning the fundamentals of mechanistically describing physical systems, in addition to groundwater hydrology—think of it as a bonus!

The course will also cover an extremely broad range of topics, more than are covered in standard text books. This scope includes single-fluid and multiple-fluid systems, both the flow of fluids and the transport of individual species in a phase, consideration of the description of systems across a range of length scales, and the use of a variety of analytical and numerical methods to derive solutions to mechanistic models intended to represent certain porous medium systems.

Because the approach and the scope of the material covered in this course don't map to any available textbook, attending the lectures and understanding the concepts presented will be a primary mode of learning. References

will be suggested to supplement the material covered in lectures. Notes written by the instructor will be distributed from time to time. Papers published in the literature will be suggested periodically as well.

While the above considerations preclude the assignment and following of a book, it is important to your education that you obtain and read one or more books on the topic during the semester. One masters a topic when one can understand different perspectives, understand commonalities, and grasp the differences in approaches. This cannot possibly happen unless the student consults a variety of sources, the more the better. In short, the goal is for you to become educated in the subject matter of this course. You are strongly encouraged to add one or more groundwater books to your personal, permanent library to aid in achieving this goal. Many books are also available through the library system, and you are encouraged to put these to use.

Some books that should be considered include the following:

1. Pinder and Gray (2008) Essentials of Multiphase Flow and Transport in Porous Media, Wiley.
2. Bear (1988) Dynamics of Fluids in Porous Media, Dover.
3. Bear (2007) Hydraulics of Groundwater, Dover.
4. Freeze and Cherry (1979) Groundwater, Prentice Hall.
5. Schwartz and Zhang (2008) Fundamentals of Ground Water, Wiley.
6. Todd and Mays (2008) Groundwater Hydrology, Third Edition, Wiley.

Many other books are available as well, literally dozens. These can be found using keyword searches that include groundwater or porous media or hydrogeology. Books that have a geologic perspective will differ greatly from the focus of this course. Our approach will be more mathematical and less conceptual than a standard book on hydrogeology. However, a hydrogeology book would be a relatively easy read and would certainly provide useful background that will not receive focused attention in this course.

10 Lecture Outline

The formal in-class portion of this course will consist of 28 lectures. These lectures will address many aspects of groundwater hydrology and porous medium physics. These lectures will not follow any book specifically, but some books are noted above and some lecture notes will be written and made available to the students. An outline of the lectures to be covered in this course are as follows:

1. Introduction (1–2)
2. Microscale Fundamentals (3–6)
3. Macroscale Fundamentals (7–10)
4. Thermodynamically Constrained Averaging Theory (11–12)
5. Single-Fluid-Phase Flow (13–18)
6. Single-Fluid-Phase Transport (19–22)
7. Multiphase Flow (23–27)
8. Multiphase Transport (28)