GEGN 583
Mathematical Modeling of Ground Water Systems
Spring 2008
CLASSROOM: BH201
Instructor: Dr Eileen Poeter
Dept of Geology and Geological Engineering, Colorado School of Mines
Office: Room 121B Berthoud Hall
OFFICE HOURS: http://www.mines.edu/~epoeter/OfficeHours.htm
phone: 303 273 3829
fax: 303 384 2037
epoeter@mines.edu
http://www.mines.edu/~epoeter
this class: http://www.mines.edu/~epoeter/583

Goal: After students complete this course, they will be able to pick up a groundwater modeling software manual and set up a simulation of a groundwater system, calibrate the model and make predictions using the model. The individual will feel a bit uncertain about details of the process, but will know how to identify concerns and find information that will help them resolve their concerns.

Course format: Information specific to this class is on http://www.mines.edu/~epoeter/583CSM. Each student should review these materials individually during the week before each class to the level they feel is useful to them. Ground water modeling is presented, in stand-alone web format, as sequential units on a web page at: http://www.mines.edu/~epoeter/583. Note topic units do not correlate with semester weeks, so see syllabus below to plan your study.

Each student will choose a specific modeling project to work on throughout the semester. There is a tendency for student to want to have modeling knowledge presented to them as lectures. I find it is not effective and does not prepare them for modeling in a professional environment where teaching yourself is critical. Consequently, class sessions will include some short presentations but primarily impromptu lectures based on student questions about both the web material and problems with their projects, the emphasis is on active learning during which the students work on and communicate about the current topic using their own modeling project. Students are encouraged to work together. We will share our results and obstacles and find ways to get around those problems.

Assignments are designed to lead you through the modeling process phase by phase, thus 9 submissions rather than 1 or 2. On average, plan approximately 6 hours per week outside of class studying related material and conducting your modeling project (likely less at first and more when you are working on your computer model). If you can do the work in less time, that is good, you are grasping quickly the essence of what is required. Longer time generally is due to thinking the task is more difficult than it is. That is a good reason to visit with me. **Start each session by reviewing this document to recall: 1) what topic to study; 2) what is due next week; and 3) submission directions for each assignment. Meet all submission deadlines with the best product you can provide. KNOW THAT: You will be allowed to resubmit at the end of the semester to improve your grade based on my comments. If you want the grade reconsidered, you must submit the paper that I marked up, your original and your revised paper in a packet at the end of the semester.**

Tentative Schedule (subject to change to adjust to our pace, changes will be announced in class and updates posted to the class web page):

JAN	**10**	**Introduction and Boundary Conditions (Units 1 & 2)** **Analytical Modeling (Units 3, 4 & 5)**
	17	**Finite Difference Theory and Grid Design (Units 6 & 7) ASSGN#1**
	24	**MODFLOW (Unit 8) ASSGN#2/ASSGN#3**
	31	**MODFLOW (Unit 8) continued**
FEB	**7**	**MODFLOW (Unit 8) continued / Trouble Shooting (Unit 12)**
	14	**Calibration (Unit 9) ASSGN#4**
	21	**Calibration (Unit 9) continued**
	28	**Calibration (Unit 9) continued**
MAR	**6**	**Model Linearity, Prediction and Predictive uncertainty (Unit 9) continued**
	13	**Spring Break**
	20	**MODFLOW GUI's (Unit 10) / Transient Flow Modeling (Unit 11) ASSGN#5**
	27	**MODFLOW GUI's / Transient Flow Modeling (continued)**
APR	**3**	**WORK SESSION (Poeter will be at an NGWA conference and Board of Directors meeting. Graduate student advisors can help you trouble shoot)**
	10	**Review calibration procedures and analysis (Unit 13 & 14) ASSGN#6**
	17	**Review transient modeling ALL RESUBMISSIONS WELCOME**
	24	**Review prediction and prediction uncertainty ALL RESUBMISSIONS WELCOME**
MAY	**1**	**Catchup & Issue resolution for modeling projects ALL RESUBMISSIONS WELCOME**
Finals Week		**Presentation during exam block ALL RESUBMISSIONS WELCOME**

All submissions should be typed except presentation of hand calculations, which should be very neat and easy to follow because of comments connecting each equation or calculation explaining what is being done (e.g. the equation, what it represents in the physical world, the values of parameters and boundary conditions and where they were obtained).

All submissions should be organized and written for a person familiar with ground-water hydrology, but not familiar with your project or the assignment.

All assignments should be submitted electronically (CD or email) in a zip file named GE583_ASSGN#_YOURLASTNAME.ZIP,
accompanied by a hard copy of the report. You do not need to make hard copies of computer input and output, which can be voluminous, but these need to be provided by email or on disk. If your **diagrams** are hand-drawn, scan them and insert them in your report**. Disperse figures throughout your report and number them in the order that you mention them in the text, referring to them by number from your text discussion.**

Deliverables:

Assignment #1 Conceptual Model: Select a **SINGLE-PHASE, SATURATED, FLOW** modeling project with a transient aspect, and write a summary describing it to me. If you do not have a place to model, I can provide one for you. Your description should use illustrations and include:

- **Title**
- **Objective**
- **Problem Description**
- **Geohydrologic Setting**
  - **location**
  - **geometry**
  - **boundary conditions**
  - **parameter value ranges**
  - **stresses that will be applied to the system for which you would like to predict the resulting system conditions**
  - **special considerations**
- **Calibration Data that are available (heads, flows or concentration data from the site)**
- **A description of what you envision your final result will be**

Assignment #2 Analytical Model: Choose an analytical model to represent some aspect of your modeling project and implement it with your model conditions. Describe the problem set up and solution in a very concise but completely clear manner.

Assignment #3 Finite Differencing: Layout the finite difference grid over a map of the model area for your problem and, as appropriate, in a vertical cross-section. Discuss why you chose to grid the problem as shown. Label the initial properties and boundary conditions you will use. These will be adjusted later in the calibration process. **Create a simplified 2D steady finite difference spreadsheet model of your problem, explain what it does.**

Assignment # 4 Steady State Numerical Models: Create two steady state MODFLOW simulations of groundwater flow in your system. One of the simulations should represent the flow system before the stress and the other should simulate the steady state condition after the stress. Build on your work from assignments 1 through 3. Now pick up the MODFLOW manuals and the class web pages and create a name file, then begin to build each of the input files. When you have

them all, execute the model, look at the output or error messages and revise the file until you have models that "run". Be sure to save your files because you will want to use them later in the semester. **Compare your results to the result of your analytical modeling.** Be sure to save your files because you will want to use them later in the semester.

Suggested Modeling Report Outline

- **Title**
- **Abstract**
- **Introduction**
  - **objective**
  - **problem description**
- **Geohydrologic Setting**
- **Results of analytical and previous numerical modeling**
- **Numerical Model setup**
  - **geometry**
  - **boundary conditions**
  - **initial conditions**
  - **parameter value ranges**
  - **stresses**
  - **special considerations**
- **Uncalibrated model results**
  - **predictions**
  - **problems encountered**
- **Comparison with Analytical results**
- **Assessment of further work, if appropriate**
- **Summary/Conclusions**

submit the paper as hard copy and include it in your zip file of model input and output
submit the model files (input and output for both simulations) in a zip file labeled:
GE583_ASSGN4_YOURLASTNAME.ZIP

Assignment # 5 Steady State Model Calibration: Calibrate your model. If you want to conduct a transient calibration, talk with me first. Perform **calibration using UCODE. Be sure your report addresses all the items in the criteria list:**
http://www.mines.edu/~epoeter/583/09/discussion/calibration_criteria.htm
Consider more than one conceptual model and compare the results**. Remember to make a prediction with your calibrated models and evaluate confidence in your prediction.** Be sure to save your files because you will want to use them later in the semester.

Suggested Modeling Report Outline

- **Title**
- **Abstract**
- **Introduction**
  - **describe the system to be calibrated (use portions of your previous report as appropriate)**
- **Observations to be matched in calibration**
  - **type of observations**
  - **locations of observations**
  - **observed values**
  - **uncertainty associated with observations**
- **Calibration Procedure**

Evaluation of calibration
- **residuals**
- **parameter values**
- **quality of calibrated model**

Calibrated model results
- **predictions**
- **problems encountered**
- **uncertainty associated with predictions**

Comparison with uncalibrated model results
Assessment of further work, if appropriate
Summary/Conclusions

submit the paper as hard copy or include it in your zip file of model input and output
submit the model files (input and output for both simulations) in a zip file labeled:
GE583_ASSGN5_YOURLASTNAME.ZIP

Assignment # 6 Transient Modeling: Using starting heads from the calibrated steady state simulation without stress that you developed under model assignment #5, develop a transient model of the stressed scenario that you simulated in steady state under model assignment #4. Then, choose a complexity associated with changing boundary conditions in time (for example the variable recharge and pumping offset in time as we did in class) and add it to the model. Whatever complexity you choose, **be sure that it requires you to use more than one stress period. Finally, carry out the same complex transient exercise with a different underlying geology** (for example, add some heterogeneity to the system). Remember that when you add the heterogeneity you will need to rerun the steady state case without pumping to obtain the proper starting heads. Be sure to save your files because you will want to use them later in the semester.

submit the paper as hard copy or include it in your zip file of model input and output
submit the model files (input and output for all simulations) in a zip file labeled
GE583_ASSGN6_YOURLASTNAME.ZIP

Assignment # 7 Final Presentation, due Exam Week (no exam): At the end of the semester present your project, the comparison of results from analytical and numerical modeling, the obstacles you encountered in conducting the project, the means by which you surmounted them, and your recommendations for further work if there was more time. **The major objective of this presentation is to teach the class what you learned from your modeling project. Assume that you are talking to a group of people who do not know your project or the assignments.** Your grade will be based on my judgment of your success in achieving this objective.

Submit mark-ups & comments from any previous work that you have improved and for which you would like me to consider raising the original score.

Grading:	**Points of 80**
Assignment #1 Conceptual Model, due January 17	5
Assignment #2 Analytical Model, due January 24	10
Assignment #3 Finite Differencing, due January 24	10
Assignment # 4 Steady State Numerical Models, due February 14	15
Assignment # 5 Model Calibration, due March 20	20
Assignment # 6 Transient Modeling, due April 10	10
Assignment # 7 Final Presentation & Revisions, due 4PM May 9 (no exam)	10
Total	**80**

View assignments 1-7 as progressive process of learning modeling using one project. These submissions do not need to be major documents. Rather they should be clear and concise illustrating your work. The most important aspect of the submission is that it reveals your understanding.

Given the liberal policy on later grade improvement, the long lead time for submission, and the importance of pushing yourself to take each step or else you will be hopelessly behind, papers submitted on one day late are 25% off and two days late 50% and 100% thereafter.

So plan to have each submission ready a week before it is due, then any unforeseen problem or slip will not get in the way of submission