

**Carleton University**  
**DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING**  
**DRAFT COURSE OUTLINE**  
**Fall 2021**

**ENVE 4006/5301 Contaminant Hydrogeology**

**Hours per week**  
**Lect./Lab/P.A.**  
**3    0    1.5**

***Learning Outcomes***

Contaminant hydrogeology focuses on groundwater flow and contaminant fate and transport with the goal to assess and remediate subsurface soils and groundwater.

By the end of this course, successful students will have achieved the following learning outcomes:

- Understand the basic concepts of groundwater flow and contaminant fate and transport
- Understand the importance of a conceptual model for a contaminated site or groundwater resource
- Evaluate the advective velocity of contaminants in the subsurface
- Evaluate the concentrations of contaminants in the subsurface under different fate and transport processes such as diffusion, dispersion, adsorption, decay, microbial degradation, etc.
- Understand the flow and transport processes in the unsaturated zone; estimate travel times in the unsaturated zone
- Understand the basics of numerical modelling including the need for boundary conditions and initial conditions, and limitations of numerical modelling
- Understand the flow and transport processes in a multiphase system in which a non-aqueous phase liquid like gasoline or a solvent is released in the subsurface
- Learn how to assess the geology, hydrogeology and chemical components of a conceptual model of a contaminated site
- Understand the components of a Phase I and Phase II environmental site assessment under Ontario's Brownfields legislation
- Develop (design) a conceptual and numerical model of a contaminated site using Visual MODFLOW
- Learn the basics concepts, processes and goals of different remediation technologies used to clean up contaminated sites

After successfully completing this course, students will have the technical knowledge and skills desired by consulting engineering firms offering services in the geoenvironmental field.

**Graduate Attributes (GAs):** Engineering programs are accredited by the Canadian Engineering Accreditation Board (CEAB). As part of this process, we collect GA data to assess how effectively we are teaching or conveying the GAs with a goal to continually improve our programs. The GA data are aggregate data for a course and are NOT linked to student names or student numbers. The GAs assessed in this course include the following:

- GA 1.11.C Discipline-specific concept; Water Resources/Contaminant Hydrology
- GA 2.1 Problem Analysis; Problem definition
- GA 2.2 Problem Analysis; Approach to the problem
- GA 2.3 Problem Analysis; Use of assumptions
- GA 2.4 Problem Analysis; Interpreting the solution – validity of results
- GA 5.1 Engineering Tools; Diagrams and engineering sketches
- GA 5.3 Engineering Tools; Tools for design, experimentation, simulation, visualization and analysis
- GA 5.5 Engineering Tools; Limitations of such tools and the assumptions inherent in their use

For information on GAs and continual curriculum improvement, visit the Accreditation section of Engineers Canada website: <https://engineerscanada.ca/>

**Topics covered:**

- 1 **Introduction**, overview of hydrologic investigations; review of darcy's law, permeability, hydraulic conductivity; REV, steady state and transient flow equations.
- 2 **Conceptual Model**, components of a conceptual model; geology, hydrogeology, chemistry, data requirements, development
- 3 **Ground Water Flow**, equations for flow in confined and unconfined aquifers, well hydraulics, Theis, Cooper-Jacob, Dupuit, Slug Test; flow nets
- 4 **Contaminant Transport**, advection and dispersion, governing equations, particle tracking, transport mechanisms (sorption, degradation, decay)
- 6 **Unsaturated Zone**, water content, soil moisture, capillary forces, infiltration, governing equations in the unsaturated zone, Richard's equation
- 7 **Numerical Modelling**, finite difference methods, finite element methods, boundary conditions, matrix equations, solution techniques
- 8 **Multi-phase Flow**, non-aqueous phase liquids, water-NAPL-air, wettability, capillary pressure-saturation relationships, hysteresis, relative permeability, residual saturation, fluid entrapment
- 9 **Hydrogeologic Site Investigations**, conceptual model, site characterization, geology, hydrology, chemistry, plume delineation, Phase 1 and Phase 2 site assessments
- 10 **Groundwater Remediation and Design**, remedial alternatives, hydraulic controls, pump and treat, soil vapour extraction, confinement and encapsulation, in-situ degradation, in-situ technologies to enhance recovery

## Reference Texts

*Ground Water Contamination, Transport and Remediation*, Philip B. Bedient, Hanadi S. Rifai and Charles J. Newell, Prentice Hall, 1999 (revised 1994 version)

*Applied Hydrogeology*, fourth edition, C.W. Fetter, Prentice Hall, 2001. (third edition, 1994)

*Contaminant Hydrogeology*, second edition, C.W. Fetter, Prentice Hall, 1999.

*Physical and Chemical Hydrogeology*, Patrick A. Domenico and Franklin W. Schwartz, John Wiley & Sons, 1990.

## Lecture Notes

Lecture notes will be provided through the cuLearn course site.

## Marking Scheme

Assignments	20 %
Midterm	30 %
Final	50 %

Students must earn a passing grade on the final to receive a passing grade in the course.

Use of e-Proctoring system: This course has timed written assessments, which include midterm and final examinations. The Carleton University e-Proctoring system may be used in your assessments, and requires the use of webcams, microphones, and smart phones

Graduate students in ENVE 5301 will also be required to submit a project; details will be provided at a later date. Project will be due the last day of classes. The project will be worth 20% of their mark. The assignments will count for 20%, the midterm will count for 20%, and the final will count for 40%.

**Instructor:** Dr. Paul Van Geel 6210 CB ext. 1884  
([paul.vangeel@carleton.ca](mailto:paul.vangeel@carleton.ca))

**Teaching Assistant:** Wameed Alghazala  
([WameedAlghazala@cmail.carleton.ca](mailto:WameedAlghazala@cmail.carleton.ca) )

<b>Lectures:</b>	Monday 4:05-5:25pm	On-line
	Wednesday 4:05-5:25pm	On-line
<b>Problem Analysis:</b>	Thursday 11:35-12:55pm	On-line

**Please note:**

***Final exam papers will not be returned to students.***

**Academic Accommodation**

You may need special arrangements to meet your academic obligations during the term. Visit <https://students.carleton.ca/course-outline/#accommodation-for-student-activities> for information. For an accommodation request the processes are as follows:

**Pregnancy obligation:** Please contact your instructor with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details, visit the above website.

**Religious obligation:** Please contact your instructor with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details, visit the above website.

**Academic Accommodations for Students with Disabilities:** The Paul Menton Centre for Students with Disabilities (PMC) provides services to students with Learning Disabilities (LD), psychiatric/mental health disabilities, Attention Deficit Hyperactivity Disorder (ADHD), Autism Spectrum Disorders (ASD), chronic medical conditions, and impairments in mobility, hearing, and vision. If you have a disability requiring academic accommodations in this course, please contact PMC at 613-520-6608 or [pmc@carleton.ca](mailto:pmc@carleton.ca) for a formal evaluation. If you are already registered with the PMC, contact your PMC coordinator to send me your ***Letter of Accommodation*** at the beginning of the term, and no later than two weeks before the first in-class scheduled test or exam requiring accommodation (*if applicable*). **Requests made within two weeks will be reviewed on a case-by-case basis.** After requesting accommodation from PMC, meet with me to ensure accommodation arrangements are made. Please consult the PMC website ([www.carleton.ca/pmc](http://www.carleton.ca/pmc)) for the deadline to request accommodations for the formally-scheduled exam (*if applicable*).

**Survivors of Sexual Violence:** As a community, Carleton University is committed to maintaining a positive learning, working and living environment where sexual violence will not be tolerated, and where survivors are supported through academic accommodations as per Carleton's Sexual Violence Policy. For more information about the services available at the university and to obtain information about sexual violence and/or support, visit: [carleton.ca/sexual-violence-support](http://carleton.ca/sexual-violence-support)

**Accommodation for Student Activities:** Carleton University recognizes the substantial benefits, both to the individual student and for the university, that result from a student participating in activities beyond the classroom experience. Reasonable accommodation must be provided to students who compete or perform at the national or international level. Please contact your instructor with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for

accommodation is known to exist. For more details, see the policy (<https://carleton.ca/senate/wp-content/uploads/Accommodation-for-Student-Activities-1.pdf> )