Division of Engineering

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CMWPE Graduate Studies, www.esf.edu/faculty/cmwpe

ERFEG Graduate Studies, www.esf.edu/erfeg

PBE Graduate Studies, www.esf.edu/pbe

Graduate Program in Environmental and Resource Engineering

The graduate program in Environmental and Resource Engineering (ERE) applies science and engineering to the conservation, restoration, holistic development, and improved utilization of the natural environment and its related resources. It represents synthesis of the professional specialties that make up the Division of Engineering. These are the Department of Environmental Resources and Forest Engineering (ERFEG), the Department of Paper and Bioprocess Engineering (PBE), and the Department of Construction Management and Wood Products Engineering (CMWPE).

The master of science, master of professional studies, and doctor of philosophy degrees are awarded in ERE.

Applicants for the M.S. are required to have a bachelor's degree in science or engineering and are expected to have at least one year of study in each of the following subjects: biological science, calculus, chemistry, computer science, and physics.

All students entering M.P.S. programs must have a baccalaureate degree. Prospective students should contact the department chair for specific information regarding pre- or co-requisites.

A minimum total of 30 credit hours is required for the M.S. and M.P.S. Coursework requirements are determined by the faculty in the specific study areas. Students select a study area at the time of application for admission to the program.

Under general requirements for the Ph.D. degree (page 17), the environmental and resource engineering program requires a minimum total of 60 graduate credits. These credits must include a minimum of 30 credits of coursework, and include not more than 30 credits for dissertation. As tool requirements, students must demonstrate competence in two of the three following areas: computer science, statistics or advanced mathematics, and a language other than English commonly used in science or engineering practice. The doctoral preliminary examination may be required of students who have not earned a master's degree that required a thesis.

A study plan that formally identifies an individual's program requirements is developed for each student as soon as possible, but at least during the first year of graduate study. This plan includes all required and elective courses as well as a tentative schedule for completion.

Options and Areas of Study

Within the graduate program in environmental and resource engineering there are three options: environmental resources and forest engineering; paper and bioprocess engineering; and construction management and wood products engineering. Options have alternative curricular requirements addressing different subjects within a degree program. Each option has several areas of study as follows:

Construction Management and Wood Products Engineering (CMWPE)

The academic objective of areas of study related to construction is to allow students with technical degrees to engage specific construction topics of current interest. There is an overall objective of having the student look at the broad environmental implications of the construction process. The efficient and environmentally correct use of materials and state-of-the-art technology is integrated into each student's practicum, thesis or dissertation, as appropriate.

The purpose of the M.P.S. degree is to update current professional skills and/or to prepare the graduate student for higher levels of management in their general area of expertise. The M.P.S. degree is intended to be a terminal degree, therefore acceptance to the M.P.S. degree in construction management or wood products engineering does not guarantee admission to the M.S. or Ph.D. programs and *vice versa*. The M.P.S. degree requires 27 credits of graduate-level coursework, a 3-credit practicum based on professional experience, and a capstone seminar. Recommended course lists are available in the department office. The student's study plan (Form 3B) must be approved by the steering committee and department chair by the end of the first semester in residence.

Students are accepted into our programs from a variety of backgrounds. When the Department of Construction Management and Wood Products Engineering (CMWPE) reviews an applicant's academic and professional experience, it may determine that preparatory coursework is required before entry into the program. Either undergraduate or graduate courses may be recommended to remedy deficiencies depending on circumstances. Remedial coursework should be completed prior to matriculation. Undergraduate courses do not meet the requirements for minimum number of graduate credit hours. Students planning to obtain graduate degrees in the construction management option should have completed the following undergraduate coursework:

- Mathematics through Calculus II
- Physics: one semester with laboratory
- Engineering Mechanics: Statics
- Mechanics of Materials
- Soil Mechanics and Foundations I
- Estimating: coursework or professional experience
- Scheduling: coursework or professional experience

The CMWPE option in environmental and resources engineering offers areas of study in:

- Construction and Construction Management (M.S., M.P.S., Ph.D.)
- Participating Faculty: KYANKA, SMITH, J., TISS
- Construction project management
- Estimating, cost engineering, building codes and zoning
- Lean construction
- Green construction
- Production management
- Computer graphics and computer applications in engineering
- Structural design

This area of study is for students who plan to specialize in construction management or structures and materials science. Studies depend upon the student's previous education, professional objectives and interests. Recent graduates have matriculated upon completion of undergraduate degrees in architecture, mechanical engineering, construction management, and civil engineering.

Engineered Wood Products and Structures: Timber Structures Design (M.S., Ph.D.)

Participating Faculty: KYANKA, MORSI-HUSSEIN

- Materials science
- Engineering mechanics and elasticity
- Engineering properties of wood composites
- Computer-aided design
- Static and dynamic properties of wood

The behavior of wood and wood-based components under loads and the effects of duration of the loads are critical elements when developing engineering codes. Wooden components as small as dowels or as large as bridge beams are considered, using elements of materials science, engineering mechanics and structural engineering. Basic property knowledge, employing theories of elasticity, viscoelasticity and fracture mechanics, is coupled with computer-aided design data to analyze the performance of wood and to solve application problems, such as those encountered in wood-frame construction and timber utility structures. How such factors as chemical fire retardant treatments, adhesive performance and mechanical fastener design interact with use requirements is considered. National and international design codes and their development play an important role in specifying research areas of current interest and need. Fabrication and testing of actual components such as trusses, composite beams, and furniture connections are completed in the department’s Wood Engineering Laboratory.

Students entering this program should have a strong background in integral calculus, statics, mechanics, and mechanical and physical properties of wood.

Tropical Timbers (M.S., Ph.D.)

Participating Faculty: ANAGNOST, MEYER

- Identification keys and systematics
- Wood properties and end use suitability
- Life zone analyses
- Expert systems

Studies in tropical timbers take many forms, depending on individual student interests. Often students from other countries bring specific problems and materials with them, so their thesis will find immediate application when they return home. The holdings of the C. deZeeuw Memorial Library and reference wood specimens of the H.P. Brown Memorial Wood Collection of the Tropical Timber Information Center (TTIC), housed in Baker Laboratory facilities, are vital to this work.

Research topics may be formulated to answer questions dealing with anatomy, identification, properties or uses of various woods from around the world, using the TTIC reference materials. These studies may be quite narrow, such as anatomy and physical properties of woods from a particular region, or much broader, such as regional distribution of species and species groups based on life zone research throughout a country or larger geographic area.

Wood Science and Technology (M.S., M.P.S., Ph.D.)

Participating Faculty: ANAGNOST, HANNA, KYANKA, MEYER, MORSI-HUSSEIN, SMITH, W.

- Adhesives and finishing
- Processing and machining
- Mechanical and physical properties
- The effects of wood anatomy on the physical and mechanical properties of wood
- Wood biodegradation
- Wood composites
- Dendrochronology

Because wood is renewable, it will meet the needs of modern society for a perpetually available, carbon dioxide-neutral material perfectly suited for a vast array of products. The study area wood science and technology includes detailed research on physical, mechanical, or anatomical aspects of wood and its utilization and leads to the M.S., M.P.S., or Ph.D. degree. Wood science stresses research on the material science of wood, dealing with properties important to its use, or to solve problems in wood utilization by practical applications of such knowledge.

Students entering this program should have an undergraduate degree in wood science or a related area.

Wood Anatomy and Ultrastructure (M.S., Ph.D.)

- Participating Faculty: ANAGNOST, HANNA, MEYER
- Wood formation and cell wall organization
- Cytoskeleton of plant cells
- Properties related to anatomy and ultrastructure
- Electron, light and video microscopy

This area requires students to develop an extensive background in all aspects of microscopy: light, scanning electron, transmission electron, video microscopy and image analysis, including micro-techniques for effective preparation of specimens for the appropriate instrument. Wood anatomy studies are basic to wood identification, wood utilization, and physical/mechanical properties. These studies may include woods from other continents.

The field of ultrastructure is very broad with applications in many biological, chemical and materials sciences. Applied to wood, it emphasizes the sub-light microscopic structures (smaller than 0.2 micrometers) found in this natural material, either in the mature form or in its formative stages where various organelles of the living cell may be studied for their roles in producing the mature wood cell.

The behavior of wood in its many applications can be observed and explained via microscopy and related instrumentation such as EDXA (energy-dispersive x-ray analysis). State-of-the-art resources and facilities are concentrated in the Center for Ultrastructure Studies, which provides instruction and research support staff.

Students entering this program should have an undergraduate degree in wood anatomy or the biological sciences.

Wood Treatments (M.S., Ph.D.)

Participating Faculty: ANAGNOST, SMITH, W.

- Wood-water relationships and wood drying
- Preservative treatments
- Polymer treatments
- Sealants and coatings

Graduate study in the area of wood treatments allows the student to investigate the scientific basis for the improvement of wood and wood products with various treatments, which include drying, preservative treatments and coatings. Preparation for research includes graduate coursework in wood-water relationships and transport processes and additional study in areas such as wood anatomy and ultrastructure, mechanical properties, wood chemistry, wood microbiology, thermodynamics, and engineering economics.

Current research interests include use of innovative techniques to dry and preserve wood, effects of drying method on the subsequent treatability of wood, evaluation of energy usage in lumber drying technologies, improving wood properties with polymer treatments, and moisture migration studies.

Students entering this program should have an undergraduate degree in wood science or a closely related field.

Environmental Resources and Forest Engineering (ERFEG)

The ERFEG department supports graduate study and research in several areas with excellent facilities. On-campus facilities include modern laboratories and instrumentation in the engineering departments at both ESF and Syracuse University. Geographic information science efforts are supported by a Mapping Sciences Laboratory with a range of computing platforms and image processing software. Off-campus facilities include the extensive ESF properties, the Heiberg Experimental Watershed, and numerous field sites supported by an array of field equipment for environmental engineering measurements. The ERFEG unit move to new facilities in 2007 further expands its capabilities. The ERFEG option in environmental and resources engineering offers areas of study in:

Ecological Engineering (M.S., Ph.D.)

Participating Faculty: DALEY, DIEMONT, ENDRENY, J.M. HASSETT, KROLL, MOUNTRAKIS, TAO

- Ecosystem restoration
- Watershed and river restoration
- Ecosystems for waste treatment
- Biomass-to-energy systems
- Industrial ecology/life cycle analysis

Ecological Engineering emphasizes engineering design of ecosystems consistent with ecological principles of natural, self-organizing, self-maintaining systems. This interdisciplinary field incorporates knowledge in engineering, ecology and social sciences to produce energy- and information-efficient solutions to environmental problems. Public policy, ethics and values are considered in the decision-making process. Students select between alternative solutions to ecological resource problems, in recognition of environmental, economic, legal, social and managerial constraints.

Students in this option must demonstrate competency in the knowledge areas of physics, biology, chemistry, calculus, probability and statistics, mechanics, and hydrology. Students must take at least one course (3 credit hours) in each of the following areas:

Systems engineering analysis

Applied systems ecology

At least 12 credit hours of graduate coursework must be completed in engineering courses; 3–6 credit hours in natural sciences; and 3-6 hours in resource management. Research credits complete the degree.

Environmental Management (M.P.S.)

Participating Faculty: DALEY, ENDRENY, J.M. HASSETT, KROLL, QUACKENBUSH, TAO

- Brownfield development
- Hazardous waste management
- Solid waste management
- Energy resources management
- Water resource management

Environmental Management combines environmental engineering with business management and environmental law or policy to provide breadth and perspective for the student aspiring to managerial responsibility in public or private employment. Student coursework is designed to enhance technical and problem-solving skills.

Students in the M.P.S. program must complete at least six 3-credit undergraduate courses from at least three of the following fields as pre- or co-requisites: chemistry, physics, geographic measurements, calculus, statistics, engineering mechanics, ecology, computer science, and economics.

At least 12 credit hours of graduate coursework must be completed in engineering courses; 3–6 credit hours in natural sciences; and 3-6 hours in resource management. A comprehensive project or practicum completes the M.P.S. degree requirements. Study programs are flexible and are tailored to the interests and strengths of individuals.

Forest Engineering (M.S., Ph.D.)

- Participating Faculty: DALEY
- Mechanization, automation, robotics
- Production management and efficiency
- Site modification
- Access design and construction

Students who focus on forest engineering are broadening the traditional areas of logging and harvesting. Emphasis is placed on engineering approaches to the design and analysis of operational systems for such activities as harvesting, construction, transportation, and land management. Graduate programs are based on a familiarity with operations and man-machine systems, biologic-geologic interactions, and various selections as needed from the array of engineering selections.

Geospatial Information Science and Engineering (M.S., Ph.D.)

Participating Faculty: MOUNTRAKIS, QUACKENBUSH

- Analytical and digital photogrammetry
- Remote sensing and digital image/video analysis
- Spatial and spatiotemporal databases
- Artificial intelligence in spatial analysis and modeling
- Environmental resources monitoring, modeling and assessment

Geospatial Information Science and Engineering is designed for specialized research in spatial information acquisition, analysis, modeling and applications. This includes theoretical and applied study in sensing systems and the location, measurement,

analysis and description of ground features and earth resources. It also includes use of geographic information systems (GIS) to incorporate spatial data into a wide range of environmental and engineering problems.

Students in this option must demonstrate competency in the knowledge areas of: physics, calculus, statistics, surveying, or computer science. Students may take fundamental and advanced courses in remote sensing, geographic information systems, global positioning systems, photogrammetry, spatial analysis and modeling, and statistics. These courses are supplemented by studies in systems analysis, environmental sciences and management, geography, computer science, and information management. Research credits complete the degree requirements.

Mapping Sciences (M.P.S.)

- Participating Faculty: MOUNTRAKIS, QUACKENBUSH
- Geographic information systems (GIS)
- Global positioning systems (GPS)
- Analytical and digital photogrammetry
- Remote sensing and image processing

Mapping Sciences covers the development and practice of mapping technologies for environmental and engineering applications. Technologies used include GIS and GPS, as well as remote sensing and image processing tools. Students may specialize by taking advanced courses in the mapping sciences, statistics, computing, environmental sciences and management, or other fields. A comprehensive project or practicum completes the M.P.S. degree requirements. Study programs are flexible and are tailored to the interests and strengths of individuals.

Students in this option should have a background in fields such as physics, calculus, statistics, surveying, or computer science and upon completion of the program must demonstrate competency in spatial data acquisition and fundamental spatial analysis concepts.

Water Resources Engineering (M.S., Ph.D.)

Participating Faculty: S. CHATTERJEE, DALEY, ENDRENY, J.M. HASSETT, KROLL, TULLY, MOUNTRAKIS

- Watershed hydrology
- Hydrologic/hydraulic monitoring and modeling
- Water resource systems engineering
- Stochastic/deterministic modeling
- Pollutant fate and transport
- Solid waste treatment and industrial residual flow capture

Water Resources Engineering deals with analysis and design of water resource systems through field, laboratory, and computer methods. Emphasis is placed on coordinating engineering to reduce impacts on human and natural systems. Students select among alternative solutions to water resource problems, in recognition of environmental, economic, legal, social and managerial constraints. Analytical techniques using statistics, numerical analyses, and computer applications are emphasized. Modeling efforts include GIS and remote sensing applications, distributed and real-time models, and model calibration and validation.

Students in this option must demonstrate competency in the knowledge areas of: physics, biology, chemistry, calculus, probability and statistics, mechanics, and hydrology.

Students must take at least one course (3 credit hours) in each of the following areas:

- Hydraulic analysis
- Watershed processes
- Systems engineering analysis
- Pollutant fate and transport

At least 12 credit hours of graduate coursework must be completed in engineering courses. Research credits complete the degree requirements.

Paper and Bioprocess Engineering (PBE)

The option in Paper and Bioprocess Engineering allows students to investigate a diverse range of topics in the area of pulp and paper design, process and product development, and manufacturing, as well as the production of chemicals, energy, and other products from sustainable raw material sources using both chemical and biological methods. The overall objective of the option is to educate students at the M.P.S., M.S., and Ph.D. level in the development of new processes and products that can be produced in an ecologically sound and sustainable manner.

Many research projects are carried out under the auspices of one of the premier research institutes of the world, the Empire State Paper Research Institute (ESPRI), a renowned organization supported jointly by ESF and the Empire State Paper Research Associates, an international consortium of leading industrial companies. ESPRI's research activities aim to generate new information regarding the fundamentals, science, engineering and technology of the production of products and chemicals, especially paper, from renewable resources such as wood in an ecologically sound manner. Recent work has been directed to fundamental investigations of pulping, bleaching, co-products from wood, additives, paper recycling, effluent disposal, the papermaking process, the properties of paper, reactions of wood components during mechanical and chemical treatments, novel wood component separation techniques, new biotechnologically-based pulping methods, process modeling paradigms, the structure of wood and wood fibers, evaporation, fluid dynamics, heat transfer, and chemical recovery. Pilot scale equipment in Walters Hall is often used as an integral part of these research programs.

Examples of inter- and intra-institutional collaborations include the Department of Environmental and Forest Biology and the Department of Chemistry, as well as many industrial cooperators. Cooperative studies enable access to the latest equipment in the computer field, including supercomputers. The department enjoys excellent external support in the form of graduate assistantships, fellowships, and grants from ESPRI, and other industry sources, as well as a number of government granting agencies.

Students can be accepted into the program from a variety of backgrounds. Successful students who have pursued advanced degrees in the Department of Paper and Bioprocess Engineering have had backgrounds in chemical engineering, pulp and paper engineering, civil engineering, mechanical engineering, environmental engineering, chemistry, biological engineering, biology, biotechnology, and manufacturing, among many others. Students planning to obtain graduate degrees in Paper and Bioprocess Engineering should have strong undergraduate preparation in some of the following areas, depending on the particular area of study chosen: mathematics, chemistry, physics, engineering, biological sciences, and computer science. The PBE option of environmental and resources engineering offers areas of study in:

Chemistry of Pulping and Bleaching (M.S., Ph.D.)

Participating Faculty: AMIDON, BUJANOVIC, FRANCIS, LAI, SCOTT

- Reaction mechanisms and kinetics
- Applications of biotechnology
- Lignin and carbohydrate chemistry
- Chemicals from wood and pulping residues
- Energy from wood and pulping residues
- Chemical modification in mechanical pulping
- Catalytic and activation effects

This area of study focuses on chemical relationships and reactions basic to the manufacture and bleaching of pulp, as well as some paper-making operations. Courses in theoretical and applied chemistry are indicated, as well as specialized courses addressed directly to pulping and bleaching. Research centers on these same topics, currently stressing new and improved processes to increase energy efficiency and reduce environmental impact. These include studies on the pre-extraction of wood chips to produce acetic acid from acetyl groups, production of hydrogen and carbon monoxide from gasification of wood and pulping effluents, delignification and brightening with oxygen, hydrogen peroxide and ozone, enzyme treatment of effluent streams, mechanisms of carbohydrate reactions, and photosensitization of bleached pulps.

Colloid Chemistry and Fiber Flocculation (M.S., Ph.D.)

Participating Faculty: AMIDON, RAMARAO

Paper sheet formation mechanisms

Wet-end chemistry and physics

Effects of additives in fiber networks

This study area deals with colloidal phenomena in the paper-making process, in particular the interaction among fibers, fine particles, polymeric additives, and electrolytes in stock preparation and sheet formation. Student programs feature courses in chemical engineering and colloid, polymer and physical chemistry, adding appropriate work in mathematics, statistics and papermaking processes. Research topics fall into two categories: fundamental colloidal behavior of particles, and behavior of paper stock on the paper machine. In the latter, extensive use is made of pilot plant facilities in Walters Hall. Presently under investigation are adsorption-desorption behavior of polymers in papermaking, the chemistry and physics of reactive sizes on model surfaces, and principles of sheet formation.

Fiber and Paper Mechanics (M.S., Ph.D.)

Participating Faculty: ANAGNOST, BUJANOVIC, S. CHATTERJEE, DOELLE, HANNA, KYANKA, RAMARAO

- Fiber orientation and sheet properties
- Adsorption and transport of moisture in paper materials
- Mechano-sorptive phenomena

Mechanical behavior of fibers, paper and board, and other fiber networks and composites depends upon variables of material, process and structure at all levels, especially structural anisotropy. Recommended courses focus on mechanical and chemical engineering, mechanics of materials, physics, mathematics and statistics, microscopy, and wood and fiber properties. Research topics are basic in nature, designed to describe and model quantitatively the properties and behavior of fibers and fibrous structures. Current projects include studies of transient moisture sorption by paper materials, the effect of moisture on mechanical properties, influence of sheet structure on properties, use of image processing to characterize deformational behavior of paper, and determination of elastic constants of paper. Several members of the engineering departments of Syracuse University collaborate closely in this work.

Renewable Energy and Bioprocess Engineering (M.S., Ph.D.)

Participating Faculty: AMIDON, BUJANOVIC, S. CHATTERJEE, DOELLE, FRANCIS, LAI, LIU, RAMARAO, SCOTT, STIPANOVIC

- Energy from biomass and other renewable sources
- Bioseparations of lignocellulosic materials into useful components
- Bioprocessing of renewable materials
- Creation of new bioproducts using ecologically sustainable processes

This area of study encompasses both the use of renewable and sustainable resources (e.g., wood) for the production of chemicals, advanced materials, fuel, and energy, as well as the use of bioprocessing technology to produce such products. Such bioproducts extend to the production of energy from renewable resources including the use of gasification, co-firing of byproducts, anerobic digestion, solar, and the production of ethanol. Courses include chemical engineering, advanced chemistry, biotechnology, and bioengineering, building on a strong base of mathematics, chemistry, and biology. Current research projects in this area include the bioseparation of xylan from hardwoods, the production of ethanol and acetic acid from wood hemicelluloses, development of separation processes for various bioproducts, gasification, enzymatic processing of lignocellulosic materials, and chemical production from sustainable resources as a replacement for non-renewable fossil fuels.

Process and Environmental Systems Engineering (M.S., M.P.S., Ph.D.)

Participating Faculty: S. CHATTERJEE, DOELLE, J.M. HASSETT, RAMARAO, SCOTT, TULLY

- Behavior and control of units and systems
- Reduction of air and water pollution
- Modeling and simulation of papermaking
- Processing of fibrous wastes

Process engineering links research with development, design, operation, and optimization of manufacturing methods and equipment, seeking improvement through technological innovation consistent with environmental and resource stewardship. Principles of engineering science and mathematics are applied to analysis and dynamic modeling of units and systems, with increasing use of computers in both research and professional practice. Research here includes process dynamics and control, studies of new pulping and bleaching processes, characterization and treatment of waste streams, byproduct recovery, and computer simulation of paper processing systems. The extensive laboratories and pilot plant in Walters Hall are strongly supported by computing facilities and expertise on campus, including the Center for Computer Applications and Software Engineering (CASE) of Syracuse University. Appropriate advanced courses in engineering, mathematics and computer science are available to suit individual student interests and needs.

Pulp and Paper Technology (M.S., M.P.S., Ph.D.)

Participating Faculty: AMIDON, BUJANOVIC, DOELLE, FRANCIS, HANNA, LAI, SCOTT

- Pulping conditions and fiber properties
- Fungal and enzymatic treatments

- Chemicals and energy as byproducts
- Statistical analysis of paper structure
- Recycling of papermaking fibers

Studies in this area deal closely with processes involved in the manufacture of pulp and paper. Courses concerned with this subject are central to a student's program, extended and enriched with selected courses in chemistry, polymers, chemical engineering, process control, applied mathematics, and computer applications. Current research projects include non-sulfur pulping, biopulping, chemicals and energy as byproducts, effects of wet pressing and press drying on sheet properties, pulping of tropical woods, and computer simulation and control of papermaking. Supporting this work is an experimental pulp and paper mill with two complete paper machines, a pressurized refiner and extensive auxiliary equipment.

Advanced (Graduate) Certificate in Advanced Engineering Tools

Advanced engineering tools (AET) is a collection of capabilities for acquiring, storing, managing, manipulating, analyzing, displaying, and reporting data or information that relates to locations. This certificate program provides participants with skills in global positioning, geographic information systems, and computer-aided design, including 3-D CAD. Students will have access to and will learn how to apply this technology to complete projects. The curriculum consists of five technical courses and a professional practicum course designed to provide participants with a culminating experience in a relevant business setting where they will test a variety of skills supporting the technical coursework of the program.

Applicants must hold a bachelor's degree from an accredited institution in engineering, science or a related area. Applicants must have prerequisite background in topics that are fundamental to using advanced engineering tools, including pre-calculus and quantitative problem-solving (calculus is desired). Students may meet prerequisites through undergraduate or graduate coursework, or by permission of the department admissions committee. **Students who are matriculated in ESF graduate degree programs are not eligible to earn the Advanced Certificate in Advanced Engineering Tools.**

Application and admissions procedures, compliance with college requirements for successful graduate-level study, and the awarding of advanced certificates are administered by the dean of Instruction and Graduate Studies. Applicants should complete and submit the application form to the Office of Instruction and Graduate Studies. Upon completion of program credit-hour requirements, students will file a certificate request form that identifies completed coursework and initiates actions to produce official transcripts, leading to the award of the certificate.

Students will complete 15 credit hours of graduate coursework, with an average grade of B or better in the following required courses: ERE 550 Introduction to Geographic Information Systems (3); ERE 566 Global Positioning Systems I (1); ERE 610 Computer-Aided Design and Drafting (3); ERE 658 Construction Contracts and Specifications (3); ERE 596 Special Topics (3); and ERE 898 Professional Experience/Synthesis (2).

Advanced (Graduate) Certificate in Bioprocessing

This bioprocessing certificate program was developed through a collaborative and interdisciplinary effort between business and academia to take advantage of this region's unique expertise and resources. Graduates of the program will support the development and manufacture of products produced through bioprocesses, such as those produced in the pharmaceutical and fermentation industries, and biorefineries.

The purpose of the certificate program is to provide:

1. Graduate education in bioprocessing that leads to a documented level of competency for practice;
2. A structured and documented course of study at the graduate level; and
3. A means for students to improve their competitive position in the employment marketplace.

Applicants must hold a bachelor's degree from an accredited institution in engineering, science or a related area. The student must have the required prerequisite background in topics that are fundamental to bioprocessing guided from previous course-work or professional experience. Applicants must demonstrate competence in pre-calculus and quantitative problem-solving, preferably with calculus. **Students who are matriculated in ESF graduate degree programs are not eligible to earn the Advanced Certificate in Bioprocessing.**

Application and admissions procedures, compliance with college requirements for successful graduate-level study, and the awarding of advanced certificates are administered by the dean of Instruction and Graduate Studies. Applicants should complete and submit the application form to the Office of Instruction and Graduate Studies. Upon completion of program credit-hour requirements, students will file a certificate request form that identifies completed coursework and initiates actions to produce official transcripts, leading to the award of the certificate.

The curriculum consists of five technical courses including a capstone professional experience/synthesis course that will provide participants with a variety of skills supporting the technical aspects of the program. The capstone course will challenge students to use the skills they learned throughout the program and apply those skills to relevant business settings. Students will complete 15 credit hours of graduate coursework with an average grade of B or better in the following required courses: ERE 501 Microbiology for Bioprocessing (3); ERE 502 Bioseparations (3); ERE 503 Bioprocess Plant Design (3); ERE 542 Bioreaction Engineering (3); and ERE 898 Professional Experience/Synthesis (3).