UMBC
Department of Chemical, Biochemical, and Environmental Engineering
ENEN 621 Groundwater Hydrology

Fall 2024
Course Syllabus

Instructor
Claire Welty, Ph.D., Professor of Environmental Engineering
E-mail: weltyc@umbc.edu
Web site: https://urbanhydrology.umbc.edu/
Phone: 410-750-0149
Office Hours: By appointment (set up appointment by email)

Class Meeting Time and Place: M W 4:00 – 5:15 PM; TRC 122

Required Text
Freeze and Cherry, *Groundwater,* Prentice Hall, 1979.
Note: This book is available for download for free from online sources.

Reference Text
Kruseman, and deRidder. Analysis and Evaluation of Pumping Test Data, 2nd Edition, International Institute for Land Reclamation and Improvement, 1990. Readings from this source will be posted on BB.

Class Notes for each lecture will be posted. You are to take notes on these either physically (print them out, punch holes in them, and put them in a 3-ring binder) or electronically. This practice is to begin on Day 1 of the course.

Grading 10% quizzes, 30% problem sets, 30% midterm, 30% final

Grading scale:

90% – 100%	A
80% – 89%	B
70% – 79%	C
60% – 69%	D
< 60%	F

Grades may be adjusted up at the end of the semester depending on course outcomes but will not be adjusted down.

Problem Sets
Due at the beginning of the class meeting time per deadlines; no late homework accepted. Do not submit homework by email. Work is to be your own. Copied work will be assigned a grade of zero.

Problem sets must be done on 8-1/2 x11" engineering paper. Work must be tidy. Points will be taken off for sloppy work. Unacceptable: Scanned sheets torn out of a spiral binder or legal pad paper. Engineering paper grids can be printed on the reverse side of recycled office paper.
All work must be shown. No partial credit will be given for wrong answers if calculations are not shown. Rules regarding significant digits are to be followed. Points will be taken off of homework and exams if rules are not followed. (See posting on Blackboard).

See more detailed set of instructions posted on Blackboard.

See sample solved problem posted in BlackBoard for level of detail expected.

Quizes on lecture material will be given once per week at the beginning of class.

Exams Midterm: ~7th week; Final exam: 15th week. Closed book exams; formula sheets provided by instructor.

UMBC Statement of Values for Academic Integrity
Academic integrity is an important value at UMBC. By enrolling in this course, each student assumes the responsibilities of an active participant in UMBC's scholarly community in which everyone's academic work and behavior are held to the highest standards of honesty. Cheating, fabrication, plagiarism, and helping others to commit these acts are all forms of academic dishonesty, and they are wrong. Academic misconduct could result in disciplinary action that may include, but is not limited to, suspension or dismissal.

Objectives of Course The learning objectives for this course are: (1) to understand the use and occurrence of groundwater in the U.S.; (2) to be able to quantify flow of groundwater in aquifers and in unsaturated soils; (3) to be able to design and evaluate laboratory tests to determine porous media parameters (permeability, hydraulic conductivity, total porosity, effective porosity); and (4) to be able to design and evaluate field tests to determine aquifer parameters (permeability, hydraulic conductivity, total porosity, effective porosity, specific yield, storage coefficient); (5) to be able to utilize stochastic approaches to modeling subsurface heterogeneity; (6) to understand the physical basis, and its relationship to mathematical modeling, of contaminant transport in aquifers; (7) to learn how to use analytical mathematical solutions to the advection-dispersion equation to model aquifer contamination under various simplified 1D, 2D, and 3D scenarios; (8) to understand how to calculate from the literature and/or conduct appropriate tests to determine input parameters needed for laboratory and field-scale contaminant transport models**.**

Course Synopsis

I. Introduction (F&C: Chapters 1, 2, 4)
Hydrologic cycle; occurrence and use of groundwater in the U.S.; NJ, PA, MD, VA and DE examples; subsurface moisture zones; concept of piezometric head; aquifer types; specific yield, total porosity, effective porosity

II. Flow Dynamics (F&C: Chapters 2, 5, 6)
Darcy's law for saturated flow; hydraulic conductivity and permeability; limitations of Darcy's law and nonlinear flow effects; heterogeneity and anisotropy of hydraulic conductivity; spatial variability and variogram analysis; Darcy's law for 3D flow systems; conceptualization of unsaturated flow; flow in fractured media; mass balance in 3D porous media; field equations for groundwater flow; piezometric or phreatic surface maps; construction and use of flownets; regional groundwater flow systems; vertical flow effects; regional circulation; storage coefficient, transmissivity, and specific storativity

III. Groundwater Hydraulics (F&C: Chapter 8; Kruseman and deRidder selected chapters)
Steady and unsteady radial flow to fully-screened wells with constant discharge in homogeneous, isotropic, confined, infinite domain aquifers; effects of nonidealities on radial flow: non-constant Q; heterogeneity and anisotropy; constant head and impermeable boundaries; phreatic aquifers; leaky aquifers; partially penetrating and/or partially screened wells. Design and analysis of pumping tests for determining aquifer hydraulic properties; slug tests; well losses; specific capacity; superposition of radial flow on natural flow fields; calculation of capture zones and stagnation points.

IV. Contaminant Transport (F&C: Chapter 9 and journal articles)
Mass balance for transport of an ideal tracer; advection, dispersion, and diffusion; non-ideal processes as sources and sinks. 1D, 2D and 3D solute transport; pulse and step inputs; solutions to the advection dispersion equation. Applications to lab data; use of CXTFIT. Field-scale considerations; scale-dependent dispersivity; uniform and nonuniform flow tracer tests. Natural

gradient tests with application to the USGS Cape Cod site; radial and doublet tracer tests with applications. Considerations for reactive tracer transport

Detailed Course Outline

I. Introduction/Occurrence and Use of Groundwater

A. Hydrologic Cycle
B. Motivation for Studying
C. Distribution of Groundwater
D. Subsurface Moisture Zones
E. Concept of Hydraulic Head
F. Aquifer Types

II. Flow Dynamics

A. Darcy's Law
B. Hydraulic Conductivity and Permeability
C. Limitations of Darcy's Law
D. Heterogeneity and Anisotropy of Hydraulic Conductivity
    1. Definitions
    2. Evidence for heterogeneity
    3. Geostatistical quantification of spatial variability
    4. Relationship between layered heterogeneity and anisotropy
E. Generalization of Darcy's Law to 3-D
    1. Isotropic case
    2. Anisotropic case
    3. Concept of hydraulic conductivity ellipse
F. Mass balance in porous media
G. Development of 3D field equations
    1. 3D general form
    2. Some example simplifications
H. 2D application: flownets
    1. Purpose
    2. General terminology/"rules"
    3. Determining total flows
    4. Estimating transmissivity along a streamtube
    5. Determining travel times
    6. Heterogeneous systems and the tangent law
    7. Anisotropic systems
    8. Use of the inverse hydraulic conductivity ellipse to determine the direction of flow
I. Regional groundwater flow systems
    1. Recharge, discharge, groundwater divides
    2. Effect of topography on groundwater flow systems
    3. Effect of geology on groundwater flow systems
J. Applications of 2D and 3D aquifer equations
    1. 2D confined
    2. 2D unconfined
    3. 3D aquifer equation and aquifer compressibility
K. Concepts in unsaturated flow
    1. Tension head
    2. Relationship among ψ, h, and θ
    3. Nonlinear flow behavior
    4. Field equations for unsaturated flow
L. Darcy’s Law and Field equations for Variable-Density Fluids
M. Flow in Fractured Media

III. Groundwater Hydraulics

A. Radial Flow to a Well in a Confined Aquifer -- Constant Q
    1. Steady Flow
    2. Unsteady Flow
    3. Applications
B. Radial Flow to a Well in a Confined Aquifer -- Nonconstant Q
C. Boundary Effects
D. Leaky Aquifers
E. Phreatic Aquifers
F. Other effects to consider in well hydraulics
G. Piezometer Tests
H. Superposition of a pumping well on a uniform flow field
I. Ghyben-Herzberg relation
J. Barometric efficiency and tidal efficiency

IV. Contaminant Transport

A. Classical equation for transport of an ideal tracer
B. Transport processes
    1. Advection
    2. Dispersion and diffusion
    3. Nonideal processes
C. 1D solute transport (lab scale; limited field scale)
    1. Governing eqn.
    2. Continuous or step input
    3. Pulse input
D. 2D, 3D Solute transport
E. Field-scale considerations
    1. Heterogeneity and scale-dependent dispersion
    2. Uniform vs non uniform flow

UMBC Policies on Equity and Inclusion

Accessibility and Disability Accommodations, Guidance and Resources
Accommodations for students with disabilities are provided for all students with a qualified disability under the Americans with Disabilities Act (ADA & ADAAA) and Section 504 of the Rehabilitation Act who request and are eligible for accommodations. The Office of Student Disability Services (SDS) is the UMBC department designated to coordinate accommodations that creates equal access for students when barriers to participation exist in University courses, programs, or activities.
If you have a documented disability and need to request academic accommodations in your courses, please refer to the SDS website at sds.umbc.edu for registration information and office procedures.
SDS email: disAbility@umbc.edu
SDS phone: 410-455-2459
If you will be using SDS approved accommodations in this class, please contact the instructor to discuss implementation of the accommodations. During remote instruction requirements due to COVID, communication and flexibility will be essential for success.

Sexual Assault, Sexual Harassment, and Gender Based Violence and Discrimination

UMBC Policy in addition to federal and state law (to include Title IX) prohibits discrimination and harassment on the basis of sex, sexual orientation, and gender identity in University programs and activities. Any student who is impacted by sexual harassment, sexual assault, domestic violence, dating violence, stalking, sexual exploitation, gender discrimination, pregnancy discrimination, gender-based harassment, or related retaliation should contact the University's Title IX Coordinator to make a report and/or access support and resources. The Title IX Coordinator can be reached at titleixcoordinator@umbc.edu or 410-455-1717.
You can access support and resources even if you do not want to take any further action. You will not be forced to file a formal complaint or police report. Please be aware that the University may take action on its own if essential to protect the safety of the community.
If you are interested in making a report, please use the Online Reporting/Referral Form. Please note that, if you report anonymously, the University's ability to respond will be limited.

Notice that Faculty and Teaching Assistants are Responsible Employees with Mandatory Reporting Obligations
All faculty members and teaching assistants are considered Responsible Employees, per UMBC's Policy on Sexual Misconduct, Sexual Harassment, and Gender Discrimination. Faculty and teaching assistants therefore required to report all known information regarding alleged conduct that may be a violation of the Policy to the Title IX Coordinator, even if a student discloses an experience that occurred before attending UMBC and/or an incident that only involves people not affiliated with UMBC. Reports are required regardless of the amount of detail provided and even in instances where support has already been offered or received.
While faculty members want to encourage you to share information related to your life experiences through discussion and written work, students should understand that faculty are required to report past and present sexual harassment, sexual assault, domestic and dating violence, stalking, and gender discrimination that is shared with them to the Title IX Coordinator so that the University can inform students of their rights, resources, and support. While you are encouraged to do so, you are not obligated to respond to outreach conducted as a result of a report to the Title IX Coordinator.
If you need to speak with someone in confidence, who does not have an obligation to report to the Title IX Coordinator, UMBC has a number of Confidential Resources available to support you:
Retriever Integrated Health (Main Campus): 410-455-2472; Monday – Friday 8:30 a.m. – 5 p.m.; For After-Hours Support, Call 988.
Center for Counseling and Well-Being (Shady Grove Campus): 301-738-6273; Monday-Thursday 10:00a.m. – 7:00 p.m. and Friday 10:00 a.m. – 2:00 p.m. (virtual) Online Appointment Request

Form
Pastoral Counseling via The Gathering Space for Spiritual Well-Being: 410-455-6795; i3b@umbc.edu; Monday – Friday 8:00 a.m. – 10:00 p.m.

Other Resources

Women's Center (open to students of all genders): 410-455-2714; womenscenter@umbc.edu; Monday – Thursday 9:30 a.m. – 5:00 p.m. and Friday 10:00 a.m. – 4 p.m.
Shady Grove Student Resources, Maryland Resources, National Resources.

Child Abuse and Neglect

Please note that Maryland law and UMBC policy require that faculty report all disclosures or suspicions of child abuse or neglect to the Department of Social Services and/or the police even if the person who experienced the abuse or neglect is now over 18.