

ENVIRONMENTAL SCIENCE

College of Agriculture and Life Sciences

Interdepartmental Undergraduate Programs

Environmental Science provides an integrated, quantitative, and interdisciplinary approach to the study of environmental systems. The magnitude and complexity of environmental problems are creating a growing need for scientists with rigorous, interdisciplinary training in environmental science. The Environmental Science program is designed to prepare students for positions of leadership in this rapidly changing discipline. Environmental Science graduates have a solid foundation in biological and physical natural sciences and the specialized training necessary for integrated analysis of environmental systems.

Undergraduate Study

The Environmental Science undergraduate major is offered through both the College of Agriculture and Life Sciences and the College of Liberal Arts and Sciences. Environmental Science majors complete foundation courses in biology, chemistry, earth science, geology, physics and mathematics, plus a major consisting of an integrated core of Environmental Science courses and additional advanced course work in Environmental Science. Scientific rigor is stressed throughout the program, beginning with the foundation courses in the first two years of the curriculum. The upper level core courses emphasize a dynamic systems approach that provides a framework for integrating physical, chemical, and biological aspects of environmental systems.

Students seeking an Environmental Science major complete the following:

1. A foundation of approved supporting courses in science and mathematics including biology, chemistry, earth science, physics, calculus, and statistics.

2. 32 credits of course work in the major, including a required core of 20 credits.

A combined average grade of C or higher is required in courses applied in the major.

1. Environmental Science: 32 credits

ENSCI 110	Orientation to Environmental Science	1
ENSCI 201	Introduction to Environmental Issues	2
ENSCI 202	Exploration of Environmental and Sustainability Issues	1
ENSCI 203	Exploration of Environmental Science	1
ENSCI 250	Environmental Geography	3
ENSCI 251	Biological Processes in the Environment	3

ENSCI 381	Environmental Systems I: Introduction to Environmental Systems	3
ENSCI 382	Environmental Systems II: Analysis of Environmental Systems	3
ENSCI 384	Introduction to Ecosystems	3
Additional ENSCI choice courses		12
Total Credits		32

2. Mathematics & Statistics: 7-8 credits

Choose one of the following:		4
MATH 160	Survey of Calculus	
MATH 165	Calculus I	
Choose one of the following:		3-4
STAT 101	Principles of Statistics	
STAT 104	Introduction to Statistics	
Total Credits		7-8

3. Physical & Life Sciences: 21-24 credits

BIOL 101	Introductory Biology	3
or BIOL 211	Principles of Biology I	
Choose from one of the following:		5-6
CHEM 163 & 163L	College Chemistry and Laboratory in College Chemistry	
CHEM 167 & 167L	General Chemistry for Engineering Students and Laboratory in General Chemistry for Engineering	
CHEM 177 & 177L	General Chemistry I and Laboratory in General Chemistry I	
CHEM 201 & 201L	Advanced General Chemistry and Laboratory in Advanced General Chemistry	
Choose from one of the following:		3-4
CHEM 231 & 231L	Elementary Organic Chemistry and Laboratory in Elementary Organic Chemistry	
CHEM 331 & 331L	Organic Chemistry I and Laboratory in Organic Chemistry I	
BBMB 221	Structure and Reactions in Biochemical Processes	
AGRON 259	Organic Compounds in Plants and Soils	
Choose from one of the following:		4-5
PHYS 111	General Physics	
PHYS 115	Physics for the Life Sciences	
PHYS 221	Introduction to Classical Physics I	
Choose 2 of the following:		6
AGRON 182	Introduction to Soil Science	
GEOL 100	How the Earth Works	
or GEOL 201	Geology for Engineers and Environmental Scientists	

MTEOR 206	Introduction to Weather and Climate	
BIOL 212	Principles of Biology II	
CHEM 178 & 178L	General Chemistry II and Laboratory in College Chemistry II	

Total Credits **21-24**

4. Communications: 7-10 credits

ENGL 150	Critical Thinking and Communication	3
ENGL 250	Written, Oral, Visual, and Electronic Composition	3
LIB 160	Information Literacy	1
Embedded communication coursework in ENSCI 203, 381 and 382		

Total Credits **7**

Additional communication Courses required of majors in the College of Agriculture and Life Sciences

SP CM 212	Fundamentals of Public Speaking	3
or AGEDS 311	Presentation and Sales Strategies for Agricultural Audiences	

Total Credits **3**

5. General Education: 15-21 credits

General Education requirements in the College of Agriculture and Life Sciences

Humanities		3
Social Science		3
Ethics		3
International Perspectives course from university approved list		3
US Diversity course from university approved list		3

Total Credits **15**

General Education requirements in the College of Liberal Arts and Sciences

Arts and Humanities courses from college approved list	12
Social Science courses from college approved list	9

(Select courses to include 3 cr. of International Perspectives and 3 cr. of US Diversity)

Students must have completed 3 years of a single world language in high school or take 4-8 credits of World Languages at the university level

Total Credits **21**

Electives (28-35 credits)

120.0 Total Credits

Environmental Science, B.S.

Freshman

Fall	Credits	Spring	Credits
ENGL 150		3 BIOL 211 & 211L or Elective	3-4
ENSCI 110 ¹		1 CHEM 178	3

ENSCI 201 ¹		2 CHEM 178L	1
CHEM 177		4 MATH 160 or 165	4
CHEM 177L		1 Social Science or Humanities Choice ²	3
LIB 160		1	
STAT 101 or 104		3-4	

15-16 **14-15**

Sophomore

Fall	Credits	Spring	Credits
ENSCI 250 ¹		3 ENSCI 251	3
Social Science or Humanities Choice ²		3 Organic Chemistry Choice ³	3
PHYS 115		4 Earth Science Choice ³	3
ENGL 250		3 Social Science or Humanities Choice ²	3
Elective		3 Communications (Speech)	3

16 **15**

Junior

Fall	Credits	Spring	Credits
ENSCI 381 ¹		3-4 ENSCI 382 ¹	3
Environmental Science Choice ¹		3 ENSCI 384	3
Social Science or Humanities Choice ²		3 Social Science or Humanities Choice ²	3
Elective		6 Electives	6

15-16 **15**

Senior

Fall	Credits	Spring	Credits
Environmental Science Choice ¹		3 Environmental Science Choice ¹	6
Elective		12 Elective	9

15 **15**

¹ Students complete at least 27 credits in Environmental Science including ENSCI 110,201, 250, 381, 382, and 15 additional credits of approved ENSCI coursework.

² Students complete at least 15 credits in humanities and social science including at least 3 credits each in ethics, humanities, social science, U.S. Diversity, and International Perspectives from approved lists.

³ Students choose one course from the following Earth Science related courses: AGRON 182, BIOL 212, GEOL 100, GEOL 201, MTEOR 206. Students choose from one of the following Organic Chemistry options: CHEM 231 & 231L, CHEM 331 & 331L, BBMB 221, or AGRON 259.

Graduate Study

Contact information for the graduate program:

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camelot@iastate.edu (mstolt@iastate.edu)

515-294-1191

<https://enscigrad.iastate.edu/>

The Environmental Science graduate program offers an interdepartmental curriculum leading to M.S. and Ph.D. degrees with a major in Environmental Science. Faculty from the colleges of Agriculture and Life Sciences, Engineering, and Liberal Arts and Sciences cooperate to offer courses and research opportunities covering a broad array of environmental topics. Cooperating departments include Agricultural and Biosystems Engineering; Agronomy; Animal Science; Civil, Construction and Environmental Engineering; Ecology, Evolution and Organismal Biology; and Geological and Atmospheric Sciences.

Applicants should have completed an undergraduate or master's degree in one of the biological, chemical, physical, or engineering sciences or should have equivalent preparation.

The Environmental Science Graduate Program emphasizes fundamental concepts and research, which at the same time address major environmental issues. The curriculum is designed to provide the interdisciplinary approach needed in environmental science education and research. In addition to work in their chosen area of specialization, students are afforded a broad exposure to the biological, chemical and physical aspects of environmental systems and the specialized training necessary for integrated analysis of these systems.

Information on application procedures, curriculum requirements, and faculty research areas is available on the Environmental Science Graduate Program website (<https://enscigrad.iastate.edu/>).

Courses primarily for undergraduates:

ENSCI 110: Orientation to Environmental Science

(1-0) Cr. 1. F.

Prereq: Freshman classification in EnSci

Overview of Environmental Science curriculum and discussion of professional opportunities. Offered on a satisfactory-fail basis only.

ENSCI 201: Introduction to Environmental Issues

(Cross-listed with BIOL, ENV S). (2-0) Cr. 2. F.

Discussion of current and emerging environmental issues such as human population growth, energy use, loss of biodiversity, water resources, and climate change.

ENSCI 202: Exploration of Environmental and Sustainability Issues

(1-0) Cr. 1. F.

Prereq: Credit or enrollment in ENSCI 201

Exploration of specific environmental and sustainability issues; designed to complement ENSCI 201. Offered on a satisfactory-fail basis only.

ENSCI 203: Exploration of Environmental Science

(1-0) Cr. 1. S.

Prereq: ENSCI 202.

Continued exploration of specific environmental science issues developed in ENSCI 202. Topics may vary in different years. Offered on a satisfactory-fail basis only.

ENSCI 250: Environmental Geography

(Cross-listed with ENV S). (3-0) Cr. 3. F.

The distribution, origins and functions of the earth's physical systems and the spatial relationship between human activity and the natural world.

ENSCI 251: Biological Processes in the Environment

(Cross-listed with BIOL). (3-0) Cr. 3. S.

Principles of Biology from the level of macromolecules to the biosphere. Biological processes that affect environmental systems: including metabolism, energy pathways, biochemical reactions in cells, plant and microbial structure and function, element and water cycles.

ENSCI 270: Geospatial Technologies

(Cross-listed with AGRON). Cr. 3.

Concepts and tools for acquiring, managing, analyzing, and displaying geographic information, including GIS, remote sensing, spatial analysis, and cartography. Focus on applications in biological, ecological, environmental, and agricultural sciences.

ENSCI 301: Natural Resource Ecology and Soils

(Cross-listed with NREM). (3-3) Cr. 4. F.

Prereq: BIOL 211, BIOL 211L; FOR 201 or a second course in biology

Effects of environmental factors on ecosystem structure and function using forest, prairie and agricultural ecosystems as models. Special emphasis is given to soil-forming factors and the role of soil in nutrient and water cycling and ecosystem dynamics. Additional emphasis is given to human influences on natural ecosystems and the role of perennial plant communities in agricultural landscapes.

ENSCI 312: Ecology

(Cross-listed with A ECL, BIOL). (3-3) Cr. 4. F.SS.

Prereq: BIOL 211, BIOL 211L, BIOL 212, and BIOL 212L

Fundamental concepts and principles of ecology dealing with organisms, populations, communities, and ecosystems. Laboratory and field exercises examine ecological principles and methods as well as illustrate habitats.

ENSCI 312I: Ecology

(Cross-listed with A ECL, IA LL). Cr. 4. SS.

An introduction to the principles of ecology at the population, community and ecosystem level. Field studies of local lakes, wetlands and prairies are used to examine factors controlling distributions, interactions, and roles of plants and animals in native ecosystems.

ENSCI 324: Energy and the Environment

(Cross-listed with ENV S, GEOL, MTEOR). (3-0) Cr. 3. S.

Prereq: CHEM 163 or CHEM 177, MATH 140

Exploration of the origin of Earth's energy resources and the environmental and climatic impacts of energy acquisition and consumption. Renewable and non-renewable energy resources within an Earth-system context. Various environmentally-relevant topics such as water quality and availability, habitat destruction, greenhouse-gas emissions, and health and safety hazards to wildlife and human communities.

ENSCI 345: Natural Resource Photogrammetry and Geographic Information Systems

(Cross-listed with NREM). (2-3) Cr. 3. S.

Prereq: Junior classification

Measurement and interpretation of aerial photos in resource management. Introduction to Geographic Information Systems (GIS) using ArcGIS including digitizing, development and query of attribute tables, georeferencing, and use of multiple GIS layers in simple spatial analyses.

ENSCI 360: Environmental Soil Science

(Cross-listed with AGRON). (2-2) Cr. 3. S.

Prereq: AGRON 182 (or equivalent) or ENSCI 250 or GEOL 201

Application of soil science to contemporary environmental problems; comparison of the impacts that different management strategies have on short- and long-term environmental quality and land development. Emphasis on participatory learning activities.

ENSCI 370: GIS for Ecology and Environmental Science

(Cross-listed with BIOL). Cr. 1-6. Repeatable. F.S.

Prereq: Six credits in biological and /or physical sciences, and permission of instructor.

Introduction to geographic information systems (GIS) with emphasis on ecological and environmental applications. No prior GIS experience required. Guided, individualized study of topics based on student background and interest. For students with prior experience, topics and activities are selected to build upon any previous experience and minimize duplication to previous GIS coursework. Potential topics include: basic concepts of GIS, data structures, database management, spatial analysis, modeling and visualization of ecological and environmental data. Case studies in ecological and environmental applications using ArcGIS. Offered on a satisfactory-fail basis only.

ENSCI 381: Environmental Systems I: Introduction to Environmental Systems

(Dual-listed with ENSCI 581). (Cross-listed with BIOL, ENV S). Cr. 3-4. F.

Prereq: 12 credits of natural science including biology and chemistry

Introduction to the structure and function of natural environmental systems. Emphasis on the analysis of material and energy flows in natural environmental systems and the primary environmental factors controlling these systems.

ENSCI 382: Environmental Systems II: Analysis of Environmental Systems

(Dual-listed with ENSCI 582). (Cross-listed with BIOL). (2-2) Cr. 3. S.

Prereq: ENSCI 381

Continuation of EnSci 381. Systems approach to the analysis of material and energy flows in natural environmental systems and the primary environmental factors controlling these systems.

ENSCI 384: Introduction to Ecosystems

(3-0) Cr. 3. S.

Prereq: 12 credits of natural science including biology and chemistry

Biological and physical processes affecting material and energy flows in natural and managed ecosystems. Understanding and predicting climate and management impacts on ecosystem services and sustainability.

ENSCI 390: Internship in Environmental Science

Cr. arr. Repeatable. F.S.SS.

Prereq: Approval of the Environmental Science coordinator

Supervised off-campus work experience in the field of environmental science. Offered on a satisfactory-fail basis only.

ENSCI 391: Apprenticeship

Cr. arr. Repeatable. F.S.SS.

Prereq: Approval of the Environmental Science Coordinator

Practical experience in an approved setting such as a research laboratory, government office, or private office. Offered on a satisfactory-fail basis only.

ENSCI 402: Watershed Hydrology

(Dual-listed with ENSCI 502). (Cross-listed with GEOL, MTEOR, NREM). (2-3) Cr. 3. F.

Prereq: Four courses in physical or biological sciences or engineering; junior standing

Examination of watersheds as systems, emphasizing the surface components of the hydrologic cycle. Combines qualitative understanding of hydrological processes and uncertainty with quantitative representation. Laboratory emphasizes field investigation and measurement of watershed processes.

ENSCI 402i: Watershed Hydrology and Surficial Processes

(Cross-listed with AGRON, IA LL). Cr. 4. SS.

Prereq: Four courses in physical or biological sciences or engineering

Effects of geomorphology, soils, and land use on transport of water and materials (nutrients, contaminants) in watersheds. Fieldwork will emphasize investigations of the Iowa Great Lakes watershed.

ENSCI 404: Global Change

(Dual-listed with ENSCI 504). (Cross-listed with AGRON, ENV S, MTEOR). (3-0) Cr. 3. S.

Prereq: Four courses in physical or biological sciences or engineering; junior standing

Recent changes in global biogeochemical cycles and climate; models of future changes in the climate system; impacts of global change on agriculture, water resources and human health; ethical issues of global environmental change. Also offered online Alt. F, even-numbered years.

ENSCI 405: Environmental Biophysics

(Dual-listed with ENSCI 505). (Cross-listed with AGRON, MTEOR). (3-0) Cr. 3. Alt. S., offered odd-numbered years.

Prereq: MATH 165 and some exposure to computer programming (any language)

The movement of energy and mass among the soil, vegetation, and atmosphere. The heat and water budget of humans, other animals, plants, and plant communities. Relevance to weather and climate, the effect of climate change on organisms, and remote sensing.

ENSCI 406: World Climates

(Cross-listed with AGRON, MTEOR). (3-0) Cr. 3. S.

Prereq: AGRON 206/MTEOR 206

Distribution and causes of different climates around the world. Effects of climate and climate variations on human activities including society, economy and agriculture. Current issues such as climate change and international efforts to assess and mitigate the consequences of a changing climate. Semester project and in-class presentation required. Meets International Perspectives Requirement.

ENSCI 407: Watershed Management

(Dual-listed with ENSCI 507). (Cross-listed with ENV S, NREM). (3-3) Cr. 4. S.

Prereq: A course in general biology

Managing human impacts on the hydrologic cycle. Field and watershed level best management practices for modifying the impacts on water quality, quantity and timing are discussed. Field project includes developing a management plan using landscape buffers.

ENSCI 408i: Aquatic Ecology

(Dual-listed with ENSCI 508i ENSCI 408i). (Cross-listed with IA LL). Cr. 4. SS.

Prereq: Courses in ecology, chemistry, and physics

Analysis of aquatic ecosystems; emphasis on basic ecological principles; ecological theories tested in the field; identification of common plants and animals.

ENSCI 409: Field Methods in Hydrogeology

(Dual-listed with ENSCI 509). (Cross-listed with GEOL). (0-4) Cr. 3. Alt. SS., offered even-numbered years.

Prereq: GEOL/ENSCI 402 or GEOL/ENSCI 411 or C E 473

Introduction to field methods used in groundwater investigations. In-field implementation of pumping tests, slug tests, monitoring well installation and drilling techniques, geochemical and water quality sampling, seepage meters, minipiezometers, stream gaging, and electronic instrumentation for data collection. Field trips to investigate water resource, water quality, and remediation projects.

ENSCI 411: Hydrogeology

(Dual-listed with ENSCI 511). (Cross-listed with GEOL). (3-2) Cr. 4. F.

Prereq: Four courses in biological or physical sciences

Physical principles of groundwater flow, nature and origin of aquifers and confining units, well hydraulics, groundwater modeling, and contaminant transport. Lab emphasizes applied field and laboratory methods for hydrogeological investigations.

ENSCI 412: Micropaleontology

(Cross-listed with GEOL). Cr. 3. Alt. F., offered even-numbered years.

Prereq: GEOL 102 and GEOL 102L

Evolution, identification and utility of major microfossil groups from the Mesozoic to present. Focus on Cenozoic applications including biostratigraphy, paleoclimate, and paleothermometry using assemblages, stable isotopes, Mg/Ca, and molecular fossils. Laboratory includes processing and analysis of specific microfossils. Major groups covered include foraminifera, calcareous nannofossils, sponge spicules, diatoms, radiolarians, and silicoflagellates.

ENSCI 413: Applied and Environmental Geophysics

(Dual-listed with ENSCI 513). (Cross-listed with C E, GEOL). (2-2) Cr. 3. Alt. S., offered odd-numbered years.

Prereq: GEOL 100 or GEOL 201, algebra and trigonometry

Seismic, gravity, magnetic, resistivity, electromagnetic, and ground-penetrating radar techniques for shallow subsurface investigations and imaging. Data interpretation methods. Lab emphasizes computer interpretation packages. Field work with seismic - and resistivity-imaging systems and radar.

ENSCI 414: Applied Groundwater Flow Modeling

(Dual-listed with ENSCI 514). (Cross-listed with GEOL). (2-2) Cr. 3. Alt. S., offered even-numbered years.

Prereq: GEOL 411 or C E 473; MATH 165 or MATH 181

Introduction to the principles of modeling groundwater flow systems. Finite-difference and analytic-element methods, spreadsheet models, boundary conditions, calibration, sensitivity analysis, parameter estimation, particle tracking, and post-audit analysis. Application of MODFLOW to regional flow-system analysis. Computer laboratory emphasizes assigned problems that illustrate topics discussed in the course.

ENSCI 415: Paleoclimatology

(Dual-listed with ENSCI 515). (Cross-listed with GEOL). (3-0) Cr. 3. Alt. S., offered odd-numbered years.

Prereq: Four courses in biological or physical science

Introduction to mechanisms that drive climate, including the interplay between oceanic and atmospheric circulation and fluctuation in Earth's orbital parameters. Examination and analysis of past climate records ranging from historical documentation to ecological and geochemical proxies (e.g. tree ring analysis; O and C isotopes of skeletal carbonates and soils). Dating methods used to constrain and correlate climatic periods, utility of computer models to reconstruct past climates and predict future climate change. Emphasis placed on paleoclimatology and paleoecology of the late Quaternary (last ~1 million years).

ENSCI 416: Hydrologic Modeling and Analysis

(Dual-listed with ENSCI 516). (Cross-listed with GEOL, MTEOR). (2-3) Cr. 3. Alt. S., offered odd-numbered years.

Prereq: Four courses in Earth science, meteorology, or engineering; junior standing.

Study of the basic principles of hydrologic modeling, including rainfall-runoff analysis, lumped and distributed modeling, conceptual and physical models, parameter estimation and sensitivity analysis, input and validation data, uncertainty analysis, and the use of models in surface water hydrology. A range of common models are applied to study hydrologic topics such as flood forecasting and land use change impacts. Previous experience with Matlab or other programming language is needed.

ENSCI 418: Stream Ecology

(Dual-listed with ENSCI 518). (Cross-listed with A ECL). (2-3) Cr. 3. Alt. F., offered odd-numbered years.

Prereq: A ECL 486

Biological, chemical, physical, and geological processes that determine the structure and function of flowing water ecosystems. Current ecological theories as well as applications to stream management for water quality and fisheries.

ENSCI 419: Aqueous and Environmental Geochemistry

(Dual-listed with ENSCI 519). (Cross-listed with GEOL). (2-2) Cr. 3. S.

Prereq: CHEM 178, CHEM 178L; junior classification

Geochemistry of natural waters and water-rock interactions. Acid-base equilibria, carbonate chemistry and buffer systems, mineral dissolution and precipitation, sorption, ion exchange, and redox reactions. Introduction to thermodynamics and kinetics. Laboratory emphasizes chemical analysis of waters and computer modeling.

ENSCI 420: Environmental Engineering Chemistry

(Dual-listed with ENSCI 520). (Cross-listed with C E). (2-3) Cr. 3. F.

Prereq: C E 326, CHEM 178

Principles of chemical and physical phenomena applicable to the treatment of water and wastewater and natural waters; including chemical equilibria, reaction kinetics, acid-base equilibria, chemical precipitation, redox reactions, and mass transfer principles. Individual laboratory practicals and group projects required.

ENSCI 422I: Prairie Ecology

(Cross-listed with IA LL). Cr. 4. SS.

Prereq: Familiarity with basic principles in biological sciences and ecology

Basic patterns and underlying physical and biotic causes of both regional and local distributions of plants and animals of North American prairies; field and laboratory analyses and projects.

ENSCI 424: Air Pollution

(Dual-listed with ENSCI 524). (Cross-listed with A B E, C E). (1-0) Cr. 1.

Prereq: Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above

1 cr. per module. Module A prereq for all modules; module B prereq for D and E.

ENSCI 424A: Air Pollution: Air quality and effects of pollutants

(Dual-listed with ENSCI 524A). (Cross-listed with A B E, C E). (1-0) Cr. 1.

Prereq: Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above

1 cr. per module. Module A prereq for all modules; module B prereq for D and E.

ENSCI 424B: Air Pollution: Climate change and causes

(Dual-listed with ENSCI 524B). (Cross-listed with A B E, C E). (1-0) Cr. 1.

Prereq: Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above

1 cr. per module. Module A prereq for all modules; module B prereq for D and E.

ENSCI 424C: Air Pollution: Transportation Air Quality

(Dual-listed with ENSCI 524C). (Cross-listed with A B E, C E). (1-0) Cr. 1.

Prereq: C E 524A; PHYS 221 or CHEM 178; MATH 166 or 3 credits in statistics. Senior classification or above.

ENSCI 424D: Air Pollution: Off-gas treatment technology

(Dual-listed with ENSCI 524D). (Cross-listed with A B E, C E). (1-0) Cr. 1.

Prereq: C E 524A, C E 524B; Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above

ENSCI 424E: Air Pollution: Agricultural sources of pollution

(Dual-listed with ENSCI 524E). (Cross-listed with A B E, C E). (1-0) Cr. 1.

Prereq: Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above

1 cr. per module. Module A prereq for all modules; module B prereq for D and E.

ENSCI 426: Stable Isotopes in the Environment

(Dual-listed with ENSCI 526). (Cross-listed with GEOL). (3-0) Cr. 3. Alt. S., offered even-numbered years.

Prereq: Four courses in biological or physical science

Introduction to the theory, methods and applications of stable isotopes. Primary focus on the origin, natural abundance, and fractionation of carbon, hydrogen, oxygen, nitrogen isotopes. Applications of isotopic occurrence for elucidation of physical, chemical, biological, and environmental processes. Effects of plant physiology, photosynthesis, trophic structure, diffusion, evaporation, chemical precipitation, soil and atmospheric processes, and environmental factors on isotope abundance.

ENSCI 437: Watershed Modeling and Policy

(Dual-listed with ENSCI 537). (Cross-listed with A B E). (2-2) Cr. 3. Alt. F., offered odd-numbered years.

Prereq: CE 372 or equivalent

A project-based course on watershed-scale models for improving water quality. Legislative and judicial basis of the Total Maximum Daily Load (TMDL) program; approaches to TMDL development; principles and techniques for implementation; stakeholder engagement strategies. Hands-on experiences with GIS-interfaced models, data sources, calibration/validation, statistical assessment of model results, and simulation using multiple tools. In addition to other assignments, graduate students will present case studies of TMDLs using different modeling tools.

ENSCI 446: Integrating GPS and GIS for Natural Resource Management

(Dual-listed with ENSCI 546). (Cross-listed with NREM). (2-3) Cr. 3. F.

Prereq: 12 credits in student's major at 300 level or above, NREM 345 or equivalent experience with ArcGIS

Emphasis on the use of GPS as a data collection tool for GIS. Basic theory of GPS. Use of Global Positioning System technology for spatial data collection and navigation. Post-processing and real-time correction of GPS data. GPS data transfer to GIS for mapping applications. Use of GIS to construct waypoints for use in GPS navigation.

ENSCI 452: GIS for Geoscientists

(Dual-listed with ENSCI 552). (Cross-listed with AGRON, GEOL). (2-2) Cr. 3. F.S.

Prereq: GEOL 100, GEOL 201 or equivalent

Introduction to geographic information systems (GIS) using ArcGIS Pro with particular emphasis on geoscientific data. Emphasizes typical GIS operations and analyses in the geosciences to prepare students for advanced GIS courses.

ENSCI 459: Environmental Soil and Water Chemistry

(Dual-listed with ENSCI 559). (Cross-listed with AGRON). (3-3) Cr. 4. F.

Prereq: Two semesters of college-level chemistry, MATH 140, AGRON 182 (or equivalent) or AGRON 360; GEOL 100 and AGRON 354 recommended

An introduction to the chemical properties of soils, chemical reactions and transformations in soils and surface waters, and their impact on the environment. Topics include solution chemistry in soils and surface waters, solid-phase composition of soils, reactions at the solid-solution interface, and applications to contemporary environmental issues.

ENSCI 461I: Introduction to GIS

(Cross-listed with ENV S, IA LL, L A). Cr. 4. SS.

Descriptive and predictive GIS modeling techniques, spatial statistics, and map algebra. Application of GIS modeling techniques to environmental planning and resource management.

ENSCI 463: Soil Formation and Landscape Relationships

(Dual-listed with ENSCI 563). (Cross-listed with AGRON). (3-0) Cr. 3. S.

Prereq: AGRON 182 (or equivalent) or AGRON 260

Relationships between soil formation, geomorphology, and environment. Soil description, classification, geography, mapping, and interpretation for land use. Two weekend field trips. Credit for one of AGRON 463 or AGRON 463I may be applied for graduation.

ENSCI 463I: Soil Formation and Landscape Relationships

(Dual-listed with ENSCI 563I). (Cross-listed with AGRON, IA LL). Cr. 2. Alt. SS., offered even-numbered years.

Prereq: AGRON 182 (or equivalent)

Relationships between soil formation, geomorphology, and environment. Soil description, classification, geography, mapping, and interpretation for land use. Credit for only Agron 563 or 563I may be applied for graduation.

ENSCI 464: Wetland Ecology

(Dual-listed with ENSCI 564). (Cross-listed with BIOL). (3-0) Cr. 3. S.

Prereq: 15 credits in biological sciences.

Ecology, classification, creation and restoration, and management of wetlands. Emphasis on North American temperate wetlands.

ENSCI 466: Ecosystem Service Management

(Dual-listed with ENSCI 566). (Cross-listed with ENT, NREM). (3-0) Cr. 3.

Alt. S., offered odd-numbered years.

Prereq: permission of instructor

Land use and conservation techniques for improving ecosystem services including: pollination of crops, biological control of pests, prevention of erosion and water quality improvement.

ENSCI 468: Applied Geostatistics for Geoscientists

(Dual-listed with ENSCI 568). (Cross-listed with GEOL, MTEOR). Cr. 3. F.

Prereq: GEOL 452, C R P 351, C R P 452, NREM 345, or NREM 446

Introduction to geospatial data collection, analysis, interpretation, and presentation. Geospatial techniques including geographic information systems (GIS), remote sensing (RS), and global positioning systems (GPS). Study of applied geostatistical analysis (e.g., interpolation and spatial regression).

ENSCI 477: Soil Physics

(Dual-listed with ENSCI 577). (Cross-listed with AGRON). (3-0) Cr. 3. S.

Prereq: AGRON 182 or equivalent and MATH 166 recommended

The physical soil system: the soil components and their physical interactions; transport processes involving water, air, and heat.

ENSCI 479: Surficial Processes

(Dual-listed with ENSCI 579). (Cross-listed with GEOL). (2-3) Cr. 3. F.

Prereq: GEOL 100 and GEOL 100L; or GEOL 201; or equivalent experience.

The study of physical processes that shape Earth's surface. Topics include weathering, sediment transport, and landform genesis with emphasis on fluvial, glacial, hillslope, eolian, and coastal processes. Applications to engineering and environmental problems. Laboratory includes topographic map interpretation and local field trips.

ENSCI 480: Engineering Analysis of Biological Systems

(Cross-listed with A B E). (2-2) Cr. 3. F.

Prereq: A B E 380 or permission of the instructor

Systems-level quantitative analysis of various biological systems, including applications in foods, feeds, biofuels, bioenergy, and other bio-based systems. Introduction to techno-economic analysis and life-cycle assessment of these systems at multiple production scales. Applying these tools to evaluate and improve cost and sustainability performance. Students enrolled in ABE 580 will be required to conduct additional learning activities.

ENSCI 483: Environmental Biogeochemistry

(Dual-listed with ENSCI 583). (Cross-listed with BIOL, GEOL). Cr. 3. Alt. S., offered odd-numbered years.

Prereq: Combined 12 credits in biology, chemistry, and physics.

An exploration of biological, physical and geochemical impacts on the structure and function of ecosystems from local to global scales. Emphasis on the cycles of carbon, nitrogen, phosphorus, sulfur, and metals, and how these have been impacted by human activity. Topics may include biological feedbacks to climate change, microbial physiology and redox reactions, plant/soil feedbacks, terrestrial/aquatic linkages, early Earth processes and the origins of life.

ENSCI 484: Ecosystem Ecology

(Cross-listed with BIOL). (3-0) Cr. 3. Alt. S., offered odd-numbered years.

Prereq: Combined 12 credits in biology, chemistry, and physics.

Introduction of the study of ecosystems and the biological and physical factors that influence their properties and dynamics. Conceptual foundations for ecosystem studies. Interactions among organisms, biological diversity, and ecosystem attributes. Quantitative analyses of accumulations, transformations, and fluxes of nutrients, water, and energy within and among ecosystems. Global change issues.

ENSCI 485: Soil and Environmental Microbiology

(Dual-listed with ENSCI 585). (Cross-listed with AGRON, MICRO). (2-3) Cr. 3. F.

Prereq: AGRON 182 or equivalent; MICRO 201 and MICRO 201L recommended

The living organisms in the soil and what they do. Emphasis on soil biota composition, the carbon cycle and bioremediation, soil-plant-microbial relationships, and environmental issues.

ENSCI 486: Aquatic Ecology

(Dual-listed with ENSCI 586). (Cross-listed with A ECL, BIOL). (3-0) Cr. 3. F.

Prereq: Biol 312 or EnSci 381 or EnSci 402 or NREM 301

Structure and function of aquatic ecosystems with application to fishery and pollution problems. Emphasis on lacustrine, riverine, and wetland ecology.

ENSCI 486L: Aquatic Ecology Laboratory

(Dual-listed with ENSCI 586L). (Cross-listed with A ECL, BIOL). (0-3) Cr. 1. F.

Prereq: Concurrent enrollment in BIOL 486

Field trips and laboratory exercises to accompany 486. Hands-on experience with aquatic research and monitoring techniques and concepts.

ENSCI 487: Microbial Ecology

(Dual-listed with ENSCI 587). (Cross-listed with BIOL, GEOL, MICRO). (3-0) Cr. 3. F.

Prereq: Six credits in biology and 6 credits in chemistry

Introduction to major functional groups of autotrophic and heterotrophic microorganisms and their roles in natural and environmental systems. Consequences of microbial activity on water chemistry, weathering, and precipitation/dissolution reactions will be emphasized.

ENSCI 488: GIS for Geoscientists II

(Dual-listed with ENSCI 588). (Cross-listed with AGRON, GEOL). (2-2) Cr. 3. Alt. S., offered odd-numbered years.

Prereq: GIS course, such as GEOL 452, CRP 451, CRP 452, NREM 345, NREM 446, AE 408 or equivalent

GIS course with focus on the spatial analysis and modeling of raster data and triangulated irregular network (TIN) data. Uses ArcGIS and various extensions, such as Spatial Analyst, 3D Analyst, and ArcScene. Includes practical exercises during lectures, lab exercises, homework assignments, and (for GEOL 588) a class project.

ENSCI 490: Independent Study

Cr. arr. Repeatable. F.S.SS.

Prereq: Permission of the instructor and approval of the Environmental Science coordinator

ENSCI 490H: Independent Study: Honors

Cr. arr. Repeatable. F.S.SS.

Permission of instructor and approval of Environmental Science coordinator.

ENSCI 495: Current Topics and Case Studies in Environmental Science

Cr. 1-3.

Prereq: Junior classification in Environmental Science, permission of instructor

Current topics and case studies related to the analysis and management of environmental systems. Individual and/or group projects.

ENSCI 496: Travel Course

Cr. arr. Repeatable.

Prereq: Permission of instructor

Extended field trips to study environmental topics in varied locations. Location and duration of trips will vary. Trip expenses paid by students. Check with department for current offerings. A. International Tour B. Domestic Tour.

ENSCI 496A: Travel Course: International Tour

Cr. arr. Repeatable.

Prereq: Permission of instructor

Extended field trips to study environmental topics in varied locations. Location and duration of trips will vary. Trip expenses paid by students. Check with department for current offerings.

ENSCI 496B: Travel Course: Domestic Tour

Cr. arr. Repeatable.

Prereq: Permission of instructor

Extended field trips to study environmental topics in varied locations. Location and duration of trips will vary. Trip expenses paid by students. Check with department for current offerings.

ENSCI 498: Cooperative Education

Cr. R. Repeatable. F.S.SS.

Prereq: Permission of Environmental Science Coordinator

Required of all cooperative education students. Students must register prior to commencing each work period.

Courses primarily for graduate students, open to qualified undergraduates:**ENSCI 502: Watershed Hydrology**

(Dual-listed with ENSCI 402). (Cross-listed with GEOL, MTEOR, NREM). (2-3) Cr. 3. F.

Prereq: Four courses in physical or biological sciences or engineering; junior standing

Examination of watersheds as systems, emphasizing the surface components of the hydrologic cycle. Combines qualitative understanding of hydrological processes and uncertainty with quantitative representation. Laboratory emphasizes field investigation and measurement of watershed processes.

ENSCI 504: Global Change

(Dual-listed with ENSCI 404). (Cross-listed with AGRON, MTEOR). (3-0) Cr. 3. S.

Prereq: Four courses in physical or biological sciences or engineering; junior standing

Recent changes in global biogeochemical cycles and climate; models of future changes in the climate system; impacts of global change on agriculture, water resources and human health; ethical issues of global environmental change. Also offered online Alt. F, even-numbered years.

ENSCI 505: Environmental Biophysics

(Dual-listed with ENSCI 405). (Cross-listed with AGRON, MTEOR). (3-0) Cr. 3. Alt. S., offered odd-numbered years.

Prereq: MATH 165 and some exposure to computer programming (any language)

The movement of energy and mass among the soil, vegetation, and atmosphere. The heat and water budget of humans, other animals, plants, and plant communities. Relevance to weather and climate, the effect of climate change on organisms, and remote sensing.

ENSCI 507: Watershed Management

(Dual-listed with ENSCI 407). (Cross-listed with NREM). (3-3) Cr. 4. S.

Prereq: A course in general biology

Managing human impacts on the hydrologic cycle. Field and watershed level best management practices for modifying the impacts on water quality, quantity and timing are discussed. Field project includes developing a management plan using landscape buffers.

ENSCI 508: Aquatic Ecology

(Cross-listed with IA LL, NREM). Cr. 4. SS.

Prereq: Courses in ecology, chemistry, and physics

Analysis of aquatic ecosystems; emphasis on basic ecological principles; ecological theories tested in the field; identification of common plants and animals.

ENSCI 509: Field Methods in Hydrogeology

(Dual-listed with ENSCI 409). (Cross-listed with GEOL). (0-4) Cr. 3. Alt. SS., offered even-numbered years.

Prereq: GEOL/ENSCI 402 or GEOL/ENSCI 411 or C E 473

Introduction to field methods used in groundwater investigations. In-field implementation of pumping tests, slug tests, monitoring well installation and drilling techniques, geochemical and water quality sampling, seepage meters, minipiezometers, stream gaging, and electronic instrumentation for data collection. Field trips to investigate water resource, water quality, and remediation projects.

ENSCI 511: Hydrogeology

(Dual-listed with ENSCI 411). (Cross-listed with GEOL). (3-2) Cr. 4. F.

Prereq: Four courses in biological or physical sciences

Physical principles of groundwater flow, nature and origin of aquifers and confining units, well hydraulics, groundwater modeling, and contaminant transport. Lab emphasizes applied field and laboratory methods for hydrogeological investigations.

ENSCI 513: Applied and Environmental Geophysics

(Dual-listed with ENSCI 413). (Cross-listed with C E, GEOL). (2-2) Cr. 3. Alt. S., offered odd-numbered years.

Prereq: GEOL 100 or GEOL 201, algebra and trigonometry

Seismic, gravity, magnetic, resistivity, electromagnetic, and ground-penetrating radar techniques for shallow subsurface investigations and imaging. Data interpretation methods. Lab emphasizes computer interpretation packages. Field work with seismic - and resistivity-imaging systems and radar.

ENSCI 514: Applied Groundwater Flow Modeling

(Dual-listed with ENSCI 414). (Cross-listed with GEOL). (2-2) Cr. 3. Alt. S., offered even-numbered years.

Prereq: GEOL 411 or C E 473; MATH 165 or MATH 181

Introduction to the principles of modeling groundwater flow systems. Finite-difference and analytic-element methods, spreadsheet models, boundary conditions, calibration, sensitivity analysis, parameter estimation, particle tracking, and post-audit analysis. Application of MODFLOW to regional flow-system analysis. Computer laboratory emphasizes assigned problems that illustrate topics discussed in the course.

ENSCI 515: Paleoclimatology

(Dual-listed with ENSCI 415). (Cross-listed with GEOL). (3-0) Cr. 3. Alt. S., offered odd-numbered years.

Prereq: Four courses in biological or physical science

Introduction to mechanisms that drive climate, including the interplay between oceanic and atmospheric circulation and fluctuation in Earth's orbital parameters. Examination and analysis of past climate records ranging from historical documentation to ecological and geochemical proxies (e.g. tree ring analysis; O and C isotopes of skeletal carbonates and soils). Dating methods used to constrain and correlate climatic periods; utility of computer models to reconstruct past climates and predict future climate change. Emphasis placed on paleoclimatology and paleoecology of the late Quaternary (last ~ 1 million years).

ENSCI 516: Hydrologic Modeling and Analysis

(Dual-listed with ENSCI 416). (Cross-listed with GEOL, MTEOR). (2-3) Cr. 3. Alt. S., offered odd-numbered years.

Prereq: Four courses in earth science, meteorology, or engineering; junior standing

Study of the basic principles of hydrologic modeling, including rainfall-runoff analysis, lumped and distributed modeling, conceptual and physical models, parameter estimation and sensitivity analysis, input and validation data, uncertainty analysis, and the use of models in surface water hydrology. A range of common models are applied to study hydrologic topics such as flood forecasting and land use change impacts. Previous experience with Matlab or other programming language is needed.

ENSCI 518: Stream Ecology

(Dual-listed with ENSCI 418). (Cross-listed with A ECL). (2-3) Cr. 3. Alt. F., offered odd-numbered years.

Prereq: A ECL 486

Biological, chemical, physical, and geological processes that determine the structure and function of flowing water ecosystems. Current ecological theories as well as applications to stream management for water quality and fisheries.

ENSCI 519: Aqueous and Environmental Geochemistry

(Dual-listed with ENSCI 419). (Cross-listed with GEOL). (2-2) Cr. 3. S.

Prereq: CHEM 178, CHEM 178L; junior classification

Geochemistry of natural waters and water-rock interactions. Acid-base equilibria, carbonate chemistry and buffer systems, mineral dissolution and precipitation, sorption, ion exchange, and redox reactions. Introduction to thermodynamics and kinetics. Laboratory emphasizes chemical analysis of waters and computer modeling.

ENSCI 520: Environmental Engineering Chemistry

(Dual-listed with ENSCI 420). (Cross-listed with C E). (2-3) Cr. 3. F.

Prereq: C E 326, CHEM 178

Principles of chemical and physical phenomena applicable to the treatment of water and wastewater and natural waters; including chemical equilibria, reaction kinetics, acid-base equilibria, chemical precipitation, redox reactions, and mass transfer principles. Individual laboratory practicals and group projects required.

ENSCI 521: Environmental Biotechnology

(Cross-listed with C E). (2-2) Cr. 3. F.

Prereq: C E 326

Fundamentals of biochemical and microbial processes applied to environmental engineering processes, role of microorganisms in wastewater treatment and bioremediation, bioenergetics and kinetics, metabolism of xenobiotic compounds, waterborne pathogens and parasites, and disinfection. Term paper and oral presentation.

ENSCI 522: Water Pollution Control Processes

(Cross-listed with C E). (2-2) Cr. 3.

Prereq: C E 421 or C E 521

Fundamentals of biochemical processes, aerobic growth in a single CSTR, multiple events in complex systems, and techniques for evaluating kinetic parameters; unit processes of activated sludge system, attached growth systems, stabilization and aerated lagoon systems, biosolids digestion and disposal, nutrient removal, and anaerobic treatment systems.

ENSCI 523: Physical-Chemical Treatment Process

(Cross-listed with C E). (2-2) Cr. 3.

Prereq: C E 520

Material and energy balances. Principles and design of physical-chemical unit processes; including screening, coagulation, flocculation, chemical precipitation, sedimentation, filtration, lime softening and stabilization, oxidation, adsorption, membrane processes, ion exchange and disinfection; recovery of resources from residuals and sludges; laboratory exercises and demonstrations; case studies in mineral processing and secondary industries.

ENSCI 524: Air Pollution

(Dual-listed with ENSCI 424). (Cross-listed with A B E, C E). (1-0) Cr. 1.

Prereq: Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above

1 cr. per module. Module A prereq for all modules; module B prereq for D and E.

ENSCI 524A: Air Pollution: Air quality and effects of pollutants

(Dual-listed with ENSCI 424A). (Cross-listed with A B E, C E). (1-0) Cr. 1.

Prereq: Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above

1 cr. per module. Module A prereq for all modules; module B prereq for D and E.

ENSCI 524B: Air Pollution: Climate change and causes

(Dual-listed with ENSCI 424B). (Cross-listed with A B E, C E). (1-0) Cr. 1.

Prereq: Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above

1 cr. per module. Module A prereq for all modules; module B prereq for D and E.

ENSCI 524C: Air Pollution: Transportation Air Quality

(Dual-listed with ENSCI 424C). (Cross-listed with A B E, C E). (1-0) Cr. 1.

Prereq: C E 524A; PHYS 221 or CHEM 178; MATH 166 or 3 credits in statistics. Senior classification or above.

ENSCI 524D: Air Pollution: Off-gas treatment technology

(Dual-listed with ENSCI 424D). (Cross-listed with A B E, C E). (1-0) Cr. 1.

Prereq: C E 524A, C E 524B; Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above

ENSCI 524E: Air Pollution: Agricultural sources of pollution

(Dual-listed with ENSCI 424E). (Cross-listed with A B E, C E). (1-0) Cr. 1.

Prereq: Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above

1 cr. per module. Module A prereq for all modules; module B prereq for D and E.

ENSCI 526: Stable Isotopes in the Environment

(Dual-listed with ENSCI 426). (Cross-listed with GEOL). (3-0) Cr. 3. Alt. S., offered even-numbered years.

Prereq: Four courses in biological or physical science

Introduction to the theory, methods and applications of stable isotopes.

Primary focus on the origin, natural abundance, and fractionation of carbon, hydrogen, oxygen, nitrogen isotopes. Applications of isotopic occurrence for elucidation of physical, chemical, biological, and environmental processes. Effects of plant physiology, photosynthesis, trophic structure, diffusion, evaporation, chemical precipitation, soil and atmospheric processes, and environmental factors on isotope abundance.

ENSCI 528: Solid and Hazardous Waste Management

(Cross-listed with C E). (3-0) Cr. 3.

Prereq: C E 326 or background courses in both environmental chemistry and microbiology; junior or higher standing

Evaluation, characterization, assessment, planning and design of solid and hazardous waste management systems, regulatory requirements, material characterization and collection, minimization and recycling, energy and materials recovery, composting, off-gas treatment, incineration, stabilization, and landfill design. Design of treatment and disposal systems, including physical, chemical, and biological treatment, solidification, incineration, secure landfill design, and final disposal site closure plus restoration.

ENSCI 531: Design and Evaluation of Soil and Water Conservation Systems

(Cross-listed with A B E). (2-3) Cr. 3. F.

Prereq: E M 378 or CH E 356

Hydrology and hydraulics in agricultural and urbanizing watersheds.

Design and evaluation of systems for the conservation and quality preservation of soil and water resources. Use and analysis of hydrologic data in engineering design; relationship of topography, soils, crops, climate, and cultural practices in conservation and quality preservation of soil and water for agriculture. Small watershed hydrology, water movement and utilization in the soil-plant-atmosphere system, agricultural water management, best management practices, and agricultural water quality. Graduate students will prepare several research literature reviews on topics covered in the class in addition to the other assignments.

ENSCI 532: Nonpoint Source Pollution and Control

(Cross-listed with A B E). (3-0) Cr. 3.

Prereq: A B E 431 or C E 372

Characteristics and courses of non-point source (NPS) pollution in agricultural and urban watersheds, computer modeling and NPS pollution for terrestrial and aquatic systems, strategies to control and manage NPS pollution of water bodies, total maximum daily loads (TMDLs) and integrated watershed management. Graduate students are required to review research papers and develop/deliver lecture models on assigned topics.

ENSCI 533: Erosion and Sediment Transport

(Cross-listed with A B E, NREM). (2-3) Cr. 3. Alt. F., offered even-numbered years.

Prereq: C E 372 or GEOL/ENSCI/MTEOR 402, MATH 166 or equivalent

Soil erosion processes, soil loss equations and their application to conservation planning, sediment properties, initiation of sediment motion and over land flow, flow in alluvial channels and theory of sediment transport, channel stability, reservoir sedimentation, wind erosion, BMPs for controlling erosion.

ENSCI 534: Contaminant Hydrogeology

(Cross-listed with GEOL). (3-0) Cr. 3. S.

Prereq: GEOL 511 or equivalent

Theory and practical considerations of fate and transport of solutes through porous geologic materials. Organic and inorganic contaminants in industrial and agricultural settings. Subsurface microbiology and biodegradation of aromatic and chlorinated hydrocarbons. Investigation of coupled processes (diffusion, advection, dispersion, sorption, and biodegradation) using computer models. Soil and groundwater monitoring and remediation strategies.

ENSCI 535: Restoration Ecology

(Cross-listed with EEOB, NREM). (2-3) Cr. 3. Alt. F., offered even-numbered years.

Prereq: BIOL 366 or BIOL 474 or graduate standing

Theory and practice of restoring animal and plant diversity, structure and function of disturbed ecosystems. Restored freshwater wetlands, forests, prairies and reintroduced species populations will be used as case studies.

ENSCI 535I: Restoration Ecology

(Cross-listed with A ECL, EEOB, IA LL). Cr. 2. Alt. SS., offered even-numbered years.

Prereq: A course in ecology

Ecological principles for the restoration of native ecosystems; establishment (site preparation, selection of seed mixes, planting techniques) and management (fire, mowing, weed control) of native vegetation; evaluation of restorations. Emphasis on the restoration of prairie and wetland vegetation.

ENSCI 536: Design and Evaluation of Soil and Water Monitoring Systems

(Cross-listed with A B E). (2-3) Cr. 3. Alt. S., offered even-numbered years.

Prereq: A B E 431

Development of monitoring systems that support effective planning, performance evaluation, modeling, or environmental impact assessment of soil-, water-, and waste-management systems. Typical soil and water pollutants and physical, chemical, and biological characteristics that affect sample location and timing. Sample collection, documentation, chain-of-custody, and quality assurance procedures. In addition to other assignments, graduate students will prepare several research literature reviews on topics covered in the class and develop monitoring plans.

ENSCI 537: Watershed Modeling and Policy

(Dual-listed with ENSCI 437). (Cross-listed with A B E). (2-2) Cr. 3. Alt. F., offered odd-numbered years.

Prereq: CE 372 or equivalent

A project-based course on watershed-scale models for improving water quality. Legislative and judicial basis of the Total Maximum Daily Load (TMDL) program; approaches to TMDL development; principles and techniques for implementation; stakeholder engagement strategies. Hands-on experiences with GIS-interfaced models, data sources, calibration/validation, statistical assessment of model results, and simulation using multiple tools. In addition to other assignments, graduate students will present case studies of TMDLs using different modeling tools.

ENSCI 546: Integrating GPS and GIS for Natural Resource Management

(Dual-listed with ENSCI 446). (Cross-listed with NREM). (2-3) Cr. 3. F.

Prereq: 12 credits in student's major at 300 level or above, NREM 345 or equivalent experience with ArcGIS

Emphasis on the use of GPS as a data collection tool for GIS. Basic theory of GPS. Use of Global Positioning System technology for spatial data collection and navigation. Post-processing and real-time correction of GPS data. GPS data transfer to GIS for mapping applications. Use of GIS to construct waypoints for use in GPS navigation.

ENSCI 552: GIS for Geoscientists

(Dual-listed with ENSCI 452). (Cross-listed with AGRON, GEOL). (2-2) Cr. 3. F.S.

Prereq: GEOL 100, GEOL 201 or equivalent

Introduction to geographic information systems (GIS) using ArcGIS Pro with particular emphasis on geoscientific data. Emphasizes typical GIS operations and analyses in the geosciences to prepare students for advanced GIS courses.

ENSCI 553: Soil-Plant Relationships

(Cross-listed with AGRON). (3-0) Cr. 3. S.

Prereq: AGRON 354

Composition and properties of soils in relation to the nutrition and growth of plants.

ENSCI 558: Laboratory Methods in Soil Chemistry

(Cross-listed with AGRON). (2-3) Cr. 3. Alt. F., offered even-numbered years.

Prereq: AGRON 354 and CHEM 211

Experimental and descriptive inorganic and organic analyses. Operational theory and principles of applicable instruments, including spectrophotometry, atomic and molecular absorption and emission spectroscopy, mass spectrometry, X-ray diffraction and fluorescence, gas and ion chromatography, and ion-selective electrodes.

ENSCI 559: Environmental Soil and Water Chemistry

(Dual-listed with ENSCI 459). (Cross-listed with AGRON). (3-3) Cr. 4. F.

Prereq: Two semesters of college-level chemistry, MATH 140, AGRON 182 (or equivalent) or AGRON 360; GEOL 100 and AGRON 354 recommended

An introduction to the chemical properties of soils, chemical reactions and transformations in soils and surface waters, and their impact on the environment. Topics include solution chemistry in soils and surface waters, solid-phase composition of soils, reactions at the solid-solution interface, and applications to contemporary environmental issues.

ENSCI 563: Soil Formation and Landscape Relationships

(Dual-listed with ENSCI 463). (Cross-listed with AGRON). (3-0) Cr. 3. S.

Prereq: AGRON 182 (or equivalent) or AGRON 260

Relationships between soil formation, geomorphology, and environment. Soil description, classification, geography, mapping, and interpretation for land use. Two weekend field trips. Credit for one of AGRON 463 or AGRON 463I may be applied for graduation.

ENSCI 563I: Soil Formation and Landscape Relationships

(Dual-listed with ENSCI 463I). (Cross-listed with AGRON, IA LL). Cr. 2. Alt. SS., offered even-numbered years.

Prereq: AGRON 182 (or equivalent)

Relationships between soil formation, geomorphology, and environment. Soil description, classification, geography, mapping, and interpretation for land use. Credit for only Agron 563 or 563I may be applied for graduation.

ENSCI 564: Wetland Ecology

(Dual-listed with ENSCI 464). (Cross-listed with EEOB). (3-0) Cr. 3. S.

Prereq: 15 credits in biological sciences.

Ecology, classification, creation and restoration, and management of wetlands. Emphasis on North American temperate wetlands.

ENSCI 564I: Wetland Ecology

(Cross-listed with EEOB, IA LL). Cr. 4. SS.

Prereq: Ia LL 312I

Ecology, classification, creation, restoration, and management of wetlands. Field studies will examine the composition, structure and functions of local natural wetlands and restored prairie pothole wetlands. Individual or group projects.

ENSCI 566: Ecosystem Service Management

(Dual-listed with ENSCI 466). (Cross-listed with ENT, NREM). (3-0) Cr. 3.

Alt. S., offered odd-numbered years.

Prereq: permission of instructor

Land use and conservation techniques for improving ecosystem services including: pollination of crops, biological control of pests, prevention of erosion and water quality improvement.

ENSCI 568: Applied Geostatistics for Geoscientists

(Dual-listed with ENSCI 468). (Cross-listed with GEOL, MTEOR). Cr. 3. F.

Prereq: GEOL 452, C R P 351, C R P 452, NREM 345, or NREM 446

Introduction to geospatial data collection, analysis, interpretation, and presentation. Geospatial techniques including geographic information systems (GIS), remote sensing (RS), and global positioning systems (GPS). Study of applied geostatistical analysis (e.g., interpolation and spatial regression).

ENSCI 571: Surface Water Hydrology

(Cross-listed with C E). (3-0) Cr. 3. S.

Prereq: C E 372

Analysis of hydrologic data including precipitation, infiltration, evapotranspiration, direct runoff and streamflow; theory and use of frequency analysis; theory of streamflow and reservoir routing; use of deterministic and statistical hydrologic models. Fundamentals of surface water quality modeling, point and non-point sources of contamination.

ENSCI 572: Analysis and Modeling Aquatic Environments

(Cross-listed with C E). (3-0) Cr. 3. Alt. F., offered even-numbered years.

Prereq: C E 372

Principles of surface water flows and mixing. Introduction to hydrologic transport and water quality simulation in natural water systems. Advection, diffusion and dispersion, chemical and biologic kinetics, and water quality dynamics. Applications to temperature, dissolved oxygen, primary productivity, and other water quality problems in rivers, lakes and reservoirs. Deterministic vs. stochastic models.

ENSCI 573: Groundwater Hydrology

(3-0) Cr. 3. F.

Prereq: C E 372

Principles of groundwater flow, hydraulics of wells, superposition, slug and pumping tests, streamlines and flownets, and regional groundwater flow. Contaminant transport. Computer modeling. Design project. Extra assignments required for graduate students.

ENSCI 575: Soil Formation and Transformation

(Cross-listed with AGRON). (3-0) Cr. 3. F.

Prereq: AGRON 463 or equivalent

Advanced study of soil formation, emphasizing relationships among soils, landscapes, environment, humans, and land use.

ENSCI 577: Soil Physics

(Dual-listed with ENSCI 477). (Cross-listed with AGRON). (3-0) Cr. 3. S.

Prereq: AGRON 182 or equivalent and MATH 166 recommended

The physical soil system: the soil components and their physical interactions; transport processes involving water, air, and heat.

ENSCI 578: Laboratory Methods in Soil Physics

(Cross-listed with AGRON). (0-3) Cr. 1. S.

Prereq: concurrent enrollment in AGRON 477 or AGRON 577

Methods of measuring soil physical properties such as texture, density, and water content, and transport of heat, water, and gases.

ENSCI 579: Surficial Processes

(Dual-listed with ENSCI 479). (Cross-listed with GEOL). (2-3) Cr. 3. F.
Prereq: GEOL 100 and GEOL 100L; or GEOL 201; or equivalent experience.
 The study of physical processes that shape Earth's surface. Topics include weathering, sediment transport, and landform genesis with emphasis on fluvial, glacial, hillslope, eolian, and coastal processes. Applications to engineering and environmental problems. Laboratory includes topographic map interpretation and local field trips.

ENSCI 581: Environmental Systems I: Introduction to Environmental Systems

(Dual-listed with ENSCI 381). (Cross-listed with EEOB). Cr. 3-4. F.
Prereq: 12 credits of natural science including biology and chemistry
 Introduction to the structure and function of natural environmental systems. Emphasis on the analysis of material and energy flows in natural environmental systems and the primary environmental factors controlling these systems.

ENSCI 582: Environmental Systems II: Analysis of Environmental Systems

(Dual-listed with ENSCI 382). (Cross-listed with EEOB). (2-2) Cr. 3. S.
Prereq: ENSCI 381
 Continuation of EnSci 381. Systems approach to the analysis of material and energy flows in natural environmental systems and the primary environmental factors controlling these systems.

ENSCI 583: Environmental Biogeochemistry

(Dual-listed with ENSCI 483). Cr. 3. Alt. S., offered odd-numbered years.
Prereq: Combined 12 credits in biology, chemistry, and physics.
 An exploration of biological, physical and geochemical impacts on the structure and function of ecosystems from local to global scales. Emphasis on the cycles of carbon, nitrogen, phosphorus, sulfur, and metals, and how these have been impacted by human activity. Topics may include biological feedbacks to climate change, microbial physiology and redox reactions, plant/soil feedbacks, terrestrial/aquatic linkages, early Earth processes and the origins of life.

ENSCI 584: Ecosystem Science

(Cross-listed with EEOB). (3-0) Cr. 3. Alt. S., offered even-numbered years.
Prereq: Combined 12 credits in biology, chemistry, and physics.
 Advanced studies of ecosystems and the biological and physical factors that influence their properties and dynamics. Conceptual foundations and modern approaches to ecosystem studies. Interactions among organisms, biological diversity, and ecosystem attributes. Quantitative analyses of accumulations, transformations, and fluxes of nutrients, water, and energy within and among ecosystems. Global change issues.

ENSCI 585: Soil and Environmental Microbiology

(Dual-listed with ENSCI 485). (Cross-listed with AGRON, MICRO). (2-3) Cr. 3. F.
Prereq: AGRON 182 or equivalent; MICRO 201 and MICRO 201L recommended
 The living organisms in the soil and what they do. Emphasis on soil biota composition, the carbon cycle and bioremediation, soil-plant-microbial relationships, and environmental issues.

ENSCI 586: Aquatic Ecology

(Dual-listed with ENSCI 486). (Cross-listed with A ECL, EEOB). (3-0) Cr. 3. F.
Prereq: Biol 312 or EnSci 381 or EnSci 402 or NREM 301
 Structure and function of aquatic ecosystems with application to fishery and pollution problems. Emphasis on lacustrine, riverine, and wetland ecology.

ENSCI 586L: Aquatic Ecology Laboratory

(Dual-listed with ENSCI 486L). (Cross-listed with A ECL, EEOB). (0-3) Cr. 1. F.
Prereq: Concurrent enrollment in BIOL 486
 Field trips and laboratory exercises to accompany 486. Hands-on experience with aquatic research and monitoring techniques and concepts.

ENSCI 587: Microbial Ecology

(Dual-listed with ENSCI 487). (Cross-listed with EEOB, GEOL, MICRO). (3-0) Cr. 3. F.
Prereq: Six credits in biology and 6 credits in chemistry
 Introduction to major functional groups of autotrophic and heterotrophic microorganisms and their roles in natural and environmental systems. Consequences of microbial activity on water chemistry, weathering, and precipitation/dissolution reactions will be emphasized.

ENSCI 588: GIS for Geoscientists II

(Dual-listed with ENSCI 488). (Cross-listed with AGRON, GEOL). (2-2) Cr. 3. Alt. S., offered odd-numbered years.
Prereq: GIS course, such as GEOL 452, CRP 451, CRP 452, NREM 345, NREM 446, AE 408 or equivalent
 GIS course with focus on the spatial analysis and modeling of raster data and triangulated irregular network (TIN) data. Uses ArcGIS and various extensions, such as Spatial Analyst, 3D Analyst, and ArcScene. Includes practical exercises during lectures, lab exercises, homework assignments, and (for GEOL 588) a class project.

ENSCI 590: Special Topics

Cr. arr. Repeatable. F.S.SS.
Prereq: Permission of major professor in Environmental Science faculty
 Literature reviews and conference in accordance with needs and interest of the student.

ENSCI 599: Creative Component

Cr. arr. Repeatable. F.S.SS.

Prereq: Permission of major professor in Environmental Science faculty

Creative component for nonthesis master of science degree.

Courses for graduate students:

ENSCI 685: Advanced Soil Biochemistry

(Cross-listed with AGRON, MICRO). (2-0) Cr. 2. Alt. S., offered even-numbered years.

Prereq: AGRON 585

Chemistry of soil organic matter and biochemical transformations brought about by microorganisms and enzymes in soils.

ENSCI 698: Seminar in Environmental Science

Cr. 1-3. Repeatable. S.

Reports and discussion of recent research and literature.

ENSCI 699: Research

Cr. arr. Repeatable. F.S.SS.