Office Hours: 10-11 am M W F, or by arrangement


Learning Objectives

My objectives for this course are to help you understand (1) how the properties of fluids, porous media and energy influence saturated and unsaturated groundwater flow; (2) the physical and mathematical relationships that integrate these concepts; (3) mathematical modeling approaches for resolving groundwater related problems; and (4) the importance of groundwater in a variety of geologic processes. Please see the learning outcomes on the last page.

Assessment

Problem Sets

An effective way to learn the material in this course is to do problems. Problem sets will be given out each week or so and will be due the following week at the beginning of class. You will be required to use Mathcad to compose your problem-set solutions. Problem sets will be deducted 10% for each day it is late. Problem sets will not be accepted after corrected works are returned.

Note: Graduate students will be responsible for an independent research project that will be worth 10% of the Geol573 grade.

Exams

One midterm exam and a comprehensive final exam will be given. My exams are typically short answer essay with an emphasis on process description. I want you to be able to tell me in words, what controls groundwater processes. I also integrate problems into exams that require equation manipulation and calculations. You will be required to take all exams. Make-up exams will be given only in the case of official emergencies. An excused absence form from the office of Student Affairs is required.

Grading

The grading break down will be as follows:

Problem Sets …..35% (25% for graduate students and 10% for the term project)
Exam 1…………30%
Final Exam……..35% (Tuesday March 19, 8:00 – 10:00 am)

A grading scale will be as follows (a curve is possible but not certain):
100-93 = A, 92-90 = A-, 89-88 = B+, 87-83 = B, 82-80 = B-, 79-78 = C+, 77-73 = C, 72-70 = C-, 69-68 = D+, 67-63 = D, 62-60 = D-, 60 or below = F

Reading Resources

In addition to Fetter, other classic hydrogeology books and resources include:


Other USGS Training Resources
**Academic honesty** is an important part of every course at WWU. For students, academic integrity means challenging yourself, striving for excellence, taking risks and learning from your mistakes, doing your own work, and giving credit whenever you use the work of others. It boils down to caring about your schoolwork and always being honest in carrying it out. However, academic integrity and honesty can be challenging due to such things as ignorance, confusion, stress, bad advice, and bad choices. To help you keep your integrity and good reputation intact, review WWU’s Integrity Website [http://www.wwu.edu/integrity/](http://www.wwu.edu/integrity/) provides all the information you need, including why integrity is important, how to promote it, as well as types of academic dishonesty and how to avoid them, particularly plagiarism. It also includes WWU’s policy and procedures on academic honesty (Appendix D of the WWU Catalog). See me if you have any concerns or questions about academic integrity regarding yourself or your classmates.

If you have a documented disability you must report to me during the first week of class to discuss your needs. If you need disability-related accommodations, please notify the Disability Access Center (DAC): telephone: 650–3083; email: drs@wwu.edu; [http://disability.wwu.edu](http://disability.wwu.edu)

**Attendance** is not required but it is expected. It is your responsibility to get notes for the classes you miss. I encourage you to visit my office for help and clarification, but do not use my office hours to obtain lecture material that you miss (unless you have an excused absence). Please feel free to talk to me anytime about your performance in the course or possible ways you can improve.

Your **professional conduct** in this course is important. I facilitate my courses in a professional manner and have the same expectations of you. By professional, I mean having a respectful demeanor, arriving to class on time, no texting or internet surfing during class, communicating with courteous emails, producing neat organized and well written student works, and by all means, maintaining academic honesty. Think about how you would like me to communicate your professionalism to a potential employer.

I am committed to establishing and maintaining a classroom climate that is inclusive and respectful for all students and an environment free of discrimination and harassment. Learning includes being able to voice a variety of perspectives, and classroom discussion is encouraged. While students’ expressed ideas may vary and/or be opposed to one another, it is important for all of us to listen and engage respectively with each other. Federal and State laws, as well as [WWU University policies](https://wwu.edu/), protect students, faculty and staff against discrimination.

**Student Services**

- In the case of a medical concern or question, please contact the Health Center: 650-3400 or [https://studenthealth.wwu.edu/](https://studenthealth.wwu.edu/)
- In the case of an emotional or psychological concern or question, please contact the Counseling Center: 650-3400 or [https://counseling.wwu.edu/](https://counseling.wwu.edu/)
- In the case of a health and safety concern, please contact the University Police: 650-3555 or [http://www.wwu.edu/ps/](http://www.wwu.edu/ps/)
- In the case of a family or personal crisis or emergency, please contact the Dean of Students: 650-3775 or [https://wp.wwu.edu/students/](https://wp.wwu.edu/students/)
- To seek confidential support related to sexual violence, please contact CASAS (650-3700), the Student Health Center, and/or the Counseling Center. To report sexual violence, please contact University Police, and/or the **Title IX Coordinator** in Western’s Equal Opportunity Office (650-3307).
Hydrogeology Topics

Introduction (Chapter 1 and pp. 95-98)
1. Ground water—what is it, where is it, and why is it important?

Fluid Mechanics (Read Handout)
4. Fluid properties - the importance of the hydrogen bond and properties such as density, compressibility and thermal expansion
5. Fluid statics – pressure, pressure head, buoyancy (effective stress), abnormal fluid pressures in sedimentary basins and accretionary prisms.
6. Fluid dynamics – steady state vs transient, 1-, 2-, 3-D flow, laminar, turbulent, compressible vs incompressible, Reynolds #, dynamic viscosity, and energy.

Properties of Porous Media (Chapter 3)
7. Properties of Porous media – in general, knowledge of three earth-material quantities are required to understand ground-water flow (porosity, intrinsic permeability, aquifer compressibility).
8. Porosity – quantitative and qualitative description, range of magnitudes and what controls the magnitude (mainly grain-size distribution and consolidation/compaction), primary vs secondary, effective porosity, and how is it determined? Porosity’s relationship to other quantities such as specific yield and water content. Demonstration.
9. Intrinsic Permeability - quantitative and qualitative description, range of magnitudes and what controls the magnitude (mainly grain-size and consolidation/compaction). How is it quantified—empirical relations using sediment characteristics and backing-it-out from hydraulic conductivity values.
10. Hydraulic Conductivity – combination of material properties (intrinsic permeability) and fluid properties (density and dynamic viscosity). Quantitative and qualitative description, range of magnitudes and what controls the magnitude (intrinsic permeability).
11. Heterogeneity – Discuss the inherent heterogeneous nature of most geologic deposits—quantifying aquifer properties for such deposits is the most challenging aspect of assessing ground-water flow in a region. Heterogeneity is “scale” dependent. Effective hydraulic conductivity (parallel and perpendicular to flow).

Energy, Head, Gradients and Darcy’s Law (Chapter 4)
12. Hydraulic Head – total hydraulic head = elevation head + pressure head. Explain all three in terms of energy. Measurement of each. Make use of a DEMONSTRATION. Emphasize that hydraulic conductivity is a measure of “energy loss” due to friction loss as fluid encounters grain surfaces.
13. Hydraulic Gradient – 1-D (horizontal and vertical) and 2-D using the classic three point problem. Introduce a “regression” technique for estimating a 2-D gradient using many wells.
15. Special Topic – effective stress and the seepage force (quick sand and liquefaction). Seepage Force results from a hydraulic gradient (and buoyancy) across the length of a grain. Quick sand Demonstration.
Unsaturated Flow and Recharge (Chapter 6)
16. Unsaturated Zone – soil water and capillarity
17. Soil-water saturation and pressure head
18. Unsaturated hydraulic conductivity and water flow in the unsaturated zone
19. Recharge – rainfall, runoff, soil storage, evapotranspiration, and recharge

MIDTERM EXAM

Ground-Water Flow Equations (Chapter 4)
20. Steady-state ground-Water Flow Equations – derivations of PDEs from a mass-balance point of view (coupling Darcy’s Law with the Continuity equation). Handouts
21. Ground-Water Flow Equations – Solution techniques and examples
22. Flow nets as a solution technique to PDEs
23. Aquifer Compressibility and Specific Storage
24. Transient groundwater flow equations

Well Hydraulics (Chapter 5)
25. Well hydraulics – establish the assumptions of the conceptual picture and Theis solution (mathematical similitude with heat flow).
26. Well hydraulics – Theis solution (pump tests) multiple wells and superposition of W(u)
27. Well hydraulics – Jacob and Thiem pump-test approximations (examples).
28. Well hydraulics – Specific Capacity test (using the Jacob-cooper approximation)
29. Pump Tests – Deviations from the Theis solution (bounded, leaky, and unconfined aquifers)
30. Slug Test – Hvorslev method

Sea-Water Intrusions (pp. 327-338)
31. Sea-water Intrusions – theory
32. Sea-water Intrusions – Islands (with examples)

Ground-Water Modeling (Chapter 13)
33. Ground-water Modeling – Use the Toth conceptual picture (and analytical solution) to introduce the finite-difference numerical approach.
Learning Outcomes for Geology 473/573

GEOL 473 Course Student Learning Outcomes: Students will understand:

1. regional glacial and alluvial history and the deposits that form Puget Sound aquifers
   Course objectives: Students will be able to:
   a. describe the depositional environments for glacial and alluvial deposits
   b. distinguish between glacial outwash, till, glaciomarine drift; and alluvium, and their relationship to hydrogeology

2. the equations and variables that describe groundwater flow in aquifers and other geologic systems
   Course objectives: Students will be able to:
   a. determine when the influence of fluid density and viscosity becomes important in groundwater systems
   b. differentiate between the porosity, intrinsic permeability, and hydraulic conductivity of aquifer sediments
   c. quantify the pressure head, elevation head and total head and hydraulic gradients
   d. apply Darcy’s Law to calculate fluxes and velocities in one and two dimensions

3. unsaturated flow and the factors that control aquifer recharge
   Course objectives: Students will be able to:
   a. estimate recharge from rainfall, soil, aquifer, and vegetation data in ArcGIS
   b. apply Darcy’s law in an unsaturated sediment

4. mathematical modeling approaches for resolving groundwater related problems
   Course objectives: Students will be able to:
   a. recognize the appropriate groundwater flow equation (PDE) that describes an aquifer conceptual picture (1,2 or 3-D, heterogeneous or homogenous, steady state or transient flow)
   b. apply the groundwater flow equations to pumping wells

5. site characterization requirements for a hydrogeological assessment
   Course objectives: Students will be able to:
   a. draw aquifer cross sections from well log information
   b. measure the pressure head, elevation head and total head at monitoring wells
   c. contour total head values and determine hydraulic gradients in one and two dimensions
   d. estimate the hydraulic conductivity of an aquifer from pump test, slug test, and specific capacity data

GEOL 573 Course Student Learning Outcomes: Students will understand:

1. the GEOL 473 course outcomes and objectives

2. how to analyze and interpret scientific data
   Course objectives: Students will be able to:
   a. Apply groundwater principles to a topic outside the realm of GEOL 473
Geology 473/573 - Hydrogeology provides information for the following Geology degree program outcomes:

<table>
<thead>
<tr>
<th>Program Outcomes</th>
<th>B.A. Geology</th>
<th>B.S. Geology</th>
<th>B.S. Geophysics</th>
<th>GUR</th>
<th>M.S. Geology</th>
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<td>2. Earth’s surface is affected by dynamic processes on a range of timescales.</td>
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<td>1. Analyze and communicate ideas effectively in oral, written, and visual forms.</td>
<td>3. Analyze and interpret scientific data;</td>
<td>4. Communicate scientific concepts and results effectively through both written and oral means, and to a range of audiences.</td>
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<td>6. Geology and society are fundamentally inter-related</td>
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<td>7. Graduates have developed their observational, analytical and quantitative skills (field, lab, computer, and classroom)</td>
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<td>3. Use quantitative and scientific reasoning to frame and solve problems.</td>
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<td>10. Graduates (alone or in teams) will be able to present geological information clearly</td>
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