Civil and Environmental Engineering

Degrees Offered

- Master of Science in Civil and Environmental Engineering
- Doctor of Philosophy in Civil and Environmental Engineering
- Master of Science in Environmental Engineering Science
- Doctor of Philosophy in Environmental Engineering Science
- Graduate Certificate in Underground Construction and Tunnel Engineering
- Graduate Certificate in Environmental Modeling

Program Description

The Civil and Environmental Engineering Department offers MS and PhD graduate degrees in Civil and Environmental Engineering (CEE) and Environmental Engineering Science (EES). Students entering this degree program should have a BS degree in engineering or science and will need to take or have taken all general and emphasis area-specific prerequisite courses.

Within the CEE degree, students complete specified requirements in one of three different emphasis areas: Environmental and Water Engineering, Geotechnical Engineering, and Structural Engineering.

The EES degree has a flexible curriculum that enables students with a BS degree in biology, chemistry, math, physics, geology, engineering, and other technical fields, to tailor a coursework program that best fits their career goals.

The non-thesis MS degrees in CEE and EES are eligible programs in the Western Regional Graduate Program (WRGP/WICHE), which promotes the sharing of higher education resources among participating western states. An important benefit of this designation is that students who are residents from Alaska, Arizona, California, Hawaii, Idaho, Montana, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Utah, Washington, and Wyoming, as well as Commonwealth of the Northern Mariana Islands, Federal States of Micronesia, Guam, American Samoa, Republic of Palau, and Republic of the Marshall Islands may be eligible for discounted-rate non-resident tuition. More information on the WRGP program is available here.

The specific requirements for the EES and CEE degrees, as well as for the three emphasis areas within the CEE degree, are described in detail under the Major tab.

To achieve the MS degree, students may elect the non-thesis option, based exclusively upon coursework and project activities, or the thesis option, which requires coursework and research conducted under the guidance of a faculty advisor and MS thesis committee. The research is described in a final written thesis that is defended in an oral presentation.

The PhD degree requires students to complete a combination of coursework and original research, under the guidance of a faculty advisor and doctoral committee, that culminates in a significant scholarly contribution (e.g., in the form of published journal articles) to a specialized field in civil and environmental engineering or environmental engineering science. The written thesis must be defended in a public oral presentation before the advisor and thesis committee. The PhD program may build upon one of the CEE or EES MS programs or a comparable MS program at another university. Full-time PhD enrollment is expected although part-time enrollment may be allowed under special circumstances.

Civil and Environmental Engineering

Geotechnical Engineering is concerned with the engineering properties and behavior of natural and engineered geomaterials (soils and rocks), as well as the design and construction of foundations, earth dams and levees, retaining walls, embankments, and underground infrastructure including tunnels. Additionally, mitigation of the impact of natural hazards such as earthquakes and landslides, sustainable use of energy and resources, and reduction of the environmental impacts of human activities require geotechnical engineers who have in-depth understanding of how geomaterials respond to loads, and environmental changes.

Structural Engineering is a study area focused on natural and engineered structures and their behavior under environmental loading. Structural engineers use general principles of structural mechanics to conduct analyses of engineered materials and design structures for civil systems. Designed systems may include bridges, dams, buildings, tunnels, sustainable infrastructure, highways, biomechanical apparatus, sustainable civil engineering materials and numerous other structures and devices.

Environmental and Water Engineering is the application of environmental processes in natural and engineered systems. CEE faculty have expertise in water resource engineering, biosystems engineering, environmental chemistry, environmental microbiology, microbial genomics, wastewater treatment, water treatment, bioremediation, mining treatment processes and systems, remediation processes, biogeochemical reactions in soils, geobiology, membrane processes, humanitarian engineering, social aspects of engineering, and energy recovery from fluids.

Environmental Engineering Science

Environmental Engineering and Science is the application of environmental processes in both natural and engineered systems. CEE faculty have expertise in water resource engineering, biosystems engineering, environmental chemistry, environmental microbiology, microbial genomics, wastewater treatment, water treatment, bioremediation, mining treatment processes and systems, remediation processes, biogeochemical reactions in soils, geobiology, membrane processes, humanitarian engineering, social aspects of engineering, and energy recovery from fluids. The EES degree does not require an undergraduate engineering degree; however, an undergraduate degree in science or engineering is preferable.

Affiliated Interdisciplinary Degrees

Humanitarian Engineering and Science (HES) offers interdisciplinary programs of study targeted towards recent graduates or mid-career professionals with a BS in science and engineering who are interested in careers, research opportunities, and/or acquiring skills that will help them work effectively with communities. In both the master's degree and graduate certificates, a unique mix of social science, applied science, and engineering perspectives prepares students to apply knowledge about the earth to promote more sustainable and just uses of water, energy, and other earth resources and to understand and mitigate potential hazards.

For more information, see the HES section of this graduate catalog listed under Interdisciplinary Programs.

Hydrologic Science and Engineering (HSE) offers interdisciplinary programs of study in fundamental hydrologic science and applied hydrology with engineering applications. Our program encompasses groundwater hydrology, surface-water hydrology, vadose-zone hydrology, watershed hydrology, contaminant transport and fate, contaminant remediation, hydrogeophysics, and water policy/law. HSE is part of the Western Regional Graduate Program (WICHE), a recognition that designates the program as unique within the western United States. An important benefit of this designation is that students from several western states are given the tuition status of Colorado residents. These states include Alaska, Arizona, California, Hawaii, Idaho, Montana, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Utah, Washington, and Wyoming.

The graduate degree program in HSE is offered jointly the Departments of Chemistry and Geochemistry, Civil and Environmental Engineering (CEE), Geology and Geological Engineering (GE), Geophysical Engineering, Humanities, Arts, and Social Sciences (HASS), Mechanical Engineering (ME), Mining Engineering (MN), and Petroleum Engineering (PE). Participating students reside in one of these departments, typically the home department of their advisor.

For more information, see the HSE section of this graduate catalog listed under Interdisciplinary Programs.

Quantitative Biosciences and Engineering (QBE) offers interdisciplinary programs of study in fundamental biosciences with engineering applications. Students may enroll in MS, non-thesis MS and PhD degree programs. As a foundation, our program encompasses core courses in cell biology and biochemistry, applied bioinformatics and systems biology with over 25 electives from biophysics to prosthetic and implant engineering to biomaterials to microfluids to geobiology. The graduate degree program in QBE is offered jointly by the Departments of Applied Mathematics and Statistics (AMS), Chemical and Biological Engineering (CBE), Chemistry and Geochemistry (CH), Civil and Environmental Engineering (CEE), Computer Science (CS), Geology and Geological Engineering (GE), Humanities, Arts, and Social Sciences (HASS), Mechanical Engineering (ME), and Physics (PH). Participating students reside in one of these departments, typically the home department of their advisor.

For more information, see the QBE section of this graduate catalog listed under Interdisciplinary Programs.

Underground Construction and Tunnel Engineering (UCTE) is an interdisciplinary field involving civil engineering, geological engineering and mining engineering, as well as mechanical engineering, geophysics, geology and others. UCTE deals with the design, construction, rehabilitation and management of underground space including caverns, shafts and tunnels for commercial, transportation, water and wastewater use. UCTE is a challenging field involving complex soil and rock behavior, groundwater conditions, excavation methods, construction materials, structural design flow, heterogeneity, and very low tolerance for deformation due to existing infrastructure in urban environments. Students pursuing a graduate degree or certificate in UCTE will gain a strong and interdisciplinary foundation in these topics. The graduate degree program in UCTE is offered jointly by the Departments of Civil and Environmental Engineering (CEE), Geology and Geological Engineering (GE), and Mining Engineering (MN). UCTE faculty from each department are collectively responsible for the operations of the program. Participating students reside in one of these departments, typically the home department of their advisor.

For more information, see the UCTE section of this graduate catalog listed under Interdisciplinary Programs.

Program Requirements

General Degree Requirements for CEE and EES degrees:

MS Non-Thesis Option: 30 total credit hours (CH), consisting of coursework (27 CH) and either a three credit hour research based Independent Study (CEEN599) OR a designated design course (3 CH) and two semesters of seminar.

MS Thesis Option: 30 total credit hours (CH), consisting of coursework (24 CH), two semesters of seminar, and research (6 CH). Students must also write and orally defend a research thesis.

PhD: 72 total credit hours (CH), consisting of coursework (at least 24 CH), two semesters of seminar, and research (at least 24 CH). Students must also successfully complete qualifying examinations, prepare and present a thesis proposal, and write and defend a doctoral thesis. PhD students are also expected to submit the thesis work for publication in scholarly journals.

All students must take at least 18 credits within the CEEN prefix. The student may petition the advisor and/or thesis committee to allow reduction of the CEEN coursework requirement to a minimum of 15 credits (however, the core course requirements must be met).

PhD Qualifying Exam

The student’s graduate faculty advisor in conjunction with the graduate thesis committee administers the PhD qualifying exam. It is designed to test some of the attributes considered essential to successful doctoral level scholarship, including foundational knowledge, critical thinking, creativity, and communication skills. The student should take the exam within four semesters of enrollment in the PhD program unless the graduate thesis committee grants an extension.

The conduct of the qualifying exam is flexible, but typically involves both written and oral components. The written component might include several take-home questions set by members of the committee, and a review or research paper on a topic related to the student’s intended research area. The duration of the written exam is set by the committee, but is expected to be approximately one week. As soon as practicable, following the return of the completed exam materials to the advisor, a meeting with the student and committee is scheduled, during which the student may be required to make an oral presentation of the paper review, followed by further oral examination of the other written materials and any other topics deemed appropriate by the committee. Following the oral component, the student is informed of the result of the examination (pass/fail), and the advisor informs the department head and graduate program manager of the outcome.

In the event the student does not pass the qualifying exam, the student may petition the department head for a re-examination within six months. If permission is granted, the dates of the re-examination are arranged in conjunction with the advisor and committee, and will follow the same guidelines as before.

A second failure of the qualifying exam does not disqualify a student for the MS degree but may affect the student’s financial support status, and will result in a recommendation from the CEE department head to the graduate school that the student be dismissed from the CEE or EES PhD program.

PhD Proposal Defense

The student's graduate faculty advisor, in conjunction with the graduate thesis committee, administers the PhD proposal defense. The purpose of the thesis proposal is to describe the student's research in sufficient detail to enable evaluation of its merit and viability. In general, the written proposal will describe the purpose and scope of work, anticipated results, literature review, preliminary findings, proposed research approach and methodologies, along with a schedule. No later than two weeks following submission of the thesis proposal to the committee, the student and committee will meet for an oral presentation, during which the student will be questioned about matters immediately relevant to the thesis proposal. The committee will reach a decision as to whether the proposed research is appropriate and achievable for a CEE or EES PhD degree. Following the meeting, the student is informed of whether the proposal has been approved, and the advisor informs the department head and department manager of the outcome.

In the event the student does not pass the proposal defense, he/she may petition the department head for a re-examination within six months. If permission is granted, the proposal can be revised for reconsideration by the committee, following exactly the same guidelines as before.

A second proposal defense failure will result in a recommendation from the CEE department head to the graduate school that the student be dismissed from the CEE or EES PhD program.

A PhD student must obtain approval of his/her thesis proposal by the committee at least one year before the final thesis defense.

NOTE: Affiliated Interdisciplinary Degree Programs may have a different PhD qualifying exam/proposal defense procedure.

Mines' Combined Undergraduate / Graduate Degree Program

Students enrolled in Mines' combined undergraduate/graduate program may double count up to 6 credits of graduate coursework to fulfill requirements of both their undergraduate and graduate degree programs. These courses must have been passed with B- or better, not be substitutes for required coursework, and meet all other university, department, and program requirements for graduate credit.

Students are advised to consult with their undergraduate and graduate advisors for appropriate courses to double count upon admission to the combined program.

Civil and Environmental Engineering

Prerequisites for CEE Degree:

- Baccalaureate degree: required, preferably in a science or engineering discipline
- College calculus I and II: two semesters required
- College physics: one semester required, two semesters highly recommended
- College chemistry I and II: two semesters required
- College statistics: one semester required
- Differential Equations
- **Emphasis Area Additional Requirements:**
    - **Geotechnical and Structural –** Mechanics of Materials, Soil Mechanics, Structural Theory/Structural Analysis, Statics
    - **Environmental and Water –** Fluid Mechanics

Required Coursework for CEE Degrees:

CEE MS and PhD students must complete the coursework requirements for at least one emphasis area, comprised of core (required) courses and elective courses.

The student's advisor and committee (if MS thesis or PhD student) must approve elective courses.

Students must take at least 18 credits within the CEEN prefix. The student may petition the advisor and/or thesis committee to allow reduction of the CEEN coursework requirement to a minimum of 15 credits (however, the core course requirements must be met).

Geotechnical Engineering

Geotechnical Core Courses: Students are required to successfully complete three courses from the following core course list plus CEEN590 Civil Engineering seminar (two semesters required).

CEEN506	FINITE ELEMENT METHODS FOR ENGINEERS	3.0
CEEN510	ADVANCED SOIL MECHANICS	3.0
CEEN511	UNSATURATED SOIL MECHANICS	3.0
CEEN512	SOIL BEHAVIOR	3.0
CEEN515	HILLSLOPE HYDROLOGY AND STABILITY	3.0
CEEN519	RISK ASSESSMENT IN GEOTECHNICAL ENGINEERING	3.0
CEEN523	UNDERGROUND CONSTRUCTION ENGINEERING IN SOFT GROUND	4.0
CEEN582	VADOSE ZONE HYDROLOGY	3.0

Structural Engineering

Structural Engineering Core Courses: Students are required to successfully complete three courses from the following core course list plus CEEN590 Civil Engineering seminar (two semesters required).

CEEN506	FINITE ELEMENT METHODS FOR ENGINEERS	3.0
CEEN530	ADVANCED STRUCTURAL ANALYSIS	3.0
CEEN531	STRUCTURAL DYNAMICS	3.0
CEEN533	MATRIX STRUCTURAL ANALYSIS	3.0
CEEN541	DESIGN OF REINFORCED CONCRETE STRUCTURES II	3.0
CEEN542	DESIGN OF WOOD STRUCTURES	3.0
CEEN543	ADVANCED DESIGN OF STEEL STRUCTURES	3.0
CEEN545	STEEL BRIDGE DESIGN	3.0

Environmental and Water Engineering

Additional Prerequisites Courses: fluid mechanics.

Environmental & Water Engineering Core Courses: Students are required to successfully complete one course as specified in each of the following areas plus CEEN596 Environmental Seminar (two semesters required):

Chemistry		
CEEN550	PRINCIPLES OF ENVIRONMENTAL CHEMISTRY	3.0

Physical Transport		
CEEN580	CHEMICAL FATE AND TRANSPORT IN THE ENVIRONMENT	3.0
Bio Processes		
CEEN566	MICROBIAL PROCESSES, ANALYSIS AND MODELING	3.0
or CEEN560	MOLECULAR MICROBIAL ECOLOGY AND THE ENVIRONMENT	
or CEEN562	ENVIRONMENTAL GEOMICROBIOLOGY	
Systems Design		
CEEN570	WATER AND WASTEWATER TREATMENT	3.0
or CEEN578	WATER TREATMENT DESIGN AND ANALYSIS	
Seminar		
CEEN596	ENVIRONMENTAL SCIENCE AND ENGINEERING SEMINAR	0.0

Designated Design Courses

Geotechnical		
CEEN515	HILLSLOPE HYDROLOGY AND STABILITY	3.0
CEEN523	UNDERGROUND CONSTRUCTION ENGINEERING IN SOFT GROUND	4.0
Structural		
CEEN541	DESIGN OF REINFORCED CONCRETE STRUCTURES II	3.0
CEEN542	DESIGN OF WOOD STRUCTURES	3.0
CEEN543	ADVANCED DESIGN OF STEEL STRUCTURES	3.0
CEEN545	STEEL BRIDGE DESIGN	3.0
CEEN547	DESIGN OF PRESTRESSED CONCRETE STRUCTURES	3.0
CEEN549	INTRODUCTION TO THE SEISMIC DESIGN OF STRUCTURES	3.0
Environmental and Water		
CEEN570	WATER AND WASTEWATER TREATMENT	3.0
CEEN575	HAZARDOUS WASTE SITE REMEDIATION	3.0
CEEN578	WATER TREATMENT DESIGN AND ANALYSIS	3.0
CEEN581	WATERSHED SYSTEMS MODELING	3.0
CEEN584	SUBSURFACE CONTAMINANT TRANSPORT	3.0

Environmental Engineering Science

Prerequisites for EES degree:

- Baccalaureate degree: required, preferably in a science or engineering discipline
- College calculus I and II: two semesters required
- College physics: one semester required, two semesters highly recommended
- College chemistry I and II: two semesters required
- College statistics: one semester required

Required Curriculum for Environmental Engineering Science (EES) Degree:

The EES curriculum consists of common core and elective courses that may be focused toward specialized areas of emphasis. The common core includes:

CEEN550	PRINCIPLES OF ENVIRONMENTAL CHEMISTRY	3.0
CEEN580	CHEMICAL FATE AND TRANSPORT IN THE ENVIRONMENT	3.0
CEEN566	MICROBIAL PROCESSES, ANALYSIS AND MODELING	3.0
or CEEN560	MOLECULAR MICROBIAL ECOLOGY AND THE ENVIRONMENT	
or CEEN562	ENVIRONMENTAL GEOMICROBIOLOGY	
ENVIRONMENTAL BASED LAW OR POLICY COURSE Commonly HASS Courses		3.0
CEEN596	ENVIRONMENTAL SCIENCE AND ENGINEERING SEMINAR (two semesters required)	0.0
CEEN ELECT	3.0 CR INDEPENDENT STUDY OR 3.0 cr DESIGN COURSE	3.0

Program Requirements

Graduate Certificate in Underground Construction and Tunnel Engineering

The interdisciplinary Graduate Certificate in Underground Construction and Tunnel Engineering (UCTE) is comprised of the three signature courses listed below. The two anchor courses teach UCTE in hard rock and soft ground while the remaining course teaches underground infrastructure construction management principles.

Applicants for the certificate are required to be admitted into the combined BS + MS program or have an undergraduate degree in science or engineering, with geotechnical and mechanics of materials coursework, to be admitted into the certificate program. Students working toward the UCTE graduate certificate are required to successfully complete 10 credits, as detailed below. The courses taken for the graduate certificate can be used towards a master's or PhD degree at Mines.

CEEN523	UNDERGROUND CONSTRUCTION ENGINEERING IN SOFT GROUND	4.0
CEEN532	UNDERGROUND INFRASTRUCTURE CONSTRUCTION MANAGEMENT	3.0
or MNGN509	CONSTRUCTION ENGINEERING AND MANAGEMENT	
MNGN504	UNDERGROUND CONSTRUCTION ENGINEERING IN HARD ROCK	3.0
Total Semester Hrs		**10.0**

Program Requirements

Graduate Certificate in Environmental Modeling (9 credits)

The Environmental Modeling Graduate Certificate is an online or residential program focusing on the tools and methods for modeling environmental impacts of systems. Students will learn basic environmental modeling methods such as chemical fate and transport, risk assessment, and systems analysis. The certificate balances an introduction to environmental issues with a deep dive into environmental modeling. Students will gain perspective on the kinds of problems that can be solved with environmental modeling and will also acquire valuable modeling skills. Moreover, the coursework will cover a broad range of applications, making it relevant for varied scientific and engineering domains.

The 2 required courses in the certificate include:

CEEN580	CHEMICAL FATE AND TRANSPORT IN THE ENVIRONMENT	3.0
CEEN501	LIFE CYCLE ASSESSMENT	3.0

To complete the certificate, students will select one elective from the following:

DSCI503	ADVANCED DATA SCIENCE	3.0
GEGN575	APPLICATIONS OF GEOGRAPHIC INFORMATION SYSTEMS	3.0
GEOL557	EARTH RESOURCE DATA SCIENCE 1: FUNDAMENTALS	3.0
MNGN502	GEOSPATIAL BIG DATA ANALYTICS	3.0

CEENADD. SPECIAL TOPICS. 4.0 Semester Hrs.

CEEN501. LIFE CYCLE ASSESSMENT. 3.0 Semester Hrs.
(I, II) Which is more sustainable: paper vs plastic, hybrid vs electric vehicles? LCA is a powerful tool used to answer these questions; LCA quantifies the environmental sustainability of a product or process. Students will learn to conduct an LCA during a semester-long project of their choosing. At the end of the course students should be able to sit for the ACLCA professional LCACP certification exam. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- 1. Identify environmental sustainability challenges and opportunities for engineered systems from a life-cycle perspective
- 2. Draw a process flow diagram and Create a life cycle inventory
- 3. Understand and calculate different environmental impact categories
- 4. Conduct a simple life cycle assessment for a product or process
- 5. Utilize LCA results for decision making
- 6. Understand the process for conducting an ISO 14000 series certified LCA

CEEN505. NUMERICAL METHODS FOR ENGINEERS. 3.0 Semester Hrs.
(II) Introduction to the use of numerical methods in the solution of commonly encountered problems of engineering analysis. Structural/solid analysis of elastic materials (linear simultaneous equations); vibrations (roots of nonlinear equations, initial value problems); natural frequency and beam buckling (eigenvalue problems); interpretation of experimental data (curve fitting and differentiation); summation of pressure distributions (integration); beam deflections (boundary value problems). All course participants will receive source code of all the numerical methods programs published in the course textbook which is coauthored by the instructor. 3 hours lecture; 3 semester hours.

CEEN506. FINITE ELEMENT METHODS FOR ENGINEERS. 3.0 Semester Hrs.
(II) A course combining finite element theory with practical programming experience in which the multidisciplinary nature of the finite element method as a numerical technique for solving differential equations is emphasized. Topics covered include simple structural elements, beams on elastic foundations, solid elasticity, steady state analysis and transient analysis. Some of the applications will lie in the general area of geomechanics, reflecting the research interests of the instructor. Students get a copy of all the source code published in the course textbook. 3 hours lecture; 3 semester hours. Prerequisite: Consent of the instructor.

CEEN510. ADVANCED SOIL MECHANICS. 3.0 Semester Hrs.
(I) Advanced soil mechanics theories and concepts as applied to analysis and design in geotechnical engineering. Topics covered will include seepage, consolidation, shear strength, failure criteria and constitutive models for soil. The course will have an emphasis on numerical solution techniques to geotechnical problems by finite elements and finite differences. 3 Lecture Hours, 3 semester hours. Fall even years. Prerequisite: A first course in soil mechanics.

CEEN511. UNSATURATED SOIL MECHANICS. 3.0 Semester Hrs.
(I) The focus of this course is on soil mechanics for unsaturated soils. It provides an introduction to thermodynamic potentials in partially saturated soils, chemical potentials of adsorbed water in partially saturated soils, phase properties and relations, stress state variables, measurements of soil water suction, unsaturated flow laws, measurement of unsaturated permeability, volume change theory, effective stress principle, and measurement of volume changes in partially saturated soils. The course is designed for seniors and graduate students in various branches of engineering and geology that are concerned with unsaturated soil's hydrologic and mechanics behavior. When this course is cross-listed and concurrent with CEEN412, students that enroll in CEEN511 will complete additional and/or more complex assignments. 3 hours lecture; 3 semester hours. Prerequisite: CEEN312.

CEEN512. SOIL BEHAVIOR. 3.0 Semester Hrs.
(I) The focus of this course is on interrelationships among the composition, fabric, and geotechnical and hydrologic properties of soils that consist partly or wholly of clay. The course will be divided into two parts. The first part provides an introduction to the composition and fabric of natural soils, their surface and pore-fluid chemistry, and the physico-chemical factors that govern soil behavior. The second part examines what is known about how these fundamental characteristics and factors affect geotechnical properties, including the hydrologic properties that govern the conduction of pore fluid and pore fluid constituents, and the geomechanical properties that govern volume change, shear deformation, and shear strength. The course is designed for graduate students in various branches of engineering and geology that are concerned with the engineering and hydrologic behavior of earth systems, including geotechnical engineering, geological engineering, environmental engineering, mining engineering, and petroleum engineering. When this course is cross-listed and concurrent with CEEN411, students that enroll in CEEN512 will complete additional and/or more complex assignments. 3 hours lecture; 3 semester hours.

CEEN513. ADVANCED GEOMATERIAL MECHANICS. 4.0 Semester Hrs.
This course deals with the classification and engineering behavior of soil and rock materials as well as materials used in underground construction such as structural steel, aggregates, cement, timber, concrete, shotcrete, accelerators and ground conditioning agents. This course presents an advanced treatment of soil and rock mechanics with focus on the following topics: Index and classification properties of soils, Physical properties and classification of intact rock and rock masses, Fluid flow in soils and rocks, Compressibility of soils and rocks, Failure theories and strength testing of soils and rocks, Shear strength of soils and rocks, Stresses and deformations around underground openings, Laboratory and field methods for evaluation of soil and rock properties, and Analytical and empirical approaches for the design and construction of structures in soil and rock materials. Undergraduate degree in a

pertinent discipline of engineering or equivalent and undergraduate level knowledge of material behavior. 4 hours lecture; 4 semester hours.
Course Learning Outcomes

- Understand the behavior of coarse- and fine-grained soils in dry and saturated conditions
- Understand the stress-strain-strength behavior of soils in drained and undrained conditions
- Estimate the soil and rock shear strength properties for design purposes
- Evaluate the engineering properties of soils and rocks and determine appropriate input parameters for numerical models
- Evaluate the potential deformation of soil and rock and the stability of structure during staged construction
- Identify and explain significant considerations in choosing a material for a specific application including mechanical properties, durability, and sustainability.
- Follow standards to conduct tests of material properties and perform the calculations necessary to analyze and interpret test results.
- Work effectively in teams to perform experimental tasks and write formal technical report and convey engineering message efficiently.
- Use commercial engineering test equipment to determine mechanical properties of soil, rock, and construction materials
- Design and make conventional and high performance concrete and shotcrete mixtures and evaluate their fresh and hardened properties.

CEEN515. HILLSLOPE HYDROLOGY AND STABILITY. 3.0 Semester Hrs.
(I) Introduction of shallow landslide occurrence and socio-economic dynamics. Roles of unsaturated flow and stress in shallow landslides. Slope stability analysis based on unsaturated effective stress conceptualization. Computer modeling of unsaturated flow and stress distributions in hillslope. Prediction of precipitation induced shallow landslides. Prerequisite: CEEN312. 3 hours lecture; 3 semester hours.

CEEN519. RISK ASSESSMENT IN GEOTECHNICAL ENGINEERING. 3.0 Semester Hrs.
(I) Soil and rock are among the most variable of all engineering materials, and as such are highly amenable to a probabilistic treatment. Assessment of the probability of failure or inadequate performance is rapidly gaining ground on the traditional factor of safety approach as a more rational approach to design decision making and risk management. Probabilistic concepts are also closely related to system reliability and Load and Resistance Factor Design (LRFD). When probability is combined with consequences of failure, this leads to the concept of risk. This course is about the theory and application of various tools enabling risk assessment in engineering with an emphasis on geotechnical applications. Prerequisite: CEEN312. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- Learn the basics of risk assessment in geotechnical engineering

CEEN523. UNDERGROUND CONSTRUCTION ENGINEERING IN SOFT GROUND. 4.0 Semester Hrs.
Design and construction of water, wastewater, transportation and utility tunnels, underground space and shafts/excavations in soft ground conditions (soil and weak rock). Addresses geotechnical site characterization, selection of design parameters, stability and deformation analysis of the ground and overlying structures, and construction methods. Includes design of temporary and permanent structural ground support according to ASD (allowable stress design) and LRFD (load resistance factor design) approaches, and design of ground improvement schemes and instrumentation/monitoring approaches to mitigate risk. This course requires post-graduate level knowledge of soil mechanics, fundamental understanding of engineering geology, and an undergraduate level knowledge of structural analysis and design. Prerequisites: CEEN312. 4 semester hours.
Course Learning Outcomes

- 1. Understand the variety of underground construction methodologies, their application, strengths and limitations
- 2. Characterize, through analytical and numerical techniques, the 3d stress and deformation fields, and stability in various shaped shallow and deep underground openings (tunnels, caverns, shafts)
- 3. Analyze and design both temporary and permanent structural support/lining for underground openings (tunnels, caverns, shafts)
- 4. Understand and design ground improvement techniques
- 5. Analyze and design for groundwater control
- 6. Estimate deformation and damage to adjacent structures due to underground construction of tunnels, caverns, shafts
- 7. Implement a formal risk assessment and management process for underground construction
- 8. Identify appropriate geotechnical parameters and their uncertainties for analysis and design of underground spaces
- 9. In a team environment, analyze and design critical elements of a real-world underground construction project

CEEN525. CEMENTITIOUS MATERIALS FOR CONSTRUCTION. 3.0 Semester Hrs.
(II) Cementitious materials, as the most commonly used construction materials, are the main focus of this course and variety of cementitious materials including Portland and non-Portland cements, supplementary cementitious materials, concrete and sprayed concrete (shotcrete), and grouts with their needed additional constituents are covered in this course. This course provides a comprehensive treatment of engineering principles and considerations for proper design, production, placement and maintenance of high quality cementitious materials for infrastructure. In addition, cementitious materials and techniques used for ground improvement purposes are covered in this course. 3 semester hours.
Course Learning Outcomes

- 1. Describe the main properties of concrete constituents and their influence on the behavior • Describe the cement composition, phases, types, and the hydration process • List the different types of cements and their proper applications • Select the right types of admixtures to be used in different applications and situations • Describe the effects of supplementary cementitious materials on concrete properties
- 2. Design and Test Cementitious Construction materials to meet specifications • Design conventional and high performance Portland cement concrete mixtures with supplementary cementitious materials to meet specifications • Design concrete mix for spraying applications to meet the requirements for ground support needs • Identify the appropriate testing method for evaluation of concrete properties
- 3. Propose ground improvement solutions for different ground conditions using Cementitious Materials • Describe the different ground improvement techniques and explain the differences among current techniques • Identify the appropriate type of ground improvement and specify the requirements for the materials needed
- 4. Apply the concepts learned in the class in understanding the nature, types and applications of cementitious materials by •

Selecting a topic of interest related to Cementitious Materials • Conducting research in groups • Presenting the work in written and oral presentation formats

CEEN526. DURABILITY OF CONCRETE. 3.0 Semester Hrs.
This course will provide an in-depth overview of concrete properties relevant to deterioration, including transport, mechanical, physical, and chemical properties. After this course, students should be able to identify, quantify, and mitigate against various deterioration mechanisms, such as freezing and thawing, sulfate attack, alkali-aggregate reactions, acid attack, and corrosion of steel rebar. This course will also illustrate how to test materials for durability (hands-on activities included) and ways in which construction methods may affect durability. Students will learn the strengths and limitations of the worlds most ubiquitous building material. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- 1. Explain how the microstructure of concrete develops.
- 2. Explain how the microstructure of concrete affects engineering properties.
- 3. Identify different deterioration mechanisms that affect concrete and explain how they impact concrete durability.
- 4. Explain the principles behind various durability tests.
- 5. Conduct durability tests and assess the performance.

CEEN530. ADVANCED STRUCTURAL ANALYSIS. 3.0 Semester Hrs.
(I) Introduction to advanced structural analysis concepts. Nonprismatic structures. Arches, Suspension and cable-stayed bridges. Structural optimization. Computer Methods. Structures with nonlinear materials. Internal force redistribution for statically indeterminate structures. Graduate credit requires additional homework and projects. Prerequisite: CEEN314. 3 hour lectures, 3 semester hours.

CEEN531. STRUCTURAL DYNAMICS. 3.0 Semester Hrs.
An introduction to the dynamics and earthquake engineering of structures is provided. Subjects include the analysis of linear and nonlinear single-degree and multi-degree of freedom structural dynamics. The link between structural dynamics and code-based analysis and designs of structures under earthquake loads is presented. The focus applications of the course include single story and multi-story buildings, and other types of structures that under major earthquake may respond in the inelastic range. Prerequisite: CEEN314. 3 hour lectures, 3 semester hours.

CEEN532. UNDERGROUND INFRASTRUCTURE CONSTRUCTION MANAGEMENT. 3.0 Semester Hrs.
In this course students will learn the fundamental and practical aspects of underground infrastructure construction management. Underground infrastructure includes tunnels for road, rail, transit, water, and utilities; shafts for tunnel access, ventilation, and pump stations; and excavations for underground transit stations, commercial, and recreational space, all of which comprises the civil infrastructure required for societies to grow and prosper. Through lectures, reading/viewing materials, case studies, assignments/exercises, and class discussions, as developed by current & former construction managers, students will gain practical instruction and practice on the traditional civil construction management process areas of contracts, procurement methods for public infrastructure, estimating and costs, scheduling, quality, safety, performance and risk management, and decision-making, all with a focus on underground infrastructure. Industry standards, specifications, and best practices that will be taught. Students will be exposed to what an underground infrastructure construction manager does on site: their roles & responsibilities, essential skillsets, and effective character attributes. Course topics also delve into the people management areas of communications, conflict resolution, stakeholder engagement, emotional intelligence, and leadership.

CEEN533. MATRIX STRUCTURAL ANALYSIS. 3.0 Semester Hrs.
Equivalent with CEEN433,
(II) Focused study on computer oriented methods for solving determinate and indeterminate structures such as trusses and frames. Classical stiffness based analysis method will be introduced with hands-on practice to develop customized matrix analysis program using Matlab. Commercial structural analysis programs will also be introduced during the class and practiced through class projects. When this course is cross-listed and concurrent with CEEN433, students that enroll in CEEN533 will complete additional and/or more complex assignments. 3 lecture hours, 3 semester hours. Prerequisite: CEEN314.
Course Learning Outcomes

- At the completion of this course, students will: 1. Gain fundamental understanding on Matrix analysis method and procedure, understand how commercial structural FEM packages work at a fundamental level 2. Be able to program basic linear member finite element code using Matlab 3. Use principle of virtual work to formulate matrix structural analysis elements 4. Use commercial structural analysis software to solve typical structural analysis problems 5. Gain fundamental Matlab programming and data process techniques # At the completion of CEEN533, students will be able to use Matlab to program matrix structural analysis code to solve determinate and indeterminate 3D truss and frame problems. This outcome will be measured by the completion of the programming tasks required in this class. Students' program will be evaluated and graded for correctness. # They will also be able to use a commercial structural analysis software package to construct 3D models for real structures, analyze the model under different static and dynamic loading conditions. This outcome will be measured by the completion of group project of modeling and analyzing a real structure using a commercial software program provide in the computer lab. # They will also be able to derive simple 2D line element stiffness matrix using the principle of virtual work. This outcome will be evaluated by a mid-term exam.

CEEN540. CONCRETE BRIDGE DESIGN. 3.0 Semester Hrs.
The course extends the coverage of steel design to include the topics: slender columns, beam-columns, frame behavior, bracing systems and connections, stability, moment resisting connections, composite design, bolted and welded connections under eccentric loads and tension, and semi-rigid connections. Course offered every third semester. 3 hours lecture; 3 semester hours.

CEEN541. DESIGN OF REINFORCED CONCRETE STRUCTURES II. 3.0 Semester Hrs.
Advanced problems in the analysis and design of concrete structures, design of slender columns; biaxial bending; two-way slabs; strut and tie models; lateral and vertical load analysis of multistory buildings; introduction to design for seismic forces; use of structural computer programs. Course offered every third semester. 3 hours lecture; 3 semester hours. Prerequisite: CEEN445.

CEEN542. DESIGN OF WOOD STRUCTURES. 3.0 Semester Hrs.
The course develops the theory and design methods required for the use of wood as a structural material. The design of walls, beams, columns, beam-columns, shear walls, and structural systems are covered with consideration of gravity, wind, snow, and seismic loads. Prerequisite: CEEN314 or equivalent.
Course Learning Outcomes

- Gain fundamental knowledge on engineered wood products, be able to recognize these products and find their design values in the code reference material
- Be able to navigate NDS code and SDPWS provisions
- Be able to design and check light frame wood structural components and simple systems
- Be able to design and check typical mass timber structural components and simple systems

CEEN543. ADVANCED DESIGN OF STEEL STRUCTURES. 3.0 Semester Hrs.
The course extends the coverage of steel design to include the topics: slender columns, beam-columns, frame behavior, bracing systems and connections, stability, moment resisting connections, composite design, bolted and welded connections under eccentric loads and tension, and semi-rigid connections. 3 hours lecture; 3 semester hours. Course offered every third semester. Prerequisite: CEEN443 or equivalent.

CEEN544. STRUCTURAL PRESERVATION OF EXISTING AND HISTORIC BUILDINGS. 3.0 Semester Hrs.
A broad discussion of historic structural systems in the United States, including stone and brick masonry, terra cotta, timber, cast and wrought iron, early steel, and early concrete. Combines research of historic manuals with contemporary analysis. Introduces nondestructive tests for historic structures. Enables prediction of deterioration mechanisms and structural deficiencies. Synthesizes structural retrofit solutions with preservation philosophy and current building codes. Emphasizes the engineer's role in stewardship of historic buildings. Every odd year Fall. 3 hours lecture and discussion; 3 semester hours. Prerequisite: CEEN443 and CEEN445.

CEEN545. STEEL BRIDGE DESIGN. 3.0 Semester Hrs.
Students are introduced to, and will develop an understanding of, the theory, analysis, and AASHTO code requirements for the design of steel bridge superstructures. The students will become familiar with bridge types, required loadings, composite action, plate girder design, and the Load and Resistance Factor Design method. The students will recognize the design requirements for a steel bridge superstructure and perform calculations for member loads and the loadings it transfers to the substructure. Course offered every third semester. Prerequisite: CEEN443.
Course Learning Outcomes

- Recognize requirements for steel bridge design
- Perform calculations to determine component loadings
- Analyze for effects of fatigue on welded bridge details
- Perform an approximate structural analysis of a multi-span steel bridge

CEEN546. STATISTICAL METHODS FOR RELIABILITY AND ENGINEERING DESIGN. 3.0 Semester Hrs.
(I, II) The course will introduce methods and principles that help quantifying the effects of uncertainty in the performance prediction of civil infrastructure systems. Students will learn to apply quantitative risk analysis and modeling approaches relevant to design problems in civil engineering. The course emphasizes that the systematic treatment of uncertainty and risk quantification are essential for adequate engineering planning, design, and operation of systems. The statistical approaches fundamental to engineering design and theory of reliability in structural and underground infrastructure design will be the focus of the course and examples. 3 hours lecture; 3 semester hours. Prerequisite: CEEN443.
Course Learning Outcomes

- Gain fundamental understanding on statistical and reliability methods and concepts.
- Be able to program basic statistical procedures using Matlab, and apply them to their research work including experimental data analysis and experiment design.
- Use first order second moment method and simulation method to estimate system reliability, understand how safety is ensured in design codes at a fundamental level.
- Gain basic understanding and simple application of performance based design

CEEN547. DESIGN OF PRESTRESSED CONCRETE STRUCTURES. 3.0 Semester Hrs.
Recognize the fundamental principles of prestressed concrete design and the behavior of prestressed members. Selecting the appropriate materials used to construct prestressed members. Perform the required calculations for the analysis and development of basic designs for prestressed beams, one-way slabs and bridge girders. Recognize the principles governing basic AASHTO prestressed concrete girder design. Read and interpret the applicable building code documents that govern prestressed concrete design. Course offered every third semester. Prerequisite: CEEN445.
Course Learning Outcomes

- 1. Recognize the fundamental principles of prestressed concrete design and the behavior of prestressed members.
- 2. Select the appropriate materials used to construct prestressed members.
- 3. Perform the required hand calculations for the analysis and development of basic designs for prestressed beams, one-way slabs and bridge girders.
- 4. Interpret the output of a common Post-Tension Concrete Design computer program.
- 5. Recognize the principles governing basic AASHTO prestressed concrete girder design.
- 6. Read and interpret the applicable building code documents that govern prestressed concrete design.

CEEN548. STRUCTURAL LOADS. 3.0 Semester Hrs.
Students will be introduced to the load types and load combinations required to design structures in compliance with building code requirements. Students will learn the theory and methods to determine the magnitude and application of loads associated with structure self-weight and occupancy. Students will be introduced to the physics underlying the requirements for environmental loads and to the accepted methods used to calculate environmental loads due to wind, snow, rain, floods, and avalanches. Students will become familiar with the common approaches used to deal with tsunami loads and blast loads. Students will learn the importance of and to recognize the load paths required to transmit applied loads from the structure to the foundation. Course offered every third semester. Prerequisite: CEEN314.
Course Learning Outcomes

- Students are expected to attend class, ask questions, utilize office hours when needed, and come to class prepared. Students are expected to display academic integrity (see Academic Integrity Section). Students will be able to determine to applicable loads to be used to design a structure, be able to calculate their magnitudes and directions, and specify load path.

CEEN549. INTRODUCTION TO THE SEISMIC DESIGN OF STRUCTURES. 3.0 Semester Hrs.
This course provides students with an introduction to seismic design as it relates to structures. Students will become familiar with the sources of seismic disturbances, the physics of seismic energy transmission, and the relationship between ground disturbance and the resulting forces experienced by structures. The theory and basis for existing building code provisions relating to seismic design of structures will be introduced. Building code requirements and design methodologies will be examined and applied. Advanced performance based seismic design method will also be introduced. Prerequisite: CEEN443, or CEEN445, or CEEN442 Co-requisite: None.
Course Learning Outcomes

- 1)
- 2)
- 3)
- 4)

CEEN550. PRINCIPLES OF ENVIRONMENTAL CHEMISTRY. 0-3 Semester Hr.
(I) This course provides an introduction to chemical equilibria in natural waters and engineered systems. Topics covered include chemical thermodynamics and kinetics, acid/base chemistry, open and closed carbonate systems, precipitation reactions, coordination chemistry, adsorption and redox reactions. 3 hours lecture; 3 semester hours. Prerequisite: none.

CEEN551. ENVIRONMENTAL ORGANIC CHEMISTRY. 3.0 Semester Hrs.
A study of the chemical and physical interactions which determine the fate, transport and interactions of organic chemicals in aquatic systems, with emphasis on chemical transformations of anthropogenic organic contaminants. Offered in alternate years. (Last offered Spring 23.) 3 semester hours.

CEEN555. LIMNOLOGY. 3.0 Semester Hrs.
(II) This course covers the natural chemistry, physics, and biology of lakes as well as some basic principles concerning contamination of such water bodies. Topics include heat budgets, water circulation and dispersal, sedimentation processes, organic compounds and their transformations, radionuclide limnochronology, redox reactions, metals and other major ions, the carbon dioxide system, oxygen, nutrients; planktonic, benthic and other communities, light in water and lake modeling. 3 hours lecture; 3 semester hours. Prerequisite: none.

CEEN556. MINING AND THE ENVIRONMENT. 3.0 Semester Hrs.
(I) The course will cover many of the environmental problems and solutions associated with each aspect of mining and ore dressing processes. Mining is a complicated process that differs according to the type of mineral sought. The mining process can be divided into four categories: Site Development; Extraction; Processing; Site Closure. Procedures for hard rock metals mining; coal mining; underground and surface mining; and in situ mining will be covered in relation to environmental impacts. Beneficiation, or purification of metals will be discussed, with cyanide and gold topics emphasized. Site closure will be focused on; stabilization of slopes; process area cleanup; and protection of surface and ground water. After discussions of the mining and beneficiation processes themselves, we will look at conventional and innovative measures to mitigate or reduce environmental impact.

CEEN560. MOLECULAR MICROBIAL ECOLOGY AND THE ENVIRONMENT. 3.0 Semester Hrs.
This course explores the diversity of microbiota in a few of the countless environments of our planet. Topics include microbial ecology (from a molecular perspective), microbial metabolism, pathogens, extreme environments, engineered systems, oxidation / reduction of metals, bioremediation of both organics and inorganics, microbial diversity, phylogenetics, analytical tools and bioinformatics. The course can have an integrated laboratory component (depends on timing) for applied molecular microbial ecology to learn microscopy, DNA extraction, PCR, gel electrophoresis, cloning, sequencing, data analysis and bioinformatic applications.

CEEN562. ENVIRONMENTAL GEOMICROBIOLOGY. 3.0 Semester Hrs.
(II) This course explores the functional activities and biological significance of microorganisms in geological and engineered systems with a focus on implications to water resources. Topics include: microorganisms as geochemical agents of change, mechanisms and thermodynamics of microbial respiration, applications of analytical, material science and molecular biology tools to the field, and the impact of microbes on the fate and transport of problematic water pollutants. Emphasis will be placed on critical analysis and communication of peer-reviewed literature on these topics. 3 hours lecture and discussion; 3 semester hours.

CEEN564. ENVIRONMENTAL TOXICOLOGY. 3.0 Semester Hrs.
This course provides an introduction to general concepts of ecology, biochemistry, and toxicology. The introductory material will provide a foundation for understanding why, and to what extent, a variety of products and by-products of advanced industrialized societies are toxic. Classes of substances to be examined include metals, coal, petroleum products, organic compounds, pesticides, radioactive materials, and others. Prerequisite: none. 3 hours lecture; 3 semester hours.

CEEN566. MICROBIAL PROCESSES, ANALYSIS AND MODELING. 3.0 Semester Hrs.
(II) Microorganisms facilitate the transformation of many organic and inorganic constituents. Tools for the quantitative analysis of microbial processes in natural and engineered systems will be presented. Stoichiometries, energetics, mass balances and kinetic descriptions of relevant microbial processes allow the development of models for specific microbial systems. Simple analytical models and complex models that require computational solutions will be presented. Systems analyzed include suspended growth and attached growth reactors for municipal and industrial wastewater treatment as well as in-stu bioremediation and bioenergy systems. 3 hours lecture; 3 semester hours.

CEEN570. WATER AND WASTEWATER TREATMENT. 3.0 Semester Hrs.
(I, II) Unit operations and processes in environmental engineering are discussed in this course, including physical, chemical, and biological treatment processes for water and wastewater. Treatment objectives, process theory, and practice are considered in detail. 3 hours lecture; 3 semester hours. Prerequisite: none.

CEEN571. ADVANCED WATER TREATMENT ENGINEERING AND WATER REUSE. 3.0 Semester Hrs.
This course presents issues relating to theory, design, and operation of advanced water and wastewater treatment unit processes and water reuse systems. Topics include granular activated carbon (GAC), advanced oxidation processes (O_3/H_2O_2), UV disinfection, pressure-driven, current-driven, and osmotic-driven membranes (MF, UF, NF, RO, electrodialysis, and forward osmosis), and natural systems such as riverbank filtration (RBF) and soil-aquifer treatment (SAT). The course

is augmented by CEEN571L offering hands-on experience using bench- and pilot-scale unit operations. 3 hours lecture; 3 semester hours. Prerequisite: CEEN470 or CEEN478 or CEEN570 or CEEN572.

CEEN572. ENVIRONMENTAL ENGINEERING PILOT PLANT LABORATORY. 4.0 Semester Hrs.

(II) This course provides an introduction to bench and pilot-scale experimental methods used in environmental engineering. Unit operations associated with water and wastewater treatment for real-world treatment problems are emphasized, including multi-media filtration, oxidation processes, membrane treatment, and disinfection processes. Investigations typically include: process assessment, design and completion of bench- and pilot-scale experiments, establishment of analytical methods for process control, data assessment, upscaling and cost estimation, and project report writing. Projects are conducted both at CSM and at the City of Golden Water Treatment Pilot Plant Laboratory. 6 hours laboratory; 4 semester hours. Prerequisite: CEEN550 and CEEN570.

CEEN573. RECLAMATION OF DISTURBED LANDS. 3.0 Semester Hrs.

Basic principles and practices in reclaiming disturbed lands are considered in this course, which includes an overview of present legal requirements for reclamation and basic elements of the reclamation planning process. Reclamation methods, including recontouring, erosion control, soil preparation, plant establishment, seed mixtures, nursery stock, and wildlife habitat rehabilitation, will be examined. Environmental policy, law and North America / global case studies also provide foundation to understand the field. Practitioners in the field will discuss their experiences.

CEEN575. HAZARDOUS WASTE SITE REMEDIATION. 3.0 Semester Hrs.

(I) This course covers remediation technologies for hazardous waste contaminated sites, including site characteristics and conceptual model development, remedial action screening processes, and technology principles and conceptual design. Institutional control, source isolation and containment, subsurface manipulation, and in situ and ex situ treatment processes will be covered, including unit operations, coupled processes, and complete systems. Case studies will be used and computerized tools for process selection and design will be employed. 3 hours lecture; 3 semester hours. Prerequisite: CEEN550 and CEEN580.

CEEN578. WATER TREATMENT DESIGN AND ANALYSIS. 3.0 Semester Hrs.

The learning objectives of this class are to build off of the information and theories presented in CEEN 470 and apply them to the design of water and wastewater treatment systems. Students will be presented with project-based assignments and, with the help of the instructors and associated lectures, will use fundamentals and commercial software to develop preliminary designs of water and wastewater systems. Students will gain experience in conventional and advanced treatment system design, software utilized by environmental consulting companies, and professional communication through the completion of this class. Course lectures will include fundamentals of design, guest lectures from practitioners, and tours of local treatment plants. Regional water and wastewater treatment employers (e.g., consultants, municipalities, industry, regulators) are actively searching for students with applied experience and this class will help promote the advancement of employment in the water and wastewater treatment field. Prerequisite: CEEN470.

Course Learning Outcomes

- At the completion of this course, students will: 1) Use fundamentals and commercial software to design and analyze water treatment systems. 2) Integrate design aspects for development of integrated water systems to treat variable water resources. 3) Summarize design components into drawings and diagrams. 4) Communicate solutions and designs to practitioners through technical reports and presentations.

CEEN580. CHEMICAL FATE AND TRANSPORT IN THE ENVIRONMENT. 3.0 Semester Hrs.

(I, II) This course describes the environmental behavior of inorganic and organic chemicals in multimedia environments, including water, air, sediment and biota. Sources and characteristics of contaminants in the environment are discussed as broad categories, with some specific examples from various industries. Attention is focused on the persistence, reactivity, and partitioning behavior of contaminants in environmental media. Both steady and unsteady state multimedia environmental models are developed and applied to contaminated sites. The principles of contaminant transport in surface water, groundwater, and air are also introduced. The course provides students with the conceptual basis and mathematical tools for predicting the behavior of contaminants in the environment. 3 hours lecture; 3 semester hours.

Course Learning Outcomes

- No change

CEEN581. WATERSHED SYSTEMS MODELING. 3.0 Semester Hrs.

(II) Introduction to surface water modeling, including rainfall-runoff analysis, input data, uncertainty analysis, lumped and distributed modeling, parameter estimation and sensitivity analysis. Course is heavy on application of models across a range of diverse watersheds for streamflow and snowmelt predictions. In general, theoretical topics are covered in the first meeting each week, followed by hands-on application of concepts and models in the second meeting. Laptops and student Matlab licenses will be required for in-class activities. 3 hours lecture per week; 3 semester hours.

CEEN582. VADOSE ZONE HYDROLOGY. 3.0 Semester Hrs.

Introduction of soil chemical compositions and water properties. Introduction of soil classifi cation.Introduction of hydrological processes in vadose zone. Introduction of chemical potentialresponsible for soil water physical interactions: capillarity, cavitation, and adsorption. Introduction ofthermodynamic laws for multiphase, and multi-physics water movement and distribution in vadosezone. Introduction of concepts of soil water potential, matric potential, soil water retention curve, andhydraulic conduction function. Introduction of laws for capillary water fl ow, fi lm water fl ow, and vaporfl ow in soil. Introduction of governing equations for spatial-temporal distributions of soil moisture andmatric potential in vadose zone. Introduction of interactions between land surface and atmosphere,and between vadose zone and groundwater zone. Introduction of techniques for measuring soilwater retention curve and hydraulic conductivity function. Prerequisites: CEEN580 and knowledge of basic statistics and computer programming.

Course Learning Outcomes

- 1) Understand the Soil Water Potential concept to determine its components of the gravitational potential, capillary potential, and adsorptive potential
- 2) Understand techniques to measure Soil Water Retention Curve and Hydraulic Conductivity Function
- 3) Understand the laws governing fluid and vapor flows in vadose zone.
- 4) Understand the governing time-space equations for transient water flows in vadose zone.

- 5) Apply the fundamental principles to find the analytical and numerical solutions of multi-phase water distribution in vadose zone
- 6) Quantify and measure constitutive relations of Soil Water Retention Curve and Hydraulic Conductivity Function

CEEN583. SURFACE WATER QUALITY MODELING. 3.0 Semester Hrs.
This course will cover modeling of water flow and quality in rivers, lakes, and reservoirs. Topics will include introduction to common analytical and numerical methods used in modeling surface water flow, water quality, modeling of kinetics, discharge of waste water into surface systems, sedimentation, growth kinetics, dispersion, and biological changes in lakes and rivers. Prerequisites: CEEN480 or CEEN580 recommended. 3 hours lecture; 3 semester hours.

CEEN584. SUBSURFACE CONTAMINANT TRANSPORT. 3.0 Semester Hrs.
This course will investigate physical, chemical, and biological processes governing the transport and fate of contaminants in the saturated and unsaturated zones of the subsurface. Basic concepts in fluid flow, groundwater hydraulics, and transport will be introduced and studied. The theory and development of models to describe these phenomena, based on analytical and simple numerical methods, will also be discussed. Applications will include prediction of extents of contaminant migration and assessment and design of remediation schemes. Prerequisites: CEEN580. 3 hours lecture; 3 semester hours.

CEEN585. FLUID MECHANICS FOR HYDROLOGY. 2.0 Semester Hrs.
(I) This class focuses on the fundamental concepts of engineering fluid mechanics as they relate to the study of hydrology. Topics include fluid statics, dynamics, continuity, energy and momentum, dimensional analysis and open channel flow. Cross-listed with GEGN585. 2 semester hours.
Course Learning Outcomes

- 1. Students will solve problems on fundamental fluid mechanics concepts including hydrostatics, momentum, pressure and flow and energy systems.
- 2. Students will conduct simple dimensional analysis and explain its application to hydrologic research.
- 3. Students will solve problems related to flow measurement, fluid properties, and fluid statics.
- 4. Students will solve problems related to energy, impulse, and momentum equations.
- 5. Students will solve problems related to pipe and other internal flow.
- 6. Student will explain (or demonstrate or predict or describe or evaluate) how fluid mechanics relates to hydrological systems.

CEEN585L. INTRODUCTION TO COMPUTATIONAL METHODS IN HYDROLOGY. 1.0 Semester Hr.
This 1-cr class is a computational lab for the lecture course GEGN/CEEN 585 (Fluid Mechanics for Hydrology). The lab may be taken alone if a Fluid Mechanics lecture course has already been taken. The lab introduces the student to computational platforms and concepts germane to Fluid Mechanics and many other sciences. We use Matlab, Python, and various parallel programming environments to solve problems that use numerical integration, finite-difference solutions of first- and second-order ODEs, random walks to solve advection/diffusion problems, and various statistical concepts. Applications include calculating pressure on a submerged surface, bacterial growth/decay, laminar flow and solute transport between plates, and gradually-varying flow in open channels. Prerequisites: Fluid Mechanics. Co-requisites: GEGN/CEEN 585 Fluid Mechanics for Hydrology.

CEEN586. HYDROMETEOROLOGY. 3.0 Semester Hrs.
Hydrometeorology lies at the intersection of meteorology and hydrology, and covers key atmospheric processes relevant to flood prediction, droughts, heatwaves, streamflow, and energy transfer between the land surface and the atmosphere. In this course, you will be introduced to the conceptual foundations of hydrometeorology as they pertain to water prediction and water resource management. The course will cover weather and climate fundamentals, observational methods used in hydrometeorology, and data analysis methods relevant to decision-making and weather and water prediction.
Course Learning Outcomes

- 1)
- 2)
- 3)
- 4)

CEEN587. HYDROCHEMICAL AND TRANSPORT PROCESSES. 3.0 Semester Hrs.
(II) Analysis of the chemistry of natural waters in the context of hydrologic systems. The course focuses on sources and dynamic behavior of common natural and anthropogenically introduced solutes of interest, their interactions with minerals, and fate and transport in subsurface and surface environments. Students should NOT enroll in CEEN587 if they enroll(ed) in either CEEN580 or CEEN550. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- 1. Evaluate the chemistry of groundwater and surface water samples
- 2. Understand the sources and behavior of common solute of interest in natural systems
- 3. Apply chemical reaction kinetic equations to evaluate the dynamic behavior of common solutes of interest in natural systems
- 4. Evaluate fate and transport of contaminants in surface water and groundwater systems.

CEEN589. WATER SUSTAINABILITY AND ENERGY PRODUCTION: CURRENT SCIENCE AND PRACTICE. 1.0 Semester Hr.
This course is designed to provide students with valuable communication and professional skills while exploring in depth the topic of joint sustainability of water and unconventional petroleum energy production. A survey of current literature combined with key speakers will introduce the students to the field, while class sessions and practical exercises will help develop important communication, research, and interpersonal skills needed for future professionals. Course curriculum includes specific topics such as speaking/writing for a variety of audiences and critical thinking and analysis. This course is required for all ConocoPhillips - WE2ST Fellows, but is also open to any interested graduate students. 1 hour seminar; 1 semester hour.
Course Learning Outcomes

- Relevant Terminology and Current State of Hydraulic Fracturing
- Current State of Water Resources in CO in Relation to Users and Overall Water Budget
- Connections between Energy Development and Water Use
- Interpersonal Skill Development
- Technical Writing for a Variety of Audiences
- Technical Speaking for a Variety of Audiences

- Critical Analysis of Technical Issues
- Community Perceptions of Technical Topics

CEEN590. CIVIL ENGINEERING SEMINAR. 0.0 Semester Hrs.
Presentations covering current civil engineering research and practice. (Two semesters required.).

CEEN592. ENVIRONMENTAL LAW. 3.0 Semester Hrs.
Equivalent with CEEN492,PEGN530,
This is a comprehensive introduction to U.S. Environmental Law, Policy, and Practice, especially designed for the professional engineer, scientist, planner, manager, consultant, government regulator, and citizen. It will prepare the student to deal with the complex system of laws, regulations, court rulings, policies, and programs governing the environment in the USA. Course coverage includes how our legal system works, sources of environmental law, the major USEPA enforcement programs, state/local matching programs, the National Environmental Policy Act (NEPA), air and water pollution (CAA, CWA), EPA risk assessment training, toxic/hazardous substances laws (RCRA, CERCLA, EPCRA, TSCA, LUST, etc.), and a brief introduction to international environmental law. Taught on Demand. 3 hours lecture; 3 semester hours.

CEEN594. RISK ASSESSMENT. 3.0 Semester Hrs.
This course evaluates the basic principles, methods, uses, and limitations of risk assessment in public and private sector decision making. Emphasis is on how risk assessments are made and how they are used in policy formation, including discussion of how risk assessments can be objectively and effectively communicated to decision makers and the public. Prerequisite: CEEN592 and one semester of statistics. 3 hours lecture; 3 semester hours.

CEEN595. ANALYSIS OF ENVIRONMENTAL IMPACT. 3.0 Semester Hrs.
Techniques for assessing the impact of mining and other anthropogenic activities on various components of the global ecosystem are considered. The National Environmental Policy Act of 1970 (NEPA) fundamentally changed how the environment is to be considered in any federal decision within the US and has become a model for nations worldwide. Training in the procedures of preparing Environmental Impact Statements (EIS) and Environmental Assessments (EA) are discussed with a particular emphasis on case studies of each, mostly focused on the western US, though all 50 states are considered. Course includes a review of pertinent laws and acts (i.e., NEPA, Endangered Species Act (ESA), Clean Water Act (CWA), Clean Air Act (CAA), Federal Land Policy Management Act (FLPMA), etc.) as well as organic acts that created the National Park Service (NPS), the US Forest Service (USFS) and the Bureau of Land Management (BLM) that deal with environmental impacts. Some field trips.

CEEN596. ENVIRONMENTAL SCIENCE AND ENGINEERING SEMINAR. 0.0 Semester Hrs.
Research presentations covering current research in a variety of environmental topics.. (Two semesters required.).

CEEN597. PRACTICES AND PRINCIPLES OF ENVIRONMENTAL CONSULTING. 3.0 Semester Hrs.
This course provides an in-depth understanding of the environmental consulting industry with a particular focus on problem solving and project delivery to meet expectations of professional services organizations (environmental consulting firms). Using case studies, real-life consulting assignments, and business scenarios, the course offers exposure to the technical, ethical, and business challenges of winning and executing environmental projects.
Course Learning Outcomes

- 1. Understand the drivers and policies that protect our environmental and water resources.
- 2. Apply knowledge gained in the course from pragmatic problems taken from real scenarios experienced within the consulting industry
- 3. Develop an appreciation for investigations and data interpretation making science-based decisions where possible and determine when decisions may require additional information.
- 4. Know the basic process of project initiation, budgeting, management, and effective delivery in executing environmental projects.
- 5. Work with a team to interpret given data to understand what information is important to advise alternatives, planning, decisions, and design.
- 6. Consider how to tailor designs to meet objectives that protect public health and to meet environment objectives and requirements.
- 7. Use data and engineering judgement to calculate sizing of infrastructure and to develop solutions to solve local environmental problems; research and consider social and economic project considerations and outcomes
- 8. Effectively deliver quality technical products to communicate issues and basis of design; develop communication and presentations skills that effectively share information to an appropriate audience; present technical materials to instructors and peers; provide constructive feedback to peers.

CEEN597. SPECIAL SUMMER COURSE. 0-6 Semester Hr.

CEEN598. SPECIAL TOPICS IN CIVIL AND ENVIRONMENTAL ENGINEERING. 0-6 Semester Hr.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CEEN598. SPECIAL TOPICS. 0-6 Semester Hr.

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CEEN599. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: “Independent Study” form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CEEN599AA. INDEPENDENT STUDY. 0.5-6 Semester Hr.

CEEN599AB. INDEPENDENT STUDY. 0.5-6 Semester Hr.

CEEN599AC. INDEPENDENT STUDY. 0.5-6 Semester Hr.

CEEN599AD. INDEPENDENT STUDY. 0.5-6 Semester Hr.

CEEN599AE. INDEPENDENT STUDY. 0.5-6 Semester Hr.

CEEN599AF. INDEPENDENT STUDY. 0.5-6 Semester Hr.

CEEN599AG. INDEPENDENT STUDY. 0.5-6 Semester Hr.

CEEN599AH. INDEPENDENT STUDY. 0.5-6 Semester Hr.

CEEN599AI. INDEPENDENT STUDY. 0.5-6 Semester Hr.

CEEN599AJ. INDEPENDENT STUDY. 0.5-6 Semester Hr.

CEEN599AK. INDEPENDENT STUDY. 0.5-6 Semester Hr.

CEEN599AL. INDEPENDENT STUDY. 0.5-6 Semester Hr.

CEEN599AM. INDEPENDENT STUDY. 0.5-6 Semester Hr.

CEEN599AN. INDEPENDENT STUDY. 0.5-6 Semester Hr.

CEEN599AO. INDEPENDENT STUDY. 0.5-6 Semester Hr.

CEEN599AP. INDEPENDENT STUDY. 0.5-6 Semester Hr.

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CEEN599. INDEPENDENT STUDY. 0.5-6 Semester Hr.

CEEN698. SPECIAL TOPICS IN CIVIL AND ENVIRONMENTAL ENGINEERING. 0-6 Semester Hr.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CEEN699. ADVANCED INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: “Independent Study” form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CEEN699. INDEPENDENT STUDY. 0.5-6 Semester Hr.

CEEN699. INDEPENDENT STUDY. 0.5-6 Semester Hr.

CEEN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.
(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

Department Head

D.V. Griffiths

Professor and Associate Department Head

Jonathan O. Sharp

Professor and Grewcock Distinguished Chair

Mike A. Mooney

University Distinguished Professor

Christopher Higgins

Professors

Tzahi Cath

Linda Figueroa

Terri Hogue

Amy Landis

Ning Lu

John E. McCray

Junko Munakata Marr

John R. Spear

Timothy Strathmann

Associate Professors

Eric Anderson

Christopher Bellona

Reza Hedayat

Shiling Pei

Assistant Professors

Yangming Shi

Lori Tunstall

Teaching Professors

Andres Guerra

Kristoph Kinzli

Susan Reynolds

Teaching Associate Professors

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Hongyan Liu

Alexandra Wayllace

Teaching Assistant Professors

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Cara Phillips

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Professor of Practice

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