Earth and Planetary Scineces 220: Groundwater Modeling Fall 2014

Andy Fisher
831-459-5598
Office hours: Mon 3-5, or by appointment, afternoons preferred

E&MS A209
afisher@ucsc.edu
http://websites.pmc.ucsc.edu/~afisher/Courses/Eart220
Class notes and electronic reader are posted, login required

Course hours: M + W, 12:30-2:15 pm
Course location: E&MS D226
Laboratory hours: Tuesday 12:30-3:30 pm
Laboratory location: E&MS D226 and/or Kresge PC lab (Kresge 317)

Assignments: eight homework/modeling exercises (you may substitute a problem of your choice for the final modeling assignment, but please check with me first); one paper critique
Required reading:

(1) Required reading is available online at the class web site
Login and password are required to access the electronic class reader

Required text:

(2) A moderately comprehensive MATLAB book such as: Hanselman and Littlefield, 2012, Mastering MATLAB (buy this or a similar book, or find one from the library)
NB: I am also posting several MATLAB references at the website, and there are a lot of resources available at various MATLAB websites

Optional texts/readings:

(1) Gilat, 2011, MATLAB, An Introduction with Applications
Especially helpful for those who are new to programming, *see online class reader*.
(2) Wang and Anderson, 1981/1995, Introduction to Groundwater Modeling
Selected chapters from this classic text are in the electronic reader
(3) Anderson and Woessner, 1992, Applied Groundwater Modeling
Selected chapters from this classic text are in the electronic reader, also on two-hour reserve at the Science Library
(4) Physical hydrogeology text of your choice (Freeze and Cherry, 1977; or Domenico and Schwartz, 1998; or Fetter, 2001, etc.)
(5) Linear algebra book could be handy
Selected chapters from Hornback, 1975 are in the electronic reader

Course overview: The class comprises three parts: a rapid overview/review of groundwater mechanics, an introduction to finite-difference methods, and application of the USGS groundwater modeling program MODFLOW. There are other models that are more sophisticated than MODFLOW, but MODFLOW remains a useful standard, and it is a capable tool. The limitations of many modeling studies are not in the computer models, but rather how these models have been applied; this topic is intended to be the *true focus* of this course.

For programming exercises, we will use MATLAB, in addition to a spreadsheet and a few hand calculations. If you have no prior programming experience, it will be a good idea to purchase an introductory MATLAB text such as that by Gilat. Beginning programmers will need to do some extra work during the first few weeks of class to avoid falling behind when the first programming problem is assigned. Since MODFLOW is written in FORTRAN, it can help to understand a bit about this language, but if you know MATLAB (which has syntax a lot like C), you can figure out FORTRAN. The Kresge PC computer lab is available for our use during subsequent lab sessions. The PCs in this lab have Excel, MATLAB, and *Groundwater Vistas* (MODFLOW) installed. You can access this facility at many times outside of the regular lab time (check online lab schedule, ITS website).

We will read papers on groundwater modeling as part of the class. Please peruse *Groundwater*, *Water Resources Research*, *Journal of Hydrology*, *Hydrogeology Journal,* and other peer-reviewed journals that publish articles on groundwater modeling. Select one paper to critique by 11/12. ***Please check with me*** after making a preliminary selection, to make sure that the topic and level is appropriate, then send me a PDF of the paper to post at the class website so that the rest of the class can also read the paper before you present your critique. Prepare a **critical** evaluation of the paper. This is not just a summary of the paper, although that should be included. Your critique should focus on methodology, assumptions, utility, and implications of the published work. Your written critique should comprise no more than 5-6 pages of text. Please also be ready to present this critique to the class and discuss with your colleagues. **Paper critiques will be presented to the class and turned in on 12/8 and/or 12/10**.

Presentation, Assignment, and Reading List

Subject to revision as the quarter progresses.

Date	Presentation/Lab topic(s)	Readings/Problem sets
Week 1: 10/2-10/3	**Class**: No class during first (short) week, but **please see reading list and assignment.**	Oreskes et al., 1994 Konikow and Bredehoeft, 1992 Find and read hydrogeology text(s).
	Lab: Set up account at ITS if needed to access Kresge computers, verify login on UCSC lab PCs	Find and read programming text(s).
Week 2: 10/6-10/8 ***Andy away: Weds 10/08***	**Class**: Physical hydrogeology review: water and soil properties, Darcy's law, potential and head, types of aquifers aquifer properties, heads and gradients, effective properties for flow along and across layers, flow nets, conservation of mass	*PS#1: Linear algebra, spreadsheet programming*
	Lab: Linear algebra overview, program structure, syntax, documentation, and execution	Hornbeck, C1-3, 6 **location:** E&MS, D226
Week 3: 10/13-10/14 ***Andy away: Weds 10/15***	**Class**: Confined versus unconfined flow, analytical solutions, finite differences, one-dimensional flow at steady state	Wang and Anderson, C1-3 Anderson and Woessner, C1-2 *PS#2: Linear algebra with MATLAB, one-dimensional heterogeneity*
	Lab: Linear algebra, spreadsheet and MATLAB modeling, representing heterogeneity in one dimension	**location:** E&MS, D226 and/or Kresge PC (to be announced)
Week 4: 10/20-10/22	**Class**: One-dimensional transient flow, two-dimensional flow, boundary conditions, sources and sinks	Wang and Anderson, C4-5 Anderson and Woessner, C3-4 *PS#3: One-dimensional steady-state flow with MATLAB*
	Lab: One-dimensional, steady state flow with MATLAB	**location:** Kresge PC
Week 5: 10/27-10/29	**Class:** MODFLOW introduction: input/output structure, stresses, sources and sinks	McDonald and Harbough, 2003 USGS, 2011 Harbaugh, 2005, C1-5 *PS#4: One dimensional, transient, implicit and explicit, spreadsheet and MATLAB*
	Lab: One-dimensional transient flow: spreadsheet, MATLAB	**location:** Kresge PC
Week 6: 11/3-11/5	**Class:** MODFLOW stress packages; streams, lakes, reservoirs, wetlands; solvers, vector representations of flow	Harbaugh, 2005, C6 Cheng and Anderson, 1993 Fenske et al., 1997 Merritt and Konikow, 2000 (skim) Hunt et al., 2003; Hunt, 2003 Restrepo et al., 1998 Harbaugh, 2005, C7 (skim) McDonald, 1988, C12, C13 (skim) Hill, 1990 (skim) Osiensky and Williams, 1997 *PS#5: MODFLOW, pumping well, anisotropy*
	Lab: MODFLOW in two dimensions, transient response to pumping	**Rumbaugh and Rumbaugh, 2007** MODFLOW handouts **location:** Kresge PC

Week 7: 11/10-11/12	**Class:** More MODFLOW, model calibration, MODFLOW case studies: particle tracking, groundwater age, surface water - groundwater	Modica et al., 1997 Goode, 1996 Bethke and Johnson, 2002 Brunner, 2010
No lab this week	Veterans' Day Holiday	**Rumbaugh and Rumbaugh, 2007** **location:** Kresge PC
Week 8: 11/17-11/19	**Class:** MODFLOW case studies and discussion, comparison to IGSM, Farm Process	Squillace, 1996 LaBolle et al., 2003 Bredehoeft, 2002 Hanson, 2010 *PS#6: MODFLOW, two-dimensional transient, self similarity, river package*
	Lab: MODFLOW in two dimensions, SW – GW interactions	**location:** Kresge PC
Week 9: 11/24-11/26	**Class**: Coupled heat and fluid flow	Bredehoeft and Papadopulos, 1965 Fisher and Hounslow, 1990 Anderson, 2005 *PS#7: MODFLOW, stream-aquifer profile model*
	Lab: *Profile modeling with MODFLOW, replication*	**location:** Kresge PC
Week 10: 12/01-12/03	**Class:** Solute transport, complexities, simplicities	Zheng and Gorelick, 2003 Zinn and Harvey, 2003 Hsieh, 2010; Hsieh, 2011 *PS#8: MODFLOW, three dimensional, river, well, wetland*
	Lab: *MODFLOW*, three-dimensional, river, well, wetland	**location:** Kresge PC
Week 11: 12/8-12/10	**Class:** Present paper critiques and final projects, discussion	
	Lab: *Finish lab exercises…*	read papers, prepare critiques