Applied Groundwater Modeling
HWRS482/582 Spring 2020

Tu/Th 12:30-1:45, Harshbarger 110

Description of Course

Introduction to groundwater flow and transport modeling with emphasis on model construction and simulation.

Course Prerequisites or Co-requisites

Course Requisites: Principles of Hydrology (HWRS 250), or equivalent course
Calculus 1 (MATH 122 A&B), and Calculus II (MATH 129)
Vector calculus is also preferred by not required.

Instructor and Contact Information

Dr. Laura Condon
lecondon@email.arizona.edu
Office: Harsbarger 324e
Office Hours:
Monday 1:30 -2:30
Thursday 10:00-11:00
or by request

Course Format and Teaching Methods

This course will consist of a mixture of lectures and computer lab activities. Roughly the first half of the term will be spent building models individually, and roughly the second half of the term will focus on how models can be used to support decision making. These assignments will be completed in groups.

Course Objectives

This course will cover the fundamentals of modeling the flow and transport in the subsurface. Our goal is to teach you modeling skills. In particular, how to conceptualize and build models and then how to use those models to explore ideas, support decision making, and prioritize data collection. Our discussion of modeling will include conceptual model development, selection of boundary conditions, model calibration, validation and sensitivity analysis. Students will build their own models at every step of the course as we walk through a series of modeling projects of increasing complexity. Exercises will use the widely used USGS groundwater flow model, MODFLOW.

Expected Learning Outcomes

1. You will be able to construct transient and steady state groundwater flow models using MODFLOW.
2. You will be able to evaluate the performance of a groundwater flow model by identifying and evaluating relevant model outputs.
3. You will understand the primary parameters needed to build a groundwater model and understand how to evaluate parameter choices.
4. You will know the primary types of boundary conditions used in groundwater flow models and when and how to implement them in models.
5. You will understand how models can be used in decision making and some approaches to building models of complex systems with competing interests.

Makeup Policy for Students Who Register Late

Students may register late with the instructor's permission but will be expected to make up all assignments that they missed within one week of their registration.

Course Communications

- Course communications will take place using your official UA email address.
- I will attempt to reply to all email inquiries in a timely manner but please be advised that if your question will take more than 5 minutes to reply to I will request that you come meet with me in person either by coming to my office hours or scheduling an appointment. For modeling questions related to homework or projects, I prefer that you come to office hours or make an appointment. Model debugging is generally difficult to describe over email.
- Emails will generally be handed in normal business hours so do not expect to get a response if you send your question out late the night before an assignment is due.
- Lecture materials along with the schedule and assignments will all be posted through D2L.

Required Texts or Readings

There is no required textbook for this course. However, if you are looking for a textbook on the topic I recommend the following, both to help you with the material of the course and to have as a reference in the future. In addition to these texts additional reading materials will be posted and shared through the course website over the course of the semester.

1. **"Applied Groundwater Modeling: Simulation of Flow and Advective Transport" by Mary P. Anderson and William W. Woessner**. This is a classic modeling text that is often cited in the literature and is a great reference for model design. It also highlights the use of MODFLOW to simulate groundwater flow. The text is an excellent introduction because it does not focus on complex mathematical derivations, but rather conceptual model design and the modeling process, from data collection to model calibration. Because it is a "classic," though it is a bit outdated in its discussion of computing capabilities and some features of MODFLOW. Any limitations of the text will be addressed through supplementary readings and class discussion.
2. **"Applied Contaminant Transport Modeling", by Zheng and Bennett**. This is also a classic text, often cited in the literature, but with a greater emphasis placed on numerical methods. There are numerous references to MODFLOW specific problems. Also, this text provides greater background on the numerical methods and specifics regarding contaminant transport (versus purely fluid transport).

Assignments and Examinations:

This course will consist of roughly weekly homework assignments, a final project and a student led discussion.

1. **Individual groundwater modeling assignments**: Each individual modeling assignment will consist of a set of modeling tasks. The student will submit a PowerPoint file summarizing their results as well as the associated model files. All must be uploaded to a file sharing site, which will be discussed in class[1,2].
2. **Group groundwater modeling assignments:** Group modeling assignments are the same as the individual assignments, but students will be working in teams and will submit one assignment and receive one grade as group[1,2].
3. **Student lead discussion:** Each student will be required to participate in one student-led discussion. These discussions will be held during class. The purpose of the sessions is to use models to explore hydrologic concepts that relate to the module for that week. Students will work in groups of two or

three. As a group, they will develop topics for discussion. During class, they will operate a laptop connected to a projector to build/modify models in real time. Finally, they will produce a PPT file that reviews the key points of the discussion, illustrated with screenshots of model results.

4. **Final report and debate:** The final exam for this course will be in the form of a report. Teams of students will take competing points of view and then build ensembles of models to support their arguments. We will finish the class with a debate to make a decision about a groundwater resource.
5. **Additional requirements for 500 level students:** Students enrolled in 582 will also be required to lead a class discussion a groundwater modeling platform other than MODFLOW and will submit an additional case study individually as part of the final report.

[1]Graded homework assignments are due BEFORE class on the due date on the schedule. There are no exceptions! The assignments must be completed so that we can spend class time on focused discussion and exploration.

[2] You must fix each graded homework assignment model BEFORE class one week after it is due. If your model is correct, you will earn 1/2 of the points that you missed on your initial submission. The correct model for each graded homework assignment will be provided during the Tuesday class one week after it is due.

Final Project:

The final exam for this course will be in the form of a report. Teams of students will take competing points of view and then build ensembles of models to support their arguments. We will finish the class with a debate to make a decision about a groundwater resource

The final modeling project will be due and debated during the final exam period: Wednesday May 13th 1:00 – 3:00 PM

Refer to the following links for information on university final exam regulations: https://www.registrar.arizona.edu/courses/final-examination-regulations-and-information , and final exam schedule, http://www.registrar.arizona.edu/schedules/finals.htm

Grading Scale and Policies:

This course will be graded using the regular university grading system (http://catalog.arizona.edu/policy/grades-and-grading-system) with the A-E scale. G

Grades will be assigned as follows:

A >= 90%

B >= 80%

C >= 70%

D >= 60%

E < 60%

This weighting for the course assignments will be as follows. Both the individual and group model assignment categories will be based on multiple assignments each of which will be weighted equally. The grade weighting for 400 & 500 level students is the same but the 500 level students will have additional requirements for the discussion and final project categories as described above.

1. Individual modeling assignments: 25%
2. Group modeling assignments: 45%
3. Student lead discussion: 15 %

4. Final project: 15%

Incomplete (I) or Withdrawal (W):

Requests for incomplete (I) or withdrawal (W) must be made in accordance with University policies, which are available at http://catalog.arizona.edu/policy/grades-and-grading-system#incomplete and http://catalog.arizona.edu/policy/grades-and-grading-system#Withdrawal respectively.

Honors Credit

Students wishing to contract this course for Honors Credit should email me to set up an appointment to discuss the terms of the contract. Information on Honors Contracts can be found at https://www.honors.arizona.edu/honors-contracts.

Scheduled Topics/Activities

The schedule for the course is provided below. This schedule is subject to change and will be updated throughout the course.

Week	Date	Topics	Assignments
1	16-Jan	Introduction	
2	21-Jan	Getting started	
	23-Jan	Getting started	
3	28-Jan	NO CLASS	
	30-Jan	Intro to GW modeling	HW0 Due
4	4-Feb	Box model	
	6-Feb		HW 1 Due
5	11-Feb	Recharge model	
	13-Feb	NO CLASS	
6	18-Feb	Pumping well model	HW 2 Due
	20-Feb		
7	25-Feb	Recharge model	
	27-Feb		HW 3 Due
8	3-Mar	ET Model	
	5-Mar		HW 4 Due
9	10-Mar	Spring break, no class	
	12-Mar	Spring break, no class	
10	17-Mar	Transient model	
	19-Mar		HW5 Due
11	24-Mar	Layered Model	
	26-Mar		HW 6 Due
12	31-Mar	Stream Package	
	2-Apr		HW 7 due
13	7-Apr	Base Model	
	9-Apr		HW 8 due
14	14-Apr		
	16-Apr	Model Ensembles	
15	21-Apr		
	23-Apr	Advocacy models	
16	28-Apr		
	30-Apr	Alternate Designs	
17	5-May	Last day of class	
18	13-May	Final exam period	Final Projects due

Classroom Behavior Policy

To foster a positive learning environment, students and instructors have a shared responsibility. We want a safe, welcoming, and inclusive environment where all of us feel comfortable with each other and where we can challenge ourselves to succeed. To that end, our focus is on the tasks at hand and not on extraneous activities (e.g., texting, chatting, reading a newspaper, making phone calls, web surfing, etc.).

Additional Resources for Students

UA Academic policies and procedures are available at http://catalog.arizona.edu/policies

Student Assistance and Advocacy information is available at http://deanofstudents.arizona.edu/student-assistance/students/student-assistance

Confidentiality of Student Records

http://www.registrar.arizona.edu/personal-information/family-educational-rights-and-privacy-act-1974-ferpa?topic=ferpa

University-wide Policies links

Links to the following UA policies are provided here, https://academicaffairs.arizona.edu/syllabus-policies:

- Absence and Class Participation Policies
- Threatening Behavior Policy
- Accessibility and Accommodations Policy
- Code of Academic Integrity
- Nondiscrimination and Anti-Harassment Policy
- Subject to Change Statement