Soils 405/Geosc 405 HYDROPEDOLOGY
— The Secret and Magic of Mrs. Soil + Mr. Water ↔ Life!

Fall 2009, 3 Credits

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Synopsis: Hydropedology is an emerging interdisciplinary science that studies interactive pedologic and hydrologic processes and properties in the Earth’s Critical Zone. Soil and water interaction creates the fundamental interface between the biotic and abiotic, and hence is a key determinant of the state of the Earth system. Hydropedology aims to understand pedologic controls on hydrologic processes and properties, and hydrologic impacts on soil formation, variability, and functions. Hydropedology emphasizes in situ soils in the real-world landscape where distinct pedogenic features (such as soil structure, horizonation, and heterogeneity), environmental variables (such as climate, landforms, and organisms), and anthropogenic impacts (such as land use and management) interact and dictate the landscape water flux. This course promotes active learning, critical thinking, and hands-on skills.

Prerequisites: Introductory soil or water sciences. Introductory courses in pedology, soil physics, and hydrology would be helpful, but not required.

Text: Lin, H.S. 2009. Architecture and Function of Complex Geoderma. Materials are to be provided throughout the course through PSU ANGEL system and in class.


Grading: Grades will be based on 100% as distributed below. Breaks between letter grades will be at 90% (A), 80% (B), 70% (C), and 60% (D), with plus and minus grades as appropriate (A: 94-100, A-: 90-93, B+: 86-89, B: 83-85, B-: 80-82, C+: 76-79, C: 73-75, C-: 70-72, D+: 65-69, D: 60-64, F: <60). Final grades may be adjusted based on overall class performance.

- Class research project (critical thinking) 35%
- Lab/field trip reports (hands-on skills) 20%
- Quizzes & discussions (reading assignments) 10%
- Attendance (participation) 5%
- Homework (active learning) 15%
- Exams (take home or in class) 15%

TOTAL 100%

Further explanations of the above requirements and relevant guidelines will be provided in the 1st class. Opportunities for bonus credit may arise during the semester.

Attendance: Regular attendance to lectures and labs is required. Students who have to miss a class must provide a legitimate reason beforehand and will be self-responsible for missed class.
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LECTURE OUTLINES

PART I  INTRODUCTION

1. Secrets Underfoot: Soil, Water, and Earth’s Critical Zone
   1.1 From Earth’s Critical Zone to Mars Exploration: The 7+1 Functions of the Soil
   1.2 Water: A Unifying Theme for Understanding Complex Environmental Systems
   1.3 Dissolving Disciplinary Boundaries: Hydropedology and Critical Zone Science
   1.4 New Ways of Doing Science and Different Ways of Representation and Quantification

PART II  FUNDAMENTAL ARCHITECTURE AND FUNCTION

2. Foundation of Soil Architecture: Key to Understanding Soil Functions
   2.1 Soil as a Porous System and Its Basic Characterizations
   2.2 Soil Architecture and Its Formation and Dynamics
   2.3 Soil Architecture over the Landscape
   2.4 Depth Functions of Soil Properties

3. Universality of Preferential Flow: It Is Everywhere in the Field
   3.1 Classical Theories of Flow and Transport in Soils
   3.2 Soil Hydraulic Properties
   3.3 Universality of Preferential Flow: Theoretical Considerations
   3.4 Preferential Flow and Transport in Soil Profiles
   3.5 Landscape Scale Preferential Flow and Transport
   3.6 Coupling Hydropedological and Biogeochemical Processes

4. Soil Morphology and Pedogenesis: Reading Stories in Profiles
   4.1 Soil Morphology
   4.2 Hydromorphology
   4.3 Pedogenic Processes
   4.4 Quantification and Modeling of Pedogenesis
   4.5 Soil Morphology for Interpreting Soil Properties and Paleoenviroment

PART III  COMPLEX SOIL SYSTEMS

5. Union of Space and Time: Thermodynamics of Open Soil Systems
   5.1 Thermodynamic Theory in Open System and Irreversible Processes
   5.2 Energy, Mass, and Entropy Budgets in Soil Systems
   5.3 Near Equilibrium and Linear Laws
   5.4 Far from Equilibrium

6. Unification of Soil Formation and Soil Functions: Evolution and Heterogeneity
   6.1 Soil forming theory: Evolutionary record
   6.2 Soil function theory: Future land use possibility
   6.3 Unifying soil formation theory and soil function theory: Foundation of Hydropedology
6.4 Water, carbon, clay, and microbe budgets in soil systems
6.5 Soil heterogeneity and soil-landscape relationships

7. Bridging Scales: Horarchy of Soil Systems
   7.1 Three Broad Scales: Macro-, Meso-, and Micro-scales
   7.2 Horarchy of Soil Systems
   7.3 Hierarchical Frameworks for Bridging Multiscales in Hydropedology

8. Integrating Geographic and Functional Approaches: Integrated 3M
   8.1 Integrated Mapping, Monitoring, and Modeling (3M)
   8.2 Databases
   8.3 Mapping Soils and Landscapes: Dealing with Heterogeneous World
   8.4 Monitoring Soils and Landscapes: Facing Dynamic World
   8.5 Modeling Pedologic Architecture and Hydrologic Functions of Geoderma

PART IV SUMMARY AND OUTLOOKS

9. Hydropedology: Synergistic Integration of Pedology and Hydrology
   9.1 A Framework for Integrated Hydropedological Studies
   9.2 Fundamental Scientific Issues of Hydropedology

    10.1 General Theory
    10.2 Key Features in Understanding the Landscape-Soil-Water-Ecosystem Relationships

Cutting-Edge Applications of Hydropedology:

- Mars exploration and extraterrestrial hydropedology
- Global climate change and hydropedology
- Environmental policy/regulation and hydropedology
- Origin of life and hydropedology
- Civilization and hydropedology
- Urban growth and hydropedology
- Spatial land use planning and hydropedology

Notes:

- The above topics and their sequences may be modified during the course of the semester.
- Each student is expected to complete the reading assignments in the week they’re assigned and be prepared for a quiz at the end of the week, and to actively participate in classroom discussions. Both quizzes and class discussions are to be based on the reading assignments of the week.
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LABORATORY AND FIELD EXERCISES

Week 1: **No Lab – (Lecture instead)**

Week 2: **Lab**: Soil Profile Morphology, Horizonation, Texture, Structure, Pores, Roots, etc.
Soil Classification and Mapping, Soil Survey Reports

**Field Trip**: Local soil pit and landscape

Week 3: **Lab**: Soil Water Content, Water Potential, Soil Water Retention Curve
Watershed Hydrology and Soil Moisture Monitoring

Week 4: **Field Trip**: Shale Hills Watershed, Hydropedology and Landscape Hydrology
Soil and Landscape Survey, Monitoring Design and Instrumentation

Week 5: **Lab**: Soil Hydraulic Conductivity, Hydraulic Conductivity Function
Bulk Density, Particle Density, Total Porosity, Pore Sizes

Week 6: **Field Trip**: Infiltration Process, Various Infiltrometers
Fox Hollow Watershed and Stormwater Management, Surface Runoff, Subsurface Flow

Week 7: **Field Trip**: PSU Wastewater Spray Irrigation (“Living Filter”), Wastewater Treatment and Disposal, Constructed Wetlands, On-Site Waste Disposal

Week 8: **Lab**: Chemical Adsorption and Solute Transport in Contrasting Soils
Preferential Flow of Water and Transport of Chemicals, Dye Tracing Flow Paths

Week 9: **Field Trip**: Agronomy Farm, Nitrate Leaching Plots
Catena Concepts, Hillslope Hydrology

Week 10: **Field Trip**: Kepler Farm, Hydropedology and Precision Agriculture
High Intensity Soil Mapping, Topography Survey, Geospatial Technologies

Week 11: **Work on Class Research Project**

Week 12: **Field Trip**: Shale Hills Watershed, Hydropedology and Landscape Hydrology
Critical Zone Observatory Interdisciplinary Research

Week 13: **Work on Class Research Project**

Week 14: Thanksgiving Holiday - **No Classes**

Week 15: **Class Research Project Presentations**

Week 16: **No Lab** (Class Research Project Final Report Due)

**Notes:**
- Lab/field reports are due in the week following each exercise. Reports are to be not more than 1 page summary of your personal observations and experience/knowledge learned;
- Field trips would be weather dependent and may be switched with labs if necessary.
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Guidelines for Class Research Project

Purpose: Each student is expected to complete a small research paper in this course. The project is designed to give students an opportunity to identify and research a small topic or problem related to hydropedology. The scope of the project should be equivalent to a small scientific paper, and should be reported accordingly. A written paper and an oral presentation will be required at the end of the class.

Oral presentation: Each student will be required to give a 10-12 minute presentation using PowerPoint (as if at a professional scientific meeting). A few minutes’ question session will follow each presentation. Graphics and tables are strongly suggested for effective, informative, and interesting presentation. Oral presentation will be graded based on 1) thoroughness in understanding of the subject presented, 2) clarity and effectiveness of presentation, and 3) response to questions (correctness and thoroughness).

Written paper: No page limit (generally 15-30 typed pages). Must type in 1.5-spacing and submit a neatly written copy. The paper needs to include important maps, figures, and/or tables. Any citation should also be provided. The report will be graded based on 1) content (thoroughness in the understanding and critical thinking of the chosen subject), 2) clarity (report format and writing skill), and 3) creativity (anything new and innovative is particularly encouraged, which often leads to bonus points).

Suggested outlines of written paper (Required format):
- Cover page: Include the title of your project, your name, class, and date
- Abstract: A brief summary of your entire project, including objectives, methods used, and main results and conclusions
- Introduction: Background information, your project motivation, and your project objectives
- Materials & Methods (or equivalent if it is a comprehensive review)
- Results & Discussion (or equivalent if it is a comprehensive review)
- Conclusion: A few sentences highlighting the main findings of your project
- Reference: List of all references cited in your report

Due dates:
- Research topic selection (including a brief justification and a work plan for completing the project) \textbf{Week 5}
- Oral presentation \textbf{Week 15}
- Final written paper \textbf{Week 16}

Suggested Topics: Each topic must be approved by the instructor. Please feel free to discuss your topic with the instructor as soon as possible. If not sure or if preferred, the instructor may assign you a topic. If possible, it is strongly recommended that a graduate student select a topic that would showcase the linkage between hydropedology and his/her own thesis research. By week 5, each student must firm up with his/her topic, and submit a brief justification of selected topic and a general work plan for completing the project by the end of the semester. Two types of class research projects are recommended:

Type I: Use one the five landscapes/watersheds shown in the Figure 1 for hydropedological studies
- You could use our existing databases or your own to conduct some hydropedological analyses
- You could also consider a comprehensive literature review and a compilation of historical and current data/information of the selected landscape/watershed
- You could also choose to design a hydropedological monitoring system in one of these study areas using hydropedological principles and approaches covered in this course
Fig. 1. Five landscapes/watersheds near PSU of different land uses for integrated soil and water studies.

**Type II: Select a landscape or watershed anywhere in the world that has been studied with data available for studying landscape, soil, hydrology, and ecosystem**

- The study area must have sufficient publications and/or available databases for studying the relationships between landscape, soil, and hydrology
- If you select this type of class research project, you must conduct a thorough compilation of the historical and current datasets for your study area related to landscape, soil, and hydrology, and then perform some analyses that are tied to hydropedological issues covered in this course.

Fig. 2. World map showing the level of interest in hydropedology.

*Total since 30 Jul 2007: 3,837.*
Selected References Related to Hydropedology

Online books or resources:
- Online USDA-NRCS books and standards: http://soils.usda.gov/technical/
- USDA-NRCS Soils Online Resources: http://soils.usda.gov/
- Online soil surveys of the U.S.: http://soils.usda.gov/survey/online_surveys/
- European Soil Bureau: http://eusoils.jrc.it/
- National Research Council books (Read online free!): http://books.nap.edu/
- Free ebooks (Project Gutenberg Online Book Catalog): http://www.gutenberg.org/wiki/Main_Page
- Interesting soil websites: http://soilweb.tripod.com/soilsite.htm

Online literature search resources:
- ISI Web of Science: http://portal.isiknowledge.com/portal.cgi/portal.cgi?DestApp=WOS&Func=Frame&Init=Yes&SID=E157McpE617CC8eAB4
- Google Scholar: http://scholar.google.com/advanced_scholar_search?hl=en&lr=
- ScienceDirect: http://www.sciencedirect.com/science
- Journal Citation Reports (JCR Web): http://scientific.thomson.com/products/jcr/

Popular soil and water scientific journals:
- Soil Science Society of America J.
- Soil Science
- Vadose Zone J.
- J. Environmental Quality
- Environmental Science & Technology
- J. Soil & Water Conservation
- J. Contaminated Soil
- Geoderma
- Catena
- Soil Tillage Research
- European J. Soil Science (J. Soil Science)
- Canadian J. Soil Science
- Australia J. Soil Res.
- Soil Science and Plant Analysis
- Hydrology and Earth System Sciences
- Water Resources Research
- J. of American Water Resources Association
- Water Research
- Hydrogeology
- J. Hydrology
- J. Contaminant Hydrology
- J. Environmental Engineering, ASCE
- Transactions of ASAE (American Society of Agricultural Engineers)
- Wetlands
- Ecological Modeling
- Ecology
- Geomorphology
- Land Degradation
- Quaternary Research

Introductory and general soil and water sciences books:

Pedology related references:

Soil physics related references:

Hydrology related references:
• Tenhunen, J.D., and P. Kabat (eds.). 1999. Integrating Hydrology, Ecosystem Dynamics, and Biogeochemistry in Complex Landscapes. John Wiley & Sons Ltd., Chichester, UK.

Geomorphology related references:

Landscape-soil-hydrology research methodology references: