HWRS 561a Physical Hydrogeology I
Fall 2025

Catalog Description

Physical Hydrogeology is the study of groundwater – it is sometimes referred to as geohydrology or groundwater hydrology. Hydrogeology deals with how water gets into the ground (recharge), how it flows in the subsurface (through aquifers) and how groundwater interacts with the surrounding landscape, including rivers and lakes. The first part of this course teaches the fundamental concepts of a watershed as the unit of hydrological inquiry. Starting with the water and energy balance of a watershed in a particular climate, the course discusses how recharge water flows through saturated porous geologic media.

Course Prerequisites or Co-requisites

No pre-requisites, but must be enrolled in the MS Hydrogeology program. Required co-registration in HWRS 599 Section 001 (Recitation), HWRS 562a Chemical Hydrogeology I, HWRS 563a Hydrogeologic Measurement Methods I, HWRS 564a Hydrogeologic Analysis Tools & Methods I, and HWRS 565a Communications in Hydrogeology I.

Required Textbooks/Materials

Flow Through Heterogeneous Geologic Media (2015) by Tian-Chyi “Jim” Yeh – Online ISBN: 9781139879323

Reference Readings (Optional)

References will be provided as needed through D2L. You will not need to purchase these references.

Professional Applications of this Course Material:

Course Objectives

Students will:

1. review and apply fundamentals of fluid statics and dynamics in the context of physical hydrogeology.
2. define the components of a watershed and their connections to each other.
3. understand water and energy balance at various scales, as well as water and energy gradients.
4. understand Darcy’s law for saturated porous media both conceptually and mathematically.
5. derive the governing flow equations for homogenous porous media
6. describe how water flows toward a well through the subsurface due to pumping.

Expected Learning Outcomes

By the end of the course, the student should be able to:

1. Characterize the soil hydraulic properties of an area at multiple scales by direct measurements, through relationships with measured soil physical properties, and based on larger geologic structures.
2. Calculate the responses of hydrologic systems to applied stresses using quantitative models.

3. Synthesize knowledge of water flow through complex terrain into both mathematical and conceptual models at multiple scales in 1D, 2D, and 3D.
4. Analyze scientific literature on physical aspects of hydrogeology and discuss the approach and main conclusions of the papers with fellow hydrologists.

Course Format and Teaching Methods

Lectures, in-class discussions, homework assignments, and exams will be given in this course. Students will work on homework individually. Midterm and final exams will test the student's capability to solve problems similar to those exercised in the homework assignments.

Planned Field Trips

The course will begin this course with a field trip during the entire first week of class, and will apply to all courses in the MS Hydrogeology Fall semester (this course, but also HWRS 562a, HWRS 563a, HWRS 564a, and HWRS 565a). The field trip will begin on the first Monday of the first full week. Students should plan to be out of town for the entire week, including camping overnight.

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Schedule of Topics & Activities

Week	Monday date	Topics covered this week	Assignment due this week
1	8/25/2025	**Road trip- No Class**	
		Module 0: Review of Hydraulic Concepts	
2	9/1/2025	**Fluid statics and dynamics**: what is a fluid; units and dimensions; fluid properties; forces on fluids; hydrostatics; Eulerian vs. Lagrangian coordinate systems; acceleration; Bernouilli's equation; head losses	
		Module 1: Porous Media within Watersheds	
3	9/8/2025	**What is a watershed:** Definition of a watershed and its components (confined vs. unconfined aquifers, vadose zone, rivers and lakes); Introducing water and energy balance at annual time scales; Water and energy partitioning at the watershed scale; Recharge.	HW#1: Fluid statics and dynamics calculations
4	9/15/2025	**What are porous geological media:** Pore-scale controls on hydraulic properties; Definition of porosity and hydraulic properties at REV scale; Soil and fractured bedrock controls on hydraulic properties; **Heterogeneity and anisotropy:** Geologic causes of heterogeneity and anisotropy; hydro-stratigraphy (the classification of geologic structures based on their ability to hold water)	Self-reflection #1 HW#2: Water and energy balance calculations Project 1 – Conceptual model of a watershed
		Module 2: Steady state flow through saturated porous media	
5	9/22/2025	**Water potential and energy gradient:** Definition of water potential; water potential distribution in the landscape; definition of potential energy gradients.	HW#3: Estimating soil hydraulic properties
6	9/29/2025	**Darcy's law:** Simple demonstration of flow through saturated soil; Definition of flux and velocity; Empirical derivation of Darcy's law.	
7	10/6/2025	**Flow through vertical columns:** Steady state saturated flow through 1D column (homogenous); Introduce layered heterogeneity effects on flow and energy distribution	HW#4: Applications of Darcy's law Midterm exam
8	10/13/2025	**2D and 3D flow:** Extend Darcy's law to 2D and 3D; Flow and equipotential lines; Physical meaning of boundary conditions; Steady state saturated flow in 2D (confined and unconfined aquifers)	Self-reflection #2 HW#5: Flow and equipotential lines Project 2 – Response of hydrological systems

Module 3: Transient flow through saturated porous media			
9	10/20/2025	**Transient flow through aquifers:** Flow through confined aquifers; Flow through unconfined aquifers; Dupuit-Forchheimer assumptions in unconfined aquifers.	HW#6: Steady state saturated flow in 2D
10	10/27/2025	**Boussinesq equation:** 1D transient flow through unconfined sloping aquifers; Analytical solutions; Baseflow recession analysis at the hillslope to watershed scale	HW#7: Applications of Dupuit Forchheimer assumptions
11	11/3/2025	**Baseflow recession analysis:** Hillslope free drainage response; Watershed free drainage response.	HW#8: Boussinesq equation applications
Module 4: Numerical solutions			
12	11/10/2025	**Steady state groundwater flow:** Building a conceptual model; Types of boundaries; Sources and sinks; Finite difference and finite elements models	Self-reflection #3 HW#9: Baseflow recessions analysis
13	11/17/2025	**Transient groundwater flow:** Initial conditions; Boundary conditions; Discretizing time; Storage in aquifers; Calibration	HW#10: Simple numerical solutions of steady state flow Project 3 – Steady-state and transient flow in aquifers
13	11/24/2025	No class: Thanksgiving break	N/A
Module 5: Pumping wells			
14	12/1/2025	**Pumping wells I:** Steady state radial flow in confined and unconfined aquifers; zone of influence.	HW#11: Simple numerical solutions of transient flow, with application to pumping tests
15	12/8/2025	**Pumping wells II:** Transient radial flow in confined and unconfined aquifers	Self-reflection #4 Final Exam (during week of 12/12-12/18)

Course Assessments and Grading Breakdown

You will be assessed based on weekly assignments. You will also be assessed based on how you apply the understanding gained in this class to the monthly projects. Finally, you will receive completion credit for completing weekly self-assessments.

HW Assignments are assigned every Friday, and they are due the following week, Thursday by 10 pm. These assignments will consist of textbook problems that can be solved based on the material discussed previously and will require detailed understanding of the materials taught. Each assignment will be given a time budget. This will give students an indication of the level of effort expected for each assignment. Students will report the time spent on the project. If individual students are spending more time than the average, the instructor will meet with them to identify and solve any issues. If many students are spending more than the assigned time, then the assignments will be modified for the remainder of the term and for subsequent years. It is expected that students will spend no more than 1.5 hours per week on these class assignments.

Exams – These will test of your understanding of elements of the course and your ability to apply that knowledge. This may include calculations, analysis, synthesis, and written elements.

Projects – Physical Hydrogeology Component - assigned monthly. These projects are designed to synthesize the content/skills you are learning in all 5 courses that month to address a hydrogeologic problem/task. This means that the projects in their entirety are not specific to any one course and require you to pull knowledge from them all to address a hydrogeologic problem. However, you will be graded and assessed on the knowledge/skills needed from physical hydrogeology to address this problem

The grade you receive for the physical hydrogeologic skills/content portion of the projects will be used to calculate your total course grade in Physical Hydrogeology I for the semester.

Self-reflection each student is expected to turn in a monthly self-reflection that focuses on what they learned about the topic, what they learned about their learning process, and/or what questions they still have about the material. These will be turned in through D2L by Sunday at 10 pm. Students will be advised to spend no more than 30 minutes on the self-reflection. This is intended to be an informal and informational assignment; it will not be graded for writing quality.

Class participation will be earned by participating in designated class discussions. Students who are not meeting expectations in participation will be addressed individually so that they can correct to meet expectations.

The percentage distribution of your grade will be as follows.

Course Assignments (11)	: 30%
Projects – physical hydrogeology component (3)	: 20%
Self-reflections (4)	: 10%
Exams (midterm and final)	: 30%
Participation	: 10%

University policy regarding grades and grading systems is available at this link.

Final Examination or Project

The final examination course will happen during the scheduled final exam time for the university. For Fall 2025, this date will be somewhere between 12/12-12/18. It has yet to be scheduled by the university.

Grading Scale

Your final grade will be informed via D2L. Letter grades are determined using the following scale:

A: >= 90.0%

B: >= 80 - 89%

C: >= 70 – 79 %

D: >= 60 to 69 %

E: below 59 %

University policy regarding grades and grading systems is available at https://catalog.arizona.edu/policy/courses-credit/grading/grading-system.

Late Work Policy

No late work will be accepted for a grade, but students will receive feedback on all submitted work. Each student will be allowed to drop the two lowest assignment grades.

Incomplete (I) or Withdrawal (W)

Requests for incomplete (I) or withdrawal (W) must be made in accordance with University policies, which are available at this link associated with the registrar.

University of Arizona Course Policies

All University of Arizona course and syllabi policies, as well as other helpful information and resources, can be found at this link. If you are in need of basic needs care, here is another helpful link, in addition to what you can find at the policy link above.

Subject to Change Statement

Information contained in the course syllabus, other than the grade and absence policy, may be subject to change with advance notice, as deemed appropriate by the instructor.