Course Numbering and Symbols—
Courses primarily for freshmen and sophomores are numbered 1000 through 1998; for juniors and seniors, 3000 through 3998; for juniors, seniors, and graduate students, 5000 through 5998. Courses numbered 8000 and above are restricted to students registered in the Graduate School.

The following symbols are used throughout the course descriptions:

, ........ The comma, used in prerequisite listings, means “and.”
† ....... All courses preceding this symbol must be completed before credit will be granted for any quarter of the sequence.
§ ....... Credit will not be granted if credit has been received for the course listed after this symbol.
¶ ...... Concurrent registration is required (or allowed) in the course listed after this symbol.
# ...... Approval of the instructor is required for registration.
∆ ...... Approval of the department offering the course is required for registration.
□ ...... Approval of the college offering the course is required for registration.
H ...... Honors course (follows the course number).

A prerequisite course listed by number only (e.g., prereq 5246) is in the same department as the course being described.

Agricultural and Applied Economics (ApEc)

ApEc 1101. Principles of Microeconomics. (4 cr, §Econ 1002; prereq 1102)
Economics of the firm and household; factor and product price determination; theory of production, consumption, and distribution; supply and demand analysis; equilibrium analysis.

Determinants of natural income and employment levels; prices and money; the banking system; monetary and fiscal policy; economic growth and development; role of government in the economy.

ApEc 3040. Economic Development of American Agriculture. (4 cr; prereq 1101 or Econ 1101)
Review of economic, political, social, and technical forces that have shaped the development of American agriculture; role of agricultural development in national economic development in the United States; implications for presently developing countries.

ApEc 3610. Resource Development and Environmental Economics. (4 cr; prereq 1101, 1102 or Econ 1101, Econ 1102 or #)
Resource use concepts, including physical and economic classifications, physical and economic feasibility, benefits and costs, external effects, cost sharing, selected resource use problems. Economic areas and units for planning and development; generation of alternative program elements and development of consequences; problems in choosing elements for an optimum resource development program.

ApEc 5600. Land and Water Economics. (3 cr; prereq 1101 or Econ 1101)
Land and water as public resources and as factors of production; economic analysis of policies that influence asset use; sale and rental markets; valuation of rights to land and water, taxation and regulation as instruments influencing private management decisions; comparative land and water legal and market settings.

ApEc 5650. Economics of Natural Resource and Environmental Policy. (4 cr; prereq 3002 or 3610 or Econ 3101 or #)
Application of economic analysis, including project evaluation, to current natural resource and environmental issues. Emphasis on conservation and resource scarcity, environmental quality, and resource use issues and their implications for public policy.

Chemistry (Chem)

Chem 1001. General Principles of Chemistry. (4 cr, §1008, §1031-1032, §1051-1052)
Introduction to chemistry, matter and energy, atoms, molecules, chemical bonding, the mole and chemical calculations, gases, liquids, solids, solutions, chemical reactions, acids, bases and equilibrium.

Chem 1002. Elementary Organic Chemistry. (4 cr, §3301, §3302; prereq 1001 or advanced placement by exam)
Short introduction to organic chemistry with emphasis on biological systems.

Chem 1051-1052†. General Principles I-II. (4 cr per qtr, §1001-1002, §1031-1032)
Introduction to chemistry from the standpoint of atomic structure; periodic properties of elements and compounds derivable from structural considerations; laws governing behavior of matter, theories of solutions, acids, bases, and equilibria.

Chem 3100. Quantitative Analysis Lecture. (3 cr; prereq 1052 for non-chem majors)
Theory of quantitative chemical analysis.
Chem 3101. Quantitative Analysis Laboratory.  
(2 cr; prereq 3100 for non-chem majors; 8 lab hrs per wk)  
Lab introduction to quantitative chemical analysis.

(4 cr, §3331; for non-chem majors; prereq 1005 or 1032 or equiv; 4 lect hrs per wk)  
Important classes of organic compounds, both aliphatic and aromatic, together with some heterocyclic compounds.

Chem 3302. Elementary Organic Chemistry II.  
(4 cr; prereq 3301, 3305; 4 lect hrs per wk; if 3305 is taken concurrently, a passing grade is required for 3305 in order to receive cr for 3302)  
Continuation of Chem 3301.

Chem 3305. Elementary Organic Chemistry Laboratory I.  
(2 cr; prereq 3301 or ¶3301; 1 lab conf, 4 lab hrs per wk)  
Techniques used to prepare typical organic substances.

Chem 3306. Elementary Organic Chemistry Laboratory II.  
(2 cr; prereq 3302 or ¶3302; 1 lab conf, 4 lab hrs per wk)  
Techniques used to prepare typical organic substances.

FW 1001. Orientation in Fisheries and Wildlife.  
(1 cr)  
Survey of technical requirements and education of fishery and wildlife managers and scientists; introduction to fields of work, problems, and career opportunities.

(3 cr)  
Controversial issues involving specific wildlife management principles and techniques. For students without natural science background interested in natural resource topics, especially wildlife issues.

FW 3052. Introduction to Fisheries and Wildlife Conservation.  
(3 cr)  
Ecological principles applied to managing fish and wildlife populations and their habitats; legislation, agencies, and policy affecting fish and wildlife conservation.

(3 cr; prereq one ecol course)  
History and current issues in biological conservation; conservation theory and practice, including management for sustained yield, exotic and endangered species, and design of protected areas. Global ecosystems; case studies of management at the landscape level.

FW 3106. Important Plants: Fisheries and Wildlife Habitats.  
(2 cr; prereq ¶3600 or #, ¶at ltasca)  
Field identification of important plants in fisheries and wildlife habitats.

FW 5129. Mammalogy.  
(5 cr, §EEB 5129; prereq Biol 1106 or 3011 or #)  
Recent families and orders of mammals of the world and genera and species of mammals of North America, with emphasis on morphology, evolution, and zoogeographic history.

FW 5200. Honors Research.  
(3 cr; admission to FW honors program)  
Lectures and discussions on current topics presented by faculty and students.

FW 5278. Special Lectures: Wildlife.  
(Cr ar; offered when feasible)  
Lectures in special fields of wildlife given by a visiting scholar or regular staff member.

FW 5279. Special Lectures: Fisheries.  
(Cr ar; offered when feasible)  
Lectures in special fields of fisheries given by a visiting scholar or regular staff member.

FW 5393. Special Problems: Fisheries Biology.  
(Cr ar; prereq #)  
Individual field, library, and lab research in fisheries biology.

(Cr ar; prereq #)  
Individual field, library, and lab research in wildlife biology.

FW 5455. Aquaculture.  
(3 cr; prereq Biol 1009, 1103, 1106 or equiv, Chem 1051-1052 or equiv or #; offered alt yrs)  
Role of aquaculture in resource management and world food production; institutional and economic considerations; principles of husbandry of aquatic organisms; interactions between fish metabolism and water quality; nutrition and energetics; fish health and genetics.

FW 5459. Fish Physiology.  
(4 cr; prereq AnSci 3301 or EEB 5136 or EEB 5156 or #)  
Relationships between the physiology of fishes, their behavior, and the aquatic environment. Includes examination of ionic and osmotic balance, gas exchange, locomotion, orientation and migration, reproduction, endocrinology, growth, and stress.

FW 5460. Pollution Impacts on Aquatic Systems.  
(2 cr; prereq Biol 5041, EEB 5601, Chem 1051-1052, 3301, 3305 or #; offered alt yrs)  
Pollution assessment approaches, biological effects, fate and flow of contaminants in aquatic systems and major types of pollutants will be described.

FW 5461. The Behavior of Fishes.  
(3 cr; prereq EEB 1111 or FW 5459 or #, offered alt yrs)  
Organismal and sub-organismal perspectives of fish behavior. Feeding behavior and optimal foraging theory, learning and intelligence in fish, genetic basis of behavior, neural and endocrine bases of behavior, communication, orientation and navigation, schooling and shoaling, reproduction, and application of an understanding of fish behavior to the harvest, management, and conservation of fishes.
FW 5465. Sustainable Fisheries and Aquaculture. (5 cr; prereq general biology, chemistry, ecology; at Itasca)
Study of the structure and function of indigenous fisheries and aquaculture ecosystems as models for sustainable aquatic ecosystems management and development. Course, field, and lab work examines fisheries ecology of Lake Itasca and its environs as examples of intact, headwaters ecosystems; experiments using lake microcosms are conducted and field work examines an intensive, lake-based cage aquaculture operation in northern Minnesota.

FW 5565. Fisheries and Wildlife Ecology and Management: Field Trip. (1 cr)
Ten-day field trip to Wyoming and points en route during spring break emphasizing a broad range of fisheries and wildlife management, including big game, waterfowl, and endangered species.

FW 5570. Avian Conservation. (4 cr; prereq EEB 5134 or grad standing or #; offered alt yrs)
Current problems in avian conservation and management, with equal emphasis on nongame, wetland, and game birds.

FW 5600. Fisheries and Wildlife Field Techniques. (4 cr; prereq Biol 5041 or EEB 3001 or #; at Itasca)
Introduction to various field techniques and skills; planning and implementing field projects; data collection and analysis using microcomputers; written reports and a field journal.

FW 5601. Fisheries Population Analysis. (4 cr; prereq NRES 1020 or computer competency, Stat 3011, Stat 3012 or Stat 5021, one qtr intro calculus)
Introduction to theory and methods for estimating vital statistics of fish populations. Students use microcomputers and statistical software to describe and model attributes of fish populations in case studies drawn from the literature of marine and freshwater fisheries management.

FW 5603. Wildlife Habitats and Management. (3 cr; prereq 3052 or 3054 or grad in biol or nat res or #, NRES 1020 or computer competency)
Environmental interactions of wildlife at both population and community levels; environmental threats from human activities; habitat management practices; objectives, policies, and regulations in population management.

FW 5604. Fisheries Ecology and Management. (3 cr; prereq NRES 1020 or computer competency, EEB 5601 or equiv or #)

FW 5620. Geographic Information Systems For Fisheries, Wildlife, and Biological Conservation. (4 cr; prereq Biol 5041)
Hands-on experience with GIS as a tool for understanding, analyzing, and managing ecological systems. ARC-INFO and how to apply it to problems in fisheries, wildlife, and biological conservation.

FW 5701, 5702. Senior Project. (1-2 cr; prereq FW sr or grad or #)
Two-quarter course providing problem-solving training. Management problem identification and analysis design, information and data gathering and analysis, and oral and written problem reporting. Problem selection influenced by guest speakers, resource agency contacts, and group discussions; topic selected is a contemporary fisheries and wildlife management issue.

FW 5801H. Honors Research. (3 cr; prereq admission to FW honors program)
First quarter of an independent research project supervised by a faculty member.

FW 5802H. Honors Research. (3 cr; prereq FW 5801H)
Continuation of FW 5801H. Students complete honors thesis and present an oral report.

For Graduate Students Only
(For description, see Graduate School Bulletin)

FW 8200. Seminar
FW 8364. Research in Fisheries Biology
FW 8377. Research in Wildlife Biology
FW 8448. Fishery Science
FW 8451. Production Biology of Fishery Environments
FW 8452. Conservation Biology: Genetic and Demographic Issues
FW 8459. Stream and River Ecology
FW 8460. Fish Habitats and Restoration
FW 8576. Wildlife Management: Large Mammals
FW 8579. Ecosystem Analysis and Simulation: A Numerical Approach

Forest Products (ForP)

ForP 1001. Forest Products Orientation. (1 cr)
Information about curricula offerings, specializations, career options, liberal education requirements, financial aid, scholarships, summer employment, and other student-related concerns.

ForP 1301. Wood as a Raw Material. (4 cr)
Physical and chemical nature of solid wood and wood fiber as it relates to the requirements of major wood-based industries. World supply and consumption. Weekly demonstration labs dealing with structure and properties of wood and manufacture of solid, particle, and fiber products.

ForP 1303. Wood Structure and Identification. (2 cr; prereq 1301 or #)
Features of wood structure vital to identifying wood of various tree species and understanding physical properties of wood. Lecture and lab.
### COURSE DESCRIPTIONS

**ForP 3300. Wood Industry Tours.** (2 cr; prereq 1301; jr or sr standing or #)
A five-day bus tour of visits to a dozen or more manufacturers representing a broad cross section of the wood-using industry. Scheduled during spring quarter break.

**ForP 3301. Industrial Internship.** (2 cr; prereq ForP cooperative ed student)
Industrial work assignment in FP cooperative education program. Evaluation based on formal report written by student at end of each quarter of work assignment.

**ForP 3303. Forest Products Marketing.** (3 cr)
Survey of marketing in the forest products industry, including review of basic marketing concepts and terminology.

**ForP 3305. Grading Standards and Product Performance.** (2 cr; prereq 1301, 1303 or #)
History, development, and practical application of hardwood and softwood log and lumber grading methods.

**ForP 3312. Building Materials Estimating.** (2 cr)
Modern methods of estimating quantity, grade, and specifications of building materials for light-frame construction.

**ForP 3325. Directed Study Experience.** (1-5 cr; prereq #)
Opportunity to pursue experiences not available under independent study or extra credit registration. The student develops, in consultation with the adviser for the project, a prospectus and completes progress reports and a final report on his or her project.

**ForP 3361. Introduction to Adhesives.** (3 cr; prereq BioC 1301, Phys 1042; offered even yrs)

**ForP 5300. Wood-Fluid Relationships.** (3 cr; prereq 1301)
Moisture in wood and its relationship to density and specific gravity, shrinking and swelling, electrical properties, strength properties, thermoconductivity, sorption isotherms, dimensional stabilization, permeability and diffusion. Lectures only.

**ForP 5301. Mechanical Properties.** (3 cr; prereq 1301 or #)
Basic mechanics and strength of materials as applied to wood products.

**ForP 5302. Wood Chemistry I.** (3 cr; prereq Chem 3302)
Molecular structure of wood cell wall. Structure, properties, and reactions of monosaccharides and derivatives; oligosaccharides. Structure, properties, and biogenesis of cellulose; cellulose derivatives; comparison with starch.

**ForP 5303. Wood Deterioration.** (4 cr; prereq 1301 or #)
Deterioration of wood and wood products by bacteria, fungi, insects, marine organisms, fire, and weathering; methods of preservation and preservatives used. Lecture and lab.

**ForP 5304. Wood Drying and Preservation Processes.** (4 cr; prereq 5300, 5303)
Materials, equipment, processes, and technical considerations inherent in the industrial drying and/or preservative treatment of wood products. Lectures, lab exercises, plant visits.

**ForP 5305. Pulp and Paper Technology.** (2 cr; prereq 5300 or #)
Pulping processes, fiber refining and processing, paper manufacturing, fiber and paper properties; paper recycling; water requirements and effluent treatment.

**ForP 5306. Analysis of Production Systems.** (3 cr; prereq 1301 or #; 3300 recommended)
Engineering and economic analysis of manufacturing and distribution systems for wood-based products. Material balances, equipment selection, economic analysis, and presentation techniques.

**ForP 5307. Wood-Based Panel Technology.** (4 cr; prereq 5300, 5301 or #)
Design, manufacture, properties, and applications of structural and nonstructural wood-base panels. Adhesives and their application in the panel industry. Lecture and lab.

**ForP 5308. Wood Machining.** (3 cr; prereq 1301, 1303)
History and fundamentals of wood machining processes. Analysis of tool and workpiece interaction and the effects on recovery efficiencies, tool wear, and surface condition. Application of wood processing systems and technologies.

**ForP 5310. Pulp and Paper Process Laboratory.** (3 cr; prereq 5305 or #)
Chemical and mechanical pulping, pulp preparation, secondary fiber, de-inking, wet end additives. Lab problems and exercises supplemented by lectures.

**ForP 5311. Pulp and Paper Process Calculations I.** (4 cr; prereq AgET 3030, CE 3400, ChEn 5001, ME 3301)
Physical and chemical process engineering calculations; steady and unsteady state material and energy balances applied to pulping and papermaking processes; flowsheet and system calculations; computer-aided material and energy balances.

**ForP 5312. Pulp and Paper Process Calculations II.** (4 cr; prereq 5311 or ChEn 5101, ME 3301)

**ForP 5313. Pulp and Paper Process Operations I.** (4 cr; prereq 5305, 5312, 5353, CE 3400, ME 3301, ME 5342 or ChEn 5102 or #)
Application of the principles of momentum, heat, and mass transfer to unit operations in the pulp and paper industry; fluid transport, filtration, sheet formation, sedimentation, drainage, pressing, heat exchange, evaporation, washing, bleaching, humidification and drying, chemical and energy recovery. Computer simulation of multiple-stage systems.
Theory and practice of the design and operation of paper machines and associated finishing and converting equipment.

ForP 5315. Paper Engineering Laboratory. (2 cr; prereq 5305, 5310 or ¶5310, 5312 or #)
Experiments that illustrate and apply the principles of momentum, heat, and mass transfer. Operation and performance optimization of pilot-plant paper machine. Process engineering studies of industrial production systems.

ForP 5316. Coated Product Development. (2 cr; prereq 5359)
Coating process and products (primarily paper); theory, techniques, and procedures for formulating and applying coatings; properties and uses of coated products.

ForP 5318. Pulp and Paper Process Dynamics and Control. (3 cr; prereq 5305, 5310, 5311, 5312, 5315, ¶5321, CE 3400, ME 3301, ME 5342 or #)
Theory and practice of process control in the pulp and paper industry: sensors, control equipment and algorithms, final control elements; applications to industrial pulp and paper manufacturing, available hardware and software.

ForP 5320. Biological and Environmental Science of Pulp and Paper. (3 cr; prereq ForP jr or sr, or grad standing or #)
Biological systems and process technology as they affect pulp and paper raw materials, manufacturing, waste treatment, and recycling. Regulations and compliance for mill expansion regarding environmental impacts, effluents, and discharge. Current developments in biological applications (e.g., enzyme treatments, biopulping, slime control) in the industry.

ForP 5321. Material Science of Paper (Paper and Fiber Physics and Properties). (4 cr; prereq 5305, 5310, 5311, 5312, 5315, 5359, CE 3400, ME 3301, ME 5342, ¶Chem 5520 or #)
Advances in understanding the response of fibers subjected to various operations of papermaking processes: mechanisms acting in stock preparation, refining, wet-end operations, web consolidation and drying; analysis of their corresponding influences on fiber, pulp suspension, and paper properties; challenges placed on end products by changing raw materials and requirements, including introduction of recycled pulp in paper products.

ForP 5331. Undergraduate Seminar. (2 cr; prereq ForP major; must be taken before sr yr)
Career planning, résumé preparation, discussion of job interviewing, and practice of technical presentation.

ForP 5350. Woody Tissue Microtechnique. (2 cr; offered when feasible)
Use of sliding and rotary microtomes, maceration, differential staining, and special techniques in preparing woody tissue for microscopic study. Lab.

ForP 5353. Wood Chemistry II. (3 cr; prereq 5302)

ForP 5355. Mechanics and Structural Design With Wood Products. (4 cr; prereq 5301)
Mechanical behavior of lumber, plywood, and particleboard as applied to structural considerations in building construction. Lecture and lab.

ForP 5356. Advanced Forest Products Marketing. (3 cr; prereq 3303 or #)
Marketing and market analysis, sales, retail and wholesale distribution of forest products. Lectures and case studies.

ForP 5359. Surface and Colloid Chemistry of Papermaking. (3 cr; prereq 5361 or #, Chem 3302, ME 3301, ¶Chem 5520)
Principles of surface and colloid chemistry applied to basic problems in pulp and paper manufacturing operations and product uses.

ForP 5361. Adhesion and Adhesives. (3 cr; prereq Chem 3302)

ForP 5401. Senior Topics. (Cr ar; prereq sr, #)
Independent study in a field of interest to a forestry major. Planned with adviser.

ForP 5405. Paper in Today’s World. (3 cr, ¶5305; UC/CEE only)
Primarily for elementary and secondary school teachers although other interested students may enroll. Enables teachers to prepare a teaching unit on pulp and paper for use in an elementary, junior high, or senior high school science class. Not open to forest products majors.

ForP 5410. Understanding Wood. (2 cr; UC/CEE only)
For woodworking professionals and serious craftsmen. Cellular structure of wood, identification of hardwoods and softwoods, interaction of water and wood. No prior technical training in wood properties is needed. Although general experience with woodworking is helpful.

ForP 5412. Understanding Residential Construction: The House as a System. (3 cr; UC/CEE only)
For builders, architects, and building materials suppliers. Energy, moisture control, and indoor air quality in residential buildings. Emphasis on design, construction, and operational aspects of the house to provide energy efficiency, durability, and a healthy environment. Interaction between moisture and wood products within the building system.
ForP 5420. Using Process Simulation in the Pulp and Paper Industry. (2 cr; UC/CEE only) This hands-on microcomputer two-day workshop provides instruction in solving flowsheet calculation problems relating to pulp and paper process engineering, and demonstrations of the types of problems that can be solved using these techniques. Primarily for practicing engineers in the paper industry. Not open to forest products majors.

For Graduate Students Only
(For description, see Graduate School Bulletin)

ForP 8300. Research Problems
ForP 8301. Research Problems
ForP 8304. Advanced Topics in Wood Drying
ForP 8306. Seminar: Forest Products
ForP 8307. Advances and Methods in Forest Products Pathology and Preservation
ForP 8310. Mechanics of Wood and Wood Composites

Forest Resources (FR)

FR 1001. Forest Resources Orientation. (1 cr) Information about curricula offerings; liberal education requirements; careers in forest resources, urban forestry, and recreation resource management; and summer job and internship programs.


FR 3100. Minnesota Plants. (2 cr; prereq Biol 1103, Δ; at Itasca) Identification of plants as related to habitat.

FR 3101. Northern Forest Ecosystems. (3 cr; prereq Chem 1001 or Chem 1051, Δ; at Itasca) Field examination of succession, soils, silvical characteristics, tree classification, stand structure, and regeneration ecology.

FR 3102. Southern Forest Resource Tour. (1 cr; prereq FR jr or sr or #; offered odd yrs) One-week field tour of selected southern forest industries and public forest management agencies. Walnut production, southern pine silviculture, hardwood use, various mill tours. Discussions, paper.


FR 3104. Forest Ecology. (4 cr; prereq 8 cr biol, 4 cr chem) Ecological concepts and principles as a basis for conservation and management of forest ecosystems.

FR 3107. Forest Ecology Laboratory. (1 cr, §3101; prereq §3104) Forest stands, communities, and ecosystems. Field trips.

FR 3201. Forest Measurement Techniques. (1 cr; prereq Math 1008, Δ; at Itasca) Introduction to land survey, tree and stand measurement, and basic forest sampling techniques.

FR 3225. Directed Study Experience. (1-5 cr; prereq fr or soph standing, #) Opportunity to pursue experiences not available under independent study or extra credit registration. Student develops, in consultation with the adviser for the project, a prospectus and completes progress reports and a final report on his or her project.

FR 3250. Role of Renewable Natural Resources in Developing Countries. (2 cr) International perspective on important resource issues, including integration of natural resource, social, and economic considerations. Overviews of issues and case studies.

FR 3300. Elements of Surveying. (2 cr; prereq Math 1008 or high school trig, Δ; at Cloquet) Basic concepts of elementary plane surveying for use in natural resource assessment. Introduction to public land and boundary surveys and geographic information systems. Lectures and labs.

FR 3500. Arboriculture. (3 cr; prereq Biol 1103, Hort 1021 or FR 1100) Selecting, planting, and caring for landscape, street, and park trees. Emphasis on proper plant site decisions, plant health care practices, and minimizing stresses from the urban environment, insects, and diseases.

FR 5100. Silviculture. (4 cr; prereq 1100, 3104 or equiv, #) Introduction to silvics, forest regeneration and site preparation techniques, intermediate silvicultural practices, and silvicultural systems.

FR 5101. Field Silviculture. (4 cr; prereq 5100, Δ; at Cloquet) Regeneration surveys, plantation inspection, site preparation, and reforestation prescription. Practice in marking for thining and determining effect on stands. Compartment examination and prescription. Written and oral reports.

FR 5102. Forest Wildlife Habitat Management. (1 cr; prereq FW 3052, §FW 5100, Δ; at Cloquet) Forest vegetation management techniques for developing and maintaining wildlife habitat; consideration of vegetation dynamics, habitat requirements, and silvicultural techniques.

FR 5104. Forest Ecology. (4 cr; prereq 8 cr biol, 4 cr chem) Ecological concepts and principles as a basis for conservation and management of forest ecosystems.

FR 5106. Senior Silviculture Seminar. (2 cr, 3 cr with research paper; prereq sr, 5100 or #) Students prepare, present, and critique seminars on silvicultural topics of interest. Guest speakers.
FR 5107. Forest Ecology Laboratory. (1 cr, §5160; prereq §§5104)
Forest stands, communities, and ecosystems. Field trips.

FR 5108. Physiological Ecology: Organisms to Ecosystems. (3 cr; prereq 5103 or 5104 or Biol 5041 or Hort 5041)
Interaction between plants and their environment; mechanisms that affect whole plant, community, and ecosystem processes. Causes and consequences of variation in resource availability and stress in diverse ecosystems. Relationships of resource availability and stress to plant establishment, growth, and survival; links between organismal, community, successional, and ecosystem processes.

FR 5114. Forest Hydrology and Watershed Management. (4 cr; prereq 3103, Biol 1009, Chem 1052, Geo 1001, Math 1142, Phys 1001 or #)
Introduction to the hydrologic cycle and hydrologic processes. Effects of forest management activities on water yield, storm flow, and water quality.

FR 5115. Forest Hydrology, Field Applications. (2 cr; prereq 5114, ∆ at Cloquet)
Use of hydrologic instrumentation to measure precipitation, streamflow, infiltration capacity, soil moisture, air temperature, evaporation, and selected water quality constituents. Collection and interpretation of hydrologic information to evaluate forest-use impacts on water quantity and quality.

FR 5120. Tree Biology. (4 cr; prereq Chem 1001 or Chem 1051, 10 cr biol)
Genetic variation in forest trees, underlying causes, use. Tree growth, nutrition, and water relations. Environmental and internal growth regulation. Plant biochemistry and photo-chemistry. Physiology related to silviculturally and ecologically significant phenomena.

FR 5126. Silviculture: Soil-Site Relationships. (2 cr; prereq 5100, ∆ at Cloquet)
Field examination of forest soils and their relationship to site productivity and forest management.

FR 5130. Geographic Information Systems in Natural Resource Analysis. (3 cr; prereq sr or grad or #)
Introduction to the application of Geographic Information Systems (GIS) to natural resource and regional planning studies. Theory and technical points; emphasis on applications. Hands-on experience with microcomputer. Case study, including map digitizing, data processing, and generation of map products. Weekly lab.

FR 5142. Tropical Forest Ecology. (3-4 cr; prereq 1 Ecol course 3xxx level or higher)
Ecological principles related to form, function, and development of wet and dry tropical forests at organismal, community, and ecosystem scales. Succession, productivity, biodiversity, sustainability, agroforestry, and management alternatives. Natural distribution of forest types; causes, consequences, and extent of deforestation.

FR 5146. Dynamics of Global Change: Plant Ecology. (3-4 cr; prereq 1 plant ecol or plant phys course 3xxx level or higher)
Implications of global change elements for wild and cultivated vegetation, including forests, grasslands, and agricultural ecosystems. Responses on ecosystem, community, organismal, and physiological scales. Potential climate change, elevated atmospheric concentrations of carbon dioxide, ozone, and other trace gases, acid deposition, and other pollutants.

FR 5152. Forest Genetics. (3 cr; prereq Biol 1103, Stat 3011)
Genetic variation of forest-tree species and underlying principles; application of plant breeding principles to forestry.

FR 5153. Advanced Forest Hydrology. (4 cr; prereq 5114 or #)
Current hydrologic problems in the management of forested watersheds. Analytical methods to evaluate effects of vegetation management on the quantity and quality of runoff. Lecture and lab.

FR 5160. Practicum in Forest Biology and Measurements. (3 cr; prereq grad, #; at Itasca)
Plant identification, plant dynamics, land survey, tree measurement.

FR 5202. Remote Sensing: Field Applications. (2 cr; at Cloquet)
Field applications of remote sensing for inventory, mapping and monitoring forest and natural resources.

FR 5215. Forest Fire Ecology and Management. (2 cr; prereq Itasca session, 1100, 3103, 5100 or #)
Effects and control of fire on wild landscapes, especially forests and grasslands. Fire effects on vegetation, fire history studies, fire behavior, fuel load modeling, fire policy in land management.

FR 5218. Assessment and Modeling of Forests. (3 cr; prereq Math 1142 or Math 1251-1252, NRES 5210, Stat 3011 or Stat 5121)
Measurement and sampling methods for forest vegetation; tree and stand growth modeling; landscape processes, characteristics, and modeling.

FR 5222. Forest Resources Inventory. (2 cr; at Cloquet)
Field application of sampling methods for estimating natural resource characteristics for inventory, appraisal, and monitoring.

FR 5225. Directed Study Experience. (1-5 cr; prereq jr or sr or grad standing, #)
Opportunity to pursue experiences not available under independent study or extra credit registration. The student develops, in consultation with the adviser for the project, a prospectus and completes progress reports and a final report on his or her project.

FR 5228. Advanced Topics in Resource Assessment and Modeling. (4 cr; prereq 5218 or equiv, NRES 5210 or equiv, Stat 5021 or equiv)
Recently developed mathematics, computer science, and statistics methodologies applied to resource functioning, management, and use problems.
FR 5231. Range Management. (3 cr; prereq Biol 1103 or #)
Important range plants; range livestock; range management methods and improvements; public grazing land administration; relationship of livestock grazing to wildlife, forest, watershed, and recreation management on public and private range lands.

FR 5232. Management of Recreational Lands. (4 cr; prereq completion of all lower div reqs; jr or sr status)
Understanding and applying recreation management tools from a public agency perspective. Management concepts such as ROS, LAC, social monitoring, and public information processes.

FR 5236. Forest Recreation Planning. (1 cr; prereq 5232, Δ; at Cloquet)
Recreation area and site planning, examples and managerial concerns. Fieldwork and presentation.

FR 5248. Harvesting and Engineering. (3 cr; prereq 3300 or CE 3100, Δ; at Cloquet)
Introduction to harvesting systems, relationship to forest management, and preparation and administration of timber sales. Fundamentals of location, construction, and maintenance of forest roads.

FR 5250. Role of Renewable Natural Resources in Developing Countries. (2 cr)
International perspective on important resource issues, including integration of natural resources and social and economic considerations. Overview of issues and case studies. Term paper.

FR 5257. Recreation Land Policy. (3 cr; prereq 5232 or #)
Policy issues affecting the use and management of lands devoted entirely or in part to recreational objectives.

FR 5259. Analysis of Outdoor Recreation Behavior. (3 cr; prereq 5232, RRM major or grad or #)
Development of environmental framework for understanding recreation behavior. Contributions of several disciplines, current cultural trends, management implications.

FR 5262. Remote Sensing of Natural Resources. (4 cr)
Overview of remote sensing basics, interpretation, measurement, and mapping from aerial photography; introduction to digital remote sensing and image analysis.

FR 5264. Quantitative Techniques in Forest Management. (3 cr; prereq 5218, 5270 or #)
Forestry applications of quantitative techniques in allocation and other decision-making problems. Mathematical programming, simulation, and other techniques.

FR 5270. Forest Management and Planning. (3 cr; prereq 5218, ApEc 1101 or Econ 1101, ApEc 1102 or Econ 1102, NRES 5260)
Role of models in resource decisions at the stand and forest-wide levels; forest regulation principles and techniques; forest management scheduling approaches; economic tradeoff and impact analysis principles.

FR 5403. Fundamentals of Natural Resource Education. (1-3 cr; UC/CEE only)
For elementary teachers. Study of soil, water, forest, and wildlife resources of Minnesota and the biological principles and ecological implications of management. Environmental issues created by natural resource manipulation. Development of outdoor teaching skills in environmental education in a metropolitan center.

FR 5412. Advanced Remote Sensing. (4 cr; prereq 5262 or #)
Working knowledge of quantitative remote sensing. Both theoretical basis and practical aspects, including energy-matter interactions, radiation measurements and sensors, and digital image analysis.

FR 5460. Water Quality: The International Dimension. (3 cr; prereq 5114 or NRES 3060, one Ecol course, jr or sr status)
Water quality management practices and policies in foreign countries. Water quality as one of many natural resources being managed by rapidly changing societies. World literature in natural resources.

FR 5500. Urban Forest Management. (4 cr)
Terminology, urban tree inventory, forest care and health evaluations principles; case studies; sociology of urban forestry and best management practices.

FR 5704. Colloquium in Natural Resources. (1-4 cr; prereq varies with topic, #)
Colloquium on specialized topics in natural resources.

For Graduate Students Only
(For description, see Graduate School Bulletin)
FR 8100. Research Problems: Silviculture
FR 8101. Research Problems: Forest-Tree Physiology
FR 8102. Research Problems: Forest-Tree Genetics
FR 8103. Research Problems: Forest Hydrology
FR 8107. Seminar: Forest Resources
FR 8112. Research Problems: Physiological Ecology
FR 8202. Research Problems: Forest Biometry
FR 8203. Research Problems: Forest Recreation
FR 8204. Research Problems: Forest Policy
**Mathematics (Math)**

**Math 1031. College Algebra and Probability.** (4 cr, §1051, §1111, §1151, §1201; prereq 3 yrs high school math, placement exam or GC 0631 with a grade of C or better) 
Algebra and analytic geometry explored in greater depth than is usually done in three years of high school mathematics. Additional topics from combinations, permutations, and probability. A suitable prerequisite for Math 1131 or 1142, but not for 1251.

**Math 1131. Finite Mathematics.** (5 cr; prereq 3 yrs high school math incl probability, satisfactory placement exam or grade of C or better in 1031) Elementary computer programming, financial mathematics, probability, linear algebra, linear programming, Markov chains.

**Math 1142. Short Calculus.** (5 cr; for students requiring minimal amount of calculus; prereq 3 yrs high school math, satisfactory placement exam or grade of C or better in 1031 or 1151) Derivatives, integrals, differential equations, maxima and minima, partial differentiation, applications.

**Math 1151. Precalculus II.** (4 cr, §1008, §1111, §1201; prereq 3½ yrs high school math, placement exam or 1051 with a grade of C or better) Second of two courses (see Math 1051) in algebra, analytic geometry, and trigonometry. Prepares students for the full calculus sequence. Not an acceptable prerequisite for Math 1131.

**Math 1251-1252. One-Variable Differential and Integral Calculus I-II.** (4 cr per course, §1411H-1421H, §1451H-1452H; prereq 4 yrs high school math incl trig, satisfactory placement exam or grade of C or better in 1151; grade of C or better in 1251 required for 1252) Calculus of functions of one variable and related geometry and applications.

**Math 1261. The Algebra and Geometry of Euclidean Space.** (4 cr, §1241, §1553H, §3142, §3511H; prereq 1251) Vectors and their operations; matrices and matrix algebra, linear algebraic equations; Gaussian elimination; determinants and their applications; linear transformations; subspaces, quadratic functions, rigid motions, and orthogonal matrices.

**Math 3251. Multivariable Differential Calculus.** (4 cr, §3211, §3311, §3521H, §3552H; prereq 1251, 1261) Differentiation of parametric curves; partial differentiation and the derivative as local linear approximation; the chain rule; applications to maximum/minimum problems with attention to boundaries and constraints, including Lagrange multipliers; Taylor’s Theorem (multivariable) and the second derivative test.

**Math 3252. Multivariable Integral Calculus.** (4 cr, §for students with [3211, 3331] or [3311, 3331] or 3551H or 3552H; prereq 1252, 3251 or §3251) Double and triple integrals; change of variable procedures with emphasis on polar and spherical coordinates; mass and centroid; integration on curves and surfaces; vector fields and the theorems of Green, Gauss, and Stokes.

**Math 3261. Differential Equations With Linear Algebra.** (4 cr, §3221, §3321, §3531H, §3551H; §1221 or 1251, 1241 or 1261 or 3142) First-order equations, linear equations with constant coefficients, and linear systems. Companion topics from linear algebra: general vector spaces, independence, spanning sets, basis, dimension, eigenvalues, and eigenvectors.

**Math 3262. Infinite Sequences and Series With Methods of Approximation.** (4 cr; prereq §3261) Infinite sequences and series; mathematical induction and its implications for recursively defined sequences; convergence and techniques for evaluation of sequential limits and sums of series; applications of sequences and series to approximations and estimates of error. Required for honors students who have not taken Math 1552H.

**Natural Resources and Environmental Studies (NRES)**

**NRES 1001. Orientation to Natural Resources and Environmental Studies.** (1 cr; S-N only) Information about NRES major. Discussions with faculty adviser. Employment information. Current topics in NRES. Information about facilities. Discussions with alumni.

**NRES 1020. Information Technology in Natural Resources.** (2 cr) Overview of computers and computer-based tools as they apply to NRES and related coursework. Techniques for information retrieval.

**NRES 1040. Natural Resources as Raw Materials.** (3 cr) Role of natural resources as raw materials for industry and economic development. Environmental and economic trade-offs associated with raw material gathering, processing and use. Implications of processing technologies, energy considerations.

**NRES 1201. Conservation of Natural Resources.** (3 cr) Natural resource conservation and its development in the United States; renewable resources and problems managing them, relates resource conservation and environmental management to their basic ecological principles.

**NRES 3001. Colloquium in Natural Resources and Environmental Studies.** (1 cr) Roundtable discussions of current NRES topics.

**NRES 3010. Ethics and Values in Resource Management.** (3 cr) Formulating a natural resources philosophy based on ethical behavior. Ethical dilemmas inherent in managing natural resources.

NRES 3050. Experience and Training in a Field Setting. (1-4 cr; prereq #) Students are required to obtain professional experience in a field setting by attending field sessions, completing a Professional Experience Program, or volunteering for various natural resource and/or environmental programs through local state or federal agencies. Approval by instructor required.


NRES 3070. From Local to Global Ecology. (3 cr) Ecosystem processes worldwide, plants and animals they support, human impacts; cultural and economic determinants of environmental problems related to ecosystems and solutions to these problems.


NRES 3201. Field Assessment Techniques. (1 cr; at Ithaca) Land survey and mapping; measurement and sampling methods for forest vegetation, wildlife, and other resources.

NRES 3202. Leadership and Management Skills Development. (3 cr; prereq jr or sr standing) Presentations and classroom exercises on managing, planning, directing, controlling, and organizing; group problem solving, implications of organizational change, time management, and career planning and development.

NRES 3225. Directed Study Experience. (1-5 cr; prereq fr or soph standing; #) Opportunity to pursue experiences not available under independent or extra credit registration. The student develops, in consultation with the adviser for the project, a prospectus and completes progress reports and a final report on his or her project.

NRES 3575. Wetlands Conservation. (3 cr; prereq Biol 5041 or EEB 3001 or EEB 3101) Freshwater wetland classification, biota, current/historic status, value, conservation strategies, ecological principles used in wetland management.

NRES 5001. Colloquium in Natural Resources and Environmental Studies. (1 cr) Key concepts and techniques in restoration; common factors in restoration projects; threats to health of aquatic ecosystems.


NRES 5100. Problem Solving in Natural Resources and Environmental Studies. (5 cr; prereq 5210 or Stat 3012, Rhet 3562; completion of at least 12 cr in area of concentration for NRES majors; completion of 5245, FR 5232 for RRM majors) Solving a real-world natural resources and/or environmental problem. Discussions and assignments reflect diverse aspects of the problem. Oral and written presentations. Students participate as a member of a team.

NRES 5101. Integrated Natural Resource Planning. (5 cr; prereq 5210, 5240, FR 5218, FR 5270, one ecol course, one hydro course, one rec mgmt course or #) Opportunity to apply skills from individual course subjects in addressing natural resource management questions. Information and models useful for assessing impact of natural resource management and trade-offs between alternative management approaches.

NRES 5210. Survey, Measurement, and Modeling Methods for Natural Resources I. (4 cr; prereq 1020 or CSci 3101 or CSci 3102 or CSci 3113 or GC 1571, Math 1142 or 1251, Stat 3011 or Stat 5021) Introduction to survey design, measurement concepts, and modeling methods useful in studying natural resources and environmental issues. Emphasis on data collection and analysis.

NRES 5220. Survey, Measurement, and Modeling Methods for Natural Resources II. (4 cr; prereq 5210; offered alt yrs) Advanced survey design, measurement concepts, and modeling methods for studying natural resources and environmental problems.

NRES 5225. Directed Study Experience. (1-5 cr; prereq jr or sr or grad standing; #) Opportunity to pursue experiences not available under independent study or extra credit registration. The student develops, in consultation with the adviser for the project, a prospectus and completes progress reports and a final report on his or her project.

NRES 5240. Natural Resources Policy and Administration. (3 cr; prereq ApEc 1101 or Econ 1101, ApEc 1102 or Econ 1102, Pol 1001, Rhet 1151) Political and administrative processes important to developing natural resource policies and programs. Policy processes, agenda setting, political decision roles, strategies for achieving agreement, participants in policy development, public means of implementing policies, and case examples.
NRES 5242. Management of Natural Resources Conflict. (3 cr; prereq NRES 5240 or #) Strategies and techniques used in conflict management and planning within the context of disputes involving the use and management of natural resources.

NRES 5245. Fundamentals of Landscape Planning for Recreation. (3 cr; prereq 5260 or FR 5232 or Rec 5310) Recreational planning from an ecosystem-based perspective. Identify recreation problems and opportunities in natural settings, establish goals, inventory and analyze the human resource, perform suitability analysis, select plan options.


NRES 5575. Wetlands Conservation. (4 cr; prereq Biol 5041 or #, EEB 3001 or 3101) Same as NRES 3575 plus one additional hour per week. Freshwater wetland classification, biota, current/historic status, value, conservation strategies, ecological principles used in wetland management.

NRES 5703. Agroforestry: Role in Watershed Management. (2 cr; prereq jr or sr status or grad, background in biological and physical sciences) Agroforestry practices, and the production and watershed protection benefits derived from them. Examples from developing countries in Africa, Asia, and Latin America. Guest speakers.

NRES 5800. Natural Resources Interpretation and Communication. (3 cr) Environmental education in the context of natural resources agencies.


Phys 1005. Physics Laboratory. (1 cr; prereq 1001 or ¶1001; S-N only) Lab experiments offered with Phys 1001.

Phys 1041-1042. Introductory Physics. (5 cr per qtr, §any other intro physics courses) Lectures and problem sessions. Mechanics, fluids and gases, heat, waves, electricity and magnetism, light, optical instruments, atoms and spectra, nuclei, radioactivity.

Phys 1104, 1107. General Physics and Laboratory. (5 cr; prereq high school calculus or Math 1142 or equiv, high school trig or Math 1108 or Math 1151) Forces and their effects. Physics principles. Description of motion, forces, conservation principles, fields, and the structure of matter.


Phys 1106, 1109. General Physics and Laboratory. (5 cr) Selected topics with applications in biology.


Rhetoric (Rhet)


Rhet 1104. Library Research Methods. (1 cr; S-N only; taught by St. Paul campus library staff) On-site instruction in information retrieval techniques. Lectures, audiovisual presentations, and problem-solving assignments strengthen skills in using the library.

Rhet 1151. Writing in Your Major. (4 cr; prereq 1101, 1104, soph status) Students investigate and write on subjects related to their majors. Assignments such as literature review, abstract, fact sheet, instructions, and feature article.

Rhet 1222. Public Speaking. (4 cr; prereq 1101, 1104) Fundamentals of speechmaking. Emphasis on organizing the speech and projecting it to the audience.

Rhet 1302. Humanities: Modern Thought and the Industrial Revolution. (4 cr) The industrial transformation of Europe: rise of laissez-faire capitalism, socialism, Marxism; modern “individualism” and traditional views of community; utilitarianism and deontological approaches to ethics.

Rhett 1310. Humanities: The Land in American Experience. (4 cr)
American attitudes toward the land from colonial times to the present as expressed in social history, literature, and the fine arts. Social thought and the relationship between farm and city, wilderness and countryside. The changing appearance of the United States.

Rhett 3254. Advanced Public Speaking. (4 cr; prereq 1222)
Training for specific speech situations most likely to be encountered professionally. Emphasis on analysis, design, preparation, and delivery of presentations to provide greater flexibility within a variety of speech environments.

Rhett 3266. Communication, Discussion in Small Group Decision Making. (4 cr; prereq 1101)
Role of communication techniques in the small group decision-making process. Emphasis on discussion within a variety of decision-making modes such as voluntary groups, business meetings, and conflict groups.

Rhett 3562. Writing in Your Profession. (4 cr; prereq 1101, 1104, 1151, jr status)
Projects in professional writing. Relationship between structuring information to meet needs of particular readers and writing effectively. Assignments such as the feasibility report, proposal, memorandum, letter of application, and résumé.

Soil Science (Soil)

Soil 1020. The Soil Resource. (5 cr; prereq Chem 1001 or Chem 1051; UC/CEE only)
Introduction to the physical, chemical, and biological aspects of soils. Use of the soil classification system to understand the use of soil survey information for land-use planning. Concepts of soil fertility for understanding plant growth requirements. Introduction to urban soils and their management. Understanding soil’s role in environmental planning and conservation decisions.

Soil 3125. Basic Soil Science. (5 cr, $1020; prereq Chem 1001 or Chem 1051)
Basic physical, chemical, and biological properties of soil. Soil genesis and classification and principles of soil fertility.

Soil 3220. Soil Conservation and Land-Use Management. (4 cr; prereq 1020 or 3125 or #)
Soil erosion and land degradation processes on rural and urban landscapes. Technical, historical, economic, social, and international considerations of soil conservation. Land-use management practices for soil conservation and methods of natural resource assessment.

Soil 3416. Plant Nutrients in the Environment. (4 cr; prereq 3125)
Fundamental concepts in soil fertility evaluation. Emphasis on dynamics of mineral elements in soil and evaluation and interpretation of plant and soil relationships.

Soil 5020. Environmental Impact Assessment. (4 cr; prereq jr or sr, 16 cr sci, 5510, ApEc 3610, #)
Roles of government agencies, consultants, and private citizens; steps needed to write an Environmental Impact Statement (EIS); case studies, writing additional components of an EIS, and preparing an EIS for a small local project.

Soil 5210. Environmental Biophysics. (3 cr; prereq Math 1251, Phys 1041 or #)
Physical microenvironment and energy/mass exchange processes among soils, plants, animals, and atmosphere. Energy transfer calculation using mathematical models and energy budget analysis.

Soil 5241. Microclimatology. (3 cr; prereq 1031 or 10 cr physics or #)
Meteorology and climatology in relation to the soil-atmosphere interface with emphasis on the microclimate, physical processes taking place within the microclimate, modification of the microclimate description of meteorological instruments, and use of weather data.

Soil 5510. Field Study of Soils: Morphology. (1 cr; prereq 1020 or 3125 or #)
Writing and classifying soil profile descriptions in the field.

Soil 5511. Field Study of Soils: Mapping. (1 cr; prereq 5510 or $5510)
Making soil maps based on soil profile descriptions.

Soil 5555. Wetland Soils. (4 cr; prereq 1020 or 3125 or #)
Formation, properties, and management of peatlands important to crop, forestry, and energy production in Minnesota and worldwide.

Soil 5610. Soil Biology. (4 cr; prereq sr or grad)
Soil environment and its biological population. Role of living organisms in soil-plant environment and mineral transformations of agronomic importance. Effects of soil microflora on soil fertility and plant nutrition.

Soil 5710. Forest Soils. (3 cr; prereq 1020, FR 5114)
Factors affecting tree growth; estimation, modification, and management effects on site productivity; regeneration.

Statistics (Stat)

Stat 3011. Statistical Analysis. (4 cr; prereq college algebra)
Descriptive statistics; elementary probability; estimation; one- and two-sample tests; correlation; regression; ANOVA; randomized blocks; multiple comparisons; factorial experiments; multiple regression; goodness of fit; nonparametric methods; contingency tables; selected topics.

Stat 3012. Statistical Analysis. (4 cr; prereq 3011)
See Stat 3011.

Stat 5021. Statistical Analysis. (5 cr, $3012; prereq college algebra)
Intensive version of Stat 3011 and 3012. Primarily for graduate students needing statistics as a research technique.