UNIVERSITY OF CALGARY
DEPARTMENT OF GEOSCIENCE
COURSE OUTLINE

1. Course: GEOLOGY 605 – GROUNDWATER FLOW AND TRANSPORT MODELLING

Lecture Section:	L01	M	08:00-10:50	SA 123	WINTER 2014
Lab(s):	B01	F	08:00-10:50	ES 924	
Instructor(s):	Dr. L. Bentley		ES 262	220-4512	lbentley@ucalgary.ca

Geoscience Department ES 118; (403) 220-5841; geoscience.ucalgary.ca

2. PREREQUISITE(S): Geology 401 or 601 or consent of the Department.

See section 3.5.C in the Faculty of Science section of the online Calendar (http://www.ucalgary.ca/pubs/calendar/current/sc-3-5.html)

3. **GRADING**: The University policy on grading and related matters is described in "Academic Regulations, sections F.1 and F.2" of the online University Calendar (**http://www.ucalgary.ca/pubs/calendar/current/f-1.html** and **http://www.ucalgary.ca/pubs/calendar/current/f-2.html**) In determining the overall grade in the course the following weights will be used:

Assignments (2)	25%	
Project	35%	
Final Examination	40%	(To be scheduled by the Registrar)

Each piece of work (assignment, laboratory report, midterm test or final examination) submitted by the student will be assigned a percentage score. The student's average percentage score for the various components listed above will be combined with the indicated weights to produce an overall percentage for the course, which will be used to determine the course letter grade.

4. **Missed Components of Term Work**. The regulations of the Faculty of Science pertaining to this matter are found in the Faculty of Science area of the Calendar in section 3.6: **http://www.ucalgary.ca/pubs/calendar/current/sc-3-6.html**. It is the student's responsibility to familiarize himself/herself with these regulations. See also **http://www.ucalgary.ca/pubs/calendar/current/e-3.html**.

5. Dates and times of class exercises held outside of class hours: None.

REGULARLY SCHEDULED CLASSES HAVE PRECEDENCE OVER ANY OUT-OF-CLASS-TIME-ACTIVITY. If you have a clash with this out-of-class-time-activity, please inform your instructor as soon as possible so that alternative arrangements may be made for you.

Department Approval: ORIGINAL SIGNED **Date: January 20 2014**

6. **EXAMINATION POLICY**: No electronic or written aids (eg. cell phones, tablets, computers, PDAs, notes, textbooks) will be allowed during writing of any exams. Non-programmable calculators will be permitted to answer quantitative questions on exams.

   Students should also read the Calendar, Section G, on Examinations: **http://www.ucalgary.ca/pubs/calendar/current/g.html**.

7. In this course, the quality of the student's writing in homework assignments and the term project will be a factor in the evaluation of those reports. See also **http://www.ucalgary.ca/pubs/calendar/current/e-2.html**.

8. OTHER IMPORTANT INFORMATION FOR STUDENTS:

(a) ACADEMIC MISCONDUCT (cheating, plagiarism, or any other form) is a very serious offence that will be dealt with rigorously in all cases. A single offence may lead to disciplinary probation or suspension or expulsion. The Faculty of Science follows a zero tolerance policy regarding dishonesty. Please read the sections of the University Calendar under K. Student Misconduct (**http://www.ucalgary.ca/pubs/calendar/current/k.html**) to inform yourself of definitions, processes and penalties

(b) ASSEMBLY POINTS in case of emergency during class time. Be sure to FAMILIARIZE YOURSELF with the information at http://www.ucalgary.ca/emergencyplan/assemblypoints.

(c) ACADEMIC ACCOMMODATION POLICY. Students with documentable disabilities are referred to the following links:
Calendar entry on students with disabilities: **http://www.ucalgary.ca/pubs/calendar/current/b-1.html**
Student Accessibility Services: www.ucalgary.ca/access

(d) SAFEWALK: Campus Security will escort individuals day or night **http://www.ucalgary.ca/security/safewalk/**). Call **220-5333** for assistance. Use any campus phone, emergency phone or the yellow phones located at most parking lot pay booths.

(e) FREEDOM OF INFORMATION AND PRIVACY: This course is conducted in accordance with the Freedom of Information and Protection of Privacy Act (FOIPP). As one consequence**, students should identify themselves on all written work by placing their name on the front page and their ID number on each subsequent page**. For more information see also **http://www.ucalgary.ca/secretariat/privacy.**

(f) STUDENT UNION INFORMATION: VP Academic **Phone**: 220-3911 **Email**: suvpaca@ucagary.ca.
SU Faculty Rep. **Phone:** 220-3913 **Email:** sciencerep@su.ucalgary.ca Website **http://www.su.ucalgary.ca/home/contact.html**.
Student Ombudsman: www.ucalgary.ca/provost/students/ombuds; ombuds@ucalgary.ca 220-6420

(g) INTERNET and ELECTRONIC COMMUNICATION DEVICE Information. You can assume that in all classes that you attend, **your cell phone should be turned off**. Also, communication with other individuals, via laptop computers, Blackberries or other devices connectable to the Internet is not allowed in class time unless specifically permitted by the instructor. If you violate this policy you may be asked to leave the classroom. Repeated abuse may result in a charge of misconduct.

UNIVERSITY OF CALGARY
DEPARTMENT OF GEOSCIENCE
COURSE OUTLINE

GEOLOGY 605
GROUNDWATER FLOW AND TRANSPORT MODELLING

TERM: Winter 2014

PREREQUISITE(S): Geology 401 or 601 or consent of the Department.

LECTURER(S): Dr. L. Bentley ES 262 220-4512 lbentley@ucalgary.ca

LECTURE :	L01	M	08 :00-10 :50	ENA 233
LAB(S):	B01	F	08:00-10:50	ES 924

TEXT: *Applied Groundwater Modeling* by Anderson and Woessner. The textbook was chosen because it is one of the few books that treat the practical aspects of computer modeling. There is much discussion on the use of MODFLOW in the book which should be useful. MODFLOW is perhaps the most widely used groundwater flow model in the consulting industry, and the book will be a good reference for anyone continuing on in computer modeling.

Unfortunately, the book does not cover transport modeling in any depth. *Applied Contaminant Transport Modeling* by Zheng and Bennett is on reserve in the library and will be used as the primary reading material for contaminant transport modeling.

We will use MODFLOW for groundwater flow modeling and MT3D for the modeling of transport. However, if you wish to use another computer code with similar capabilities, talk with the instructor.

RESERVE READING ROOM: . *Applied Contaminant Transport Modeling* by Zheng and Bennett

MARK DISTRIBUTION: A. Composition of Final Grade

Grading System

Assignment 1	12.5%	
Assignment 2	12.5%	
Project	35 %	
Final Examination	40 %	(To be scheduled by Registrar)

B. Final Exam

There will be a final examination scheduled by the Registrar's Office.

C. Components of Course for Which a Passing Grade is Essential: NONE

D. Grading Scheme

Grading System

Percentage	Grade
95	A+
85	A
82	A-
78	B+
75	B
72	B-
68	C+
65	C
60	C-
55	D+
50	D
<50	F

COURSE CONTENT, OBJECTIVES AND ORGANIZATION:

The objective of the course is to have students learn the basic concepts needed to model saturated groundwater flow systems and the transport of dissolved chemical species within those systems. It is also designed to give students hands on experience in the use of a groundwater flow and transport simulator. During the course, the essential theoretical background material will be introduced and practical aspects of groundwater flow and transport modeling will be discussed.

Elements of the course include:

1. Review the partial differential equations and boundary conditions that are used to describe the flow of groundwater and the transport of dissolved species.
2. Summarize some essential elements of numerical techniques for solving partial differential equations.
3. Introduce the concepts of finite difference and finite element modeling.
4. Homework exercises using Visual MODFLOW.
5. Class presentations of assigned papers.

COURSE STRUCTURE

There will be one 150 minute hour lecture/seminar and a three hour computer each week. Lectures will concentrate on the theoretical aspects of the course. Modeling exercises will give students hands-on experience in modeling with groundwater flow and transport codes.

LECTURE OUTLINE

1. Introduce the modeling process
2. Review the saturated flow equation and transport equations
3. Finite Difference Modeling
4. Setting Model Parameters
5. Explicit vs Implicit
6. Stability, consistency and convergence
7. Solvers
8. Introducing the finite element method
9. Numerical difficulties associated with the transport equation
10. Upwinding
11. Eulerian-Lagrangian methods
12. Other Transport solution techniques

READING

From Anderson and Woessner:

Chapter 1 Introduction
Chapter 2 Equations and Numerical Methods (skip spreadsheet modeling)
Chapter 3 Conceptual Model and Grid Design (skip AQUEFEM, PLASM descriptions)
Chapter 4 Boundaries (skip PLASM, AQUIFEM descriptions)
Chapter 5. Sources and Sinks
Chapter 6. Profile Models
(Get the major concepts, don't worry about the detail).
Chapter 7. Special Needs for Transient Solutions
Chapter 8. Model Execution and Calibration
Chapter 9 Documenting and Reporting
Chapter 10 Post Audits
Chapter 11 Partical Tracking
Chapter 12 Advanced Topics

From *Applied Contaminant Transport Modeling* by Zheng and Bennett (on reserve Gallagher Library).

Chapters 1-3

Journal articles as assigned during the semester.