Department of
Civil and Environmental Engineering

College of Engineering

Head: Professor *Loren R. Anderson*, geotechnical engineering
Office in Engineering Laboratory 211, (435) 797-2932

Undergraduate Division Heads:

Civil Engineering: Professor *Kevin C. Womack*, structural mechanics
Environmental Engineering: Professor *R. Ryan Dupont*, hazardous waste management, bioremediation

Graduate Program Division Heads:

Environmental Engineering: Professor *R. Ryan Dupont*, hazardous waste management, bioremediation
Geotechnical Engineering: Associate Professor *Joseph A. Caliendo*, geotechnical engineering
Structural Engineering: Professor *Kevin C. Womack*, structural mechanics
Transportation Engineering: Professor *Prianka N. Seneviratne*, transportation systems analysis and modeling
Water Engineering: Professor *David G. Tarboton*, hydrology and water resources

FAX (435) 797-1185
E-mail beckyjh@cc.usu.edu
WWW http://www.engineering.usu.edu/Departments/cee/

Professors *A. Bruce Bishop*, engineering systems and planning; *David S. Bowles*, risk assessment, hydrology, water resources engineering; *William J. Doucette*, environmental analytical chemistry; *William J. Grenney*, Advanced Center for Transportation Studies; *Thomas B. Hardy*, ecological system modeling, statistical analysis; *Daniel H. Hoggan*, hydrologic and hydraulic modeling; *Jagath J. Kaluarachchi*, surface and groundwater, flow and contaminant transport; *Marian W. Kemblowski*, subsurface hydrology and transport processes; *Mac McKee*, water resources planning and analysis; *William J. Rahmeyer*, hydraulics, hydraulic structures, scour and erosion; *Ronald C. Sims*, hazardous waste management; *David K. Stevens*, treatment process analysis; *Muzz Yener*, structural engineering and mechanics; **Research Professor** *Darwin L. Sorensen*, aquatic microbiology; **Professors Emeriti** *Jay M. Bagley*, hydrology, water resources; *W. O. Carter*, structures; *Calvin G. Clyde*, fluid mechanics and groundwater; *Irving S. Dunn*, geotechnical engineering; *Gordon H. Flammer*, hydraulics; *Trevor C. Hughes*, water resources systems analysis; *C. Earl Israelsen*, hydrology, hydraulics, water resources, erosion control; *Roland W. Jeppson*, numerical modeling; *Fred W. Kiefer, Jr.*, geotechnical engineering; *Elliot Rich*, structural engineering; *J. Paul Riley*, water resources systems, hydrology; *J. Paul Tullis*, hydraulics, hydraulic structures, and hydromachinery; *Reynold K. Watkins*, geotechnical engineering; **Adjunct Professors** *Lloyd H. Austin*, water resources; *George G. Goble*, deep foundations and structural dynamics; *Jeffrey R. Keaton*, geotechnical engineering, engineering geology; *Upmanu Lall*, climate modeling, statistical hydrology, water resource systems; *Neil Parrett*, performance and safety of dams; *Norman E. Stauffer, Jr.*, engineering hydrology and computer modeling; *Daniel A. Stone*, environmental chemistry; **Associate Professors** *Marvin W. Halling*, structural dynamics, earthquake engineering; *Sonia S. Manuel-Dupont*, technical writing; *Randal S. Martin*, environmental engineering (air pollution); *Michael J. McFarland*, environmental engineering; *J. Derle Thorpe*, engineering materials, measurements; *Gilberto E. Urroz-Aguire*, hydraulics, hydraulic structures; **Adjunct Associate Professors** *Ronald Christiansen*, water law; *Danny Marks*, snow hydrology; *Eva C. Nieminski*, water quality; *Mufeed M. Odeh*, physical and mathematical modeling of hydraulic systems; *Anthony Turhollow*, transportation; **Assistant Professors** *James A. Bay*, geotechnical engineering; *Anthony Chen*, traffic engineering and network planning; *Laurie S. McNeill*, environmental engineering (drinking water); **Research Assistant Professors** *Sanjay Chauhan*, dam safety, risk assessment, hydrologic modeling; *Joan E. McLean*, fate and behavior of metals in subsurfaces; *Robert T. Pack*, geomatics and engineering geology; *Judith L. Sims*, fate and behavior of organic chemicals; *Blake P. Tullis*, hydraulics, hydraulics structures, and hydromachinery; **Adjunct Assistant Professors** *Steve Barfuss*, hydraulics; *Arnfinn J. Emdal*, geotechnical; *Jon S. Ginn*, environmental; *Michael C. Johnson*, hydraulics; **Affiliate Faculty** *Robert W. Hill*, professor, Biological and Irrigation Engineering; *John E. Keith*, professor, Economics; *Jack Keller*, professor emeritus, Biological and Irrigation Engineering; *Wynn R. Walker*, professor, Biological and Irrigation Engineering

Degrees offered: Bachelor of Science (BS) in Civil Engineering; BS in Environmental Engineering; Master of Engineering (ME), Master of Science (MS), Civil Engineer (CE) and Doctor of Philosophy (PhD) in Civil and Environmental Engineering

Graduate specializations: Environmental Engineering, Fluid Mechanics and Hydraulic Engineering, Geotechnical Engineering, Hazardous Waste Management, Structural Engineering and Mechanics, Transportation Engineering, Water Engineering, Water Resources Engineering and Hydrology

Undergraduate Programs

Objectives

Civil and Environmental Engineering is concerned with planning, designing, constructing, and operating various physical works; developing and utilizing natural resources in an environmentally sound manner; providing the infrastructure which supports the highest quality of life in the history of the world; and protecting public health and renovating impacted terrestrial and aquatic systems from the mismanagement of toxic and hazardous wastes. The Department of Civil and Environmental Engineering offers Bachelor of Science degrees in Civil Engineering and in Environmental Engineering. Both degrees are accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (EAC/ABET).

The objectives of the undergraduate programs in Civil Engineering and Environmental Engineering are to graduate engineers who have a broad educational background and experiences in engineering, the sciences, and the humanities; who have passed the Fundamentals of Engineering examination; and who are prepared to enter graduate school, other professional training, or the workplace as effective professionals. These graduates will understand the significance of life-long learning and will be qualified to become professional engineers and contribute significantly to the engineering profession and society as a whole.

Outcomes

Graduates with a BS degree in Civil Engineering from Utah State University will have:

1. Proven themselves proficient in mathematics; the sciences; and the structures, geotechnical, hydraulics, and transportation areas of civil engineering.

2. Demonstrated the ability to solve engineering problems, utilizing fundamental engineering principles, as well as the latest technologies and engineering tools, in the process of engineering analysis and design. They will have done this as individuals and as members of multidisciplinary teams.

3. Shown a capacity for investigation and experimentation into physical (engineering) phenomena, along with the ability to analyze and interpret engineering data in at least two of the following areas of civil engineering: structures, geotechnical, hydraulics, and transportation.

4. Demonstrated the capability to communicate verbally, in writing, and through the use of engineering communication media. They will also have shown the capacity to present the outcomes of their problem solving and design projects for groups of engineers and lay persons.

5. Exhibited an understanding of the role civil engineering plays in our modern global society, that much is to be learned from the past and applied to the present, and that a responsible engineer is ethical and will continue to increase his or her knowledge throughout his or her lifetime.

Graduates with a BS degree in Environmental Engineering from Utah State University will have:

1. Knowledge of basic science and engineering principles fundamental to the practice of environmental engineering including: mathematics, biology, chemistry, soil science, physics, fluid and solid mechanics, hydrology, and engineering economics.

2. Knowledge of environmental engineering practice in the areas of water supply and treatment; environmental systems dynamics; environmental chemistry and analysis; wastewater, air quality, and solid and hazardous waste management; and public health and industrial hygiene.

3. Advanced knowledge of science and engineering principles in two of the following program emphasis areas: water, solids, natural systems, and public health.

4. Integration of advanced science and engineering principles in a multidisciplinary team environment for the solution of a comprehensive design problem in one of the program emphasis areas incorporating: applicable design standards; state-of-the-practice design tools; real-life economic, social, regulatory, political, ethical, and business design constraints; and applicable considerations for contemporary issues, such as product manufacturability, process sustainability, health and safety concerns, and system constructability.

5. Experience in written and oral communication using state-of-the-practice presentation methods throughout the course of their Professional Program in Environmental Engineering which include: laboratory reports and presentations, research paper presentations, design proposal and progress reports and presentations, and final design project presentations to both technical and lay audiences.

6. Experience in one of the environmental engineering practice areas in the design and conduct of experiments; collection, analysis, and interpretation of data; and modeling and representation of experimental results and presentation of experimental findings.

Assessment

The Civil and Environmental Engineering Department employs several methods to assess the quality of the two BS programs offered by the department. Assessments are made prior to graduation by measuring the performance of students in each class. In addition, the results of the FE exam, senior exit interviews, and faculty reviews of student portfolios are used. Postgraduate assessment of Civil and Environmental Engineering graduates is also conducted up to six years after graduation. Assistance from outside reviewers is also obtained in making the assessment.

Requirements

Admission Requirements. Admission requirements for the Department of Civil and Environmental Engineering are the same as those described for the University on pages 48-51. Students in good standing may apply for admission to the department. In addition, students must maintain the academic requirements outlined for the College of Engineering on pages 91-92.

Bachelor of Science Degrees. The Department of Civil and Environmental Engineering offers two Bachelor of Science degrees: one in Civil Engineering and one in Environmental Engineering. The four-year programs leading to these two degrees are listed below. During the first two years, students are in a pre-engineering program. Students must successfully complete the pre-engineering program or, in the case of transfer students, substantially equivalent coursework at another institution before they are accepted into the professional program. Transfer students may apply for permission to take upper-division courses in cases where postponement of these courses will prolong the student's time to graduate.

Design is a cornerstone of engineering that requires creative thinking, technical knowledge, the ability to organize and solve complex problems, and teamwork. Engineering design activities begin during the first two years and progress in-depth as each student's proficiency increases. These design activities culminate in a major senior design course, which integrates past engineering coursework into a focused, realistic design project. An important feature of the senior design experience is that students work in teams to complete the project.

The student who is majoring in or planning to major in Civil Engineering or Environmental Engineering needs to be aware of the College of Engineering requirements concerning admission to the college, pre-engineering program, admission to professional engineering programs, University Studies, and other academic requirements. Additional information concerning these items is given in the College of Engineering write-up on pages 90-92. It is the responsibility of the student to be aware of these rules and regulations. **Passing the Fundamentals of Engineering Exam is required for graduation**.

The Civil and Environmental Engineering Department strongly recommends that students have a high-end calculator, such as an HP-48 or HP-49 calculator, that has the capabilities to do units, matrices, and programs in BASIC. Although not a requirement at this time, CEE students are strongly encouraged to have a modern desktop or laptop personal computer. Since computer technology is changing rapidly, students should seek advice from a knowledgeable professional on hardware and software requirements before purchasing a computer.

Undergraduate Course Requirements for Civil Engineering

Preengineering Program (freshmen and sophomore years): CEE 1880, 2240, 2870, 3030; Engr 1010, 2000, 2020, 2040, 2200, 2210; ITE 2270; Chem 1210; Engl 1010, 2010; Geol 1150; Math 1210, 1220, 2250; Phyx 2200 (or High School AP Physics), 2220; University Studies courses (see College of Engineering University Studies requirements).

Professional Engineering Program (junior and senior years): CEE 3010, 3080, 3210, 3430, 3500, 3510, 3610, 3640, 3870, 4200, 4300; Civil Engineering Design Elective, one course chosen from: CEE 3780, 5070, 5230, 5350, 5460, 5540; Design project consisting of CEE 3880, 4870, and 4880; Technical electives (15 credits) chosen from: CEE 3670, 3780, 5010, 5050, 5070, 5080, 5100, 5190, 5220, 5230, 5240, 5350, 5430, 5440, 5450, 5460, 5470, 5540, 5550, 5560, 5690, 5700, 5860, 5870, 5880, 5900, MAE 2060, 2400; University Studies courses (see College of Engineering University Studies requirements).

Undergraduate Course Requirements for Environmental Engineering

Preengineering Program (freshman and sophomore years): CEE 1880, 2240, 2890; Engr 1010, 2000, 2020, 2040, 2200; ITE 2270; MAE 2400; Biol 1210, 3300; Chem 1210, 2300; Engl 2010; Math 1210, 1220, 2250; Phyx 2200 (or High School AP Physics), 2220; University Studies courses (see College of Engineering University Studies requirements).

Professional Engineering Program (junior and senior years): CEE 3030, 3430, 3500, 3510, 3640, 3670, 3780, 3870, 3890, 4200, 5610, 5860; PubH 3310; Environmental Engineering Design Elective, one class chosen from: CEE 5690, 5740, 5810, 5880; Design project consisting of CEE 3890, 4790, 4890. Technical Electives (5 credits), with one course chosen from Area 1, 2, or 3, and one course chosen from Area 4 or 5: *1—Solids:* CEE 5670, 5680, 5730, 5830, 5870, 5880; *2—Water:* CEE 5430, 5620, 5730, 5810; *3—Air:* Bmet 4300, CEE 5710, 5750, 5790, 5870; *4—Natural Systems:* AWER 4500, 4530, CEE 5690, 5700, 5740; *5—Occupational Safety and Health:* PubH 5310, 5320, 5330, CEE 5670, 5710, 5790. University Studies courses (see College of Engineering University Studies requirements).

Additional Information

For more information about Bachelor of Science requirements and the sequence in which courses should be taken, see major requirement sheet, available from the Civil and Environmental Engineering Department.

Departmental honors can be earned by completing 20 credits of upper-division honors engineering courses. Students should work with the department in selecting appropriate courses.

Concurrent BS/Master's Program

The concurrent BS/Master's program allows engineering students to begin taking graduate-level classes during their senior year. This permits them to complete requirements for *both* the BS degree *and* the master's degree concurrently during two years. Students in this program have a greater selection of graduate courses, since many graduate courses are taught during alternate years. In addition, the student's senior design project could be a start for a graduate design project or thesis. After completing their BS degree, students in the program can earn a master's degree in only one additional year. Both the BS and the master's degree can generally be earned with 150 total credits, although students should note that a Plan C MS requires 3 extra credits. Finally, students with a master's degree can expect a much higher starting salary following graduation. (For more information, see *College of Engineering* section of this catalog, page 92.)

Graduate Programs

The ME degree emphasizes professional practice and coursework. A minimum of 30 credits of technical and scientific coursework is required. The MS degree emphasizes research and the preparation of a significant publication. A minimum of 30 credits, 6 to 9 of which shall be thesis research, is required for an MS. In special cases, as decided by the student's supervisory committee, a second MS is available with a Plan B option, which requires 30 credits, including 3 to 6 credits of CEE 6970, Thesis Research. The CE degree, which prepares students for professional engineering careers, requires 60 credits beyond the bachelor's degree, or 30 credits beyond the master's degree, including a technical engineering report. The PhD degree represents high scholarly achievement demonstrated by independent research and competence in a area of specialization approved by the student's supervisory committee.

Admission Requirements

See general admission requirements, pages 72-73. Admission committees consider GRE scores and experience, undergraduate record and curriculum, and formal recommendations. A student without an undergraduate civil and environmental engineering background may be required to complete selected undergraduate courses prior to admission as a fully matriculated graduate student.

Graduate Program Divisions

The graduate program in the Department of Civil and Environmental Engineering is administered through five academic divisions, as described below.

Structural Engineering. The structural engineer is involved in the design, construction, repair, and retrofit of all types of structures: buildings, bridges, dams, and many others. The safety of the structures we occupy and utilize every day is the responsibility of structural engineers. They must be able to evaluate the loads placed on a structure, determine their effects on the structure, and select the appropriate materials and structural elements, or repair strategy, to withstand these loads. Today's structural engineer is using new space materials in the design of new structures or the retrofit of older structures.

Mathematics, physics, and materials science constitute a foundation for structural engineering. Structural analysis and design are added to this foundation and become the focus of the structural engineering program. Graduate students in the structures program also engage in structural mechanics, numerical methods, structural dynamics, geotechnical engineering, and the study of new structural materials. Current research in the structures area is focusing on the dynamic characteristics of structures, their potential response to earthquakes, and new seismic retrofit measures, using advanced composite materials, for older structures. Materials research is focusing on cementious materials and constitutive modeling.

Geotechnical Engineering. Engineering studies of soils are concerned with the physical and engineering properties of soils and how these are related to engineering projects.

Traditional geotechnical engineering includes the application of engineering principles to the analysis and/or design of building foundations, earth embankments, retaining walls, drainage systems, earthquake motion, buried structures, and other systems involving soil and rock. Engineers and architects cannot ignore the problems of investigating properties of soils in connection with engineering construction. Undergraduate and graduate courses offered by the department provide the basic knowledge necessary for the design of foundations and various types of earth structures. Fundamental concepts and their application are emphasized so that the student will be properly trained for his or her initial job, as well as being prepared to understand future development in this field.

The Geotechnical Engineering Division, in cooperation with the Environmental Engineering Division, is offering a new program in Geoenvironmental Engineering. This new program uses the strengths of both divisions to provide a program involving the geotechnical aspects of hazardous waste management, the investigation of hazardous waste sites, and the design of hazardous waste containment systems.

The geotechnical division has a strong research program. Current research projects in this division include studies on liquefaction, seismic slope stability, pile foundations, landslides, mechanically stabilized embankments, risk analysis of dams, finite element analysis of soil-structure systems, and the long-term properties of clay soils used in hazardous waste containment systems.

Water Engineering. The water engineering program is a multidisciplinary graduate program in the College of Engineering and is intended to enable engineers and scientists interested in water to obtain graduate degrees in the areas of fluid mechanics and hydraulics, hydrology, groundwater, and water resources engineering. Core courses and departmental offerings cover these fundamental areas, as well as essential numerical and statistical methods. The water engineering faculty are committed to a strong academic program. The curriculum offered is one of the most comprehensive offered in the U.S. Elements of ongoing research projects are routinely and effectively incorporated into the classes. The program combines training, research, and experience to understand the water issues and water resources management challenges in the United States and internationally. Graduate students can supplement departmental offerings by selecting courses in Mathematics and Statistics; Computer Science; Aquatic, Watershed, and Earth Resources; Environment and Society; Forest, Range, and Wildlife Sciences; Economics; Political Science; Geology; Biological and Irrigation Engineering; Mechanical and Aerospace Engineering; Plants, Soils, and Biometeorology; Biology; Chemistry and Biochemistry; and Physics. This ensures that graduates are well-grounded in the fundamentals, but have a breadth of training and are prepared to contribute professionally to the solution of multidisciplinary local, national, and international water problems. Graduate students in the water program have the opportunity for research support through the Utah Water Research Laboratory (UWRL) while working on theses or dissertations. Excellent laboratory and computing facilities are available. Strong, continuous state and federal research funding keeps the research topics and facilities current. Specialty areas within the program comprise fluid mechanics and hydraulics, hydrology, groundwater, and water resources engineering.

Fluid mechanics and hydraulic engineering covers both fundamental principles and theory and their applications in a variety of engineering fields. Elementary fluid mechanics, based on fundamental principles of conservation of mass, energy, and momentum, is the logical core for all water-related engineering programs. Consequently, other specialties in water engineering study fluid mechanics. Students specializing in fluid mechanics and hydraulics emphasize theoretical fluid mechanics, hydraulic design, numerical methods, and laboratory hydraulic techniques. A good variety and balance of courses supporting research in theoretical fluid mechanics, open channel hydraulics, hydraulic design, transients, sedimentation, municipal water system design, and cavitation are available at the graduate level. Graduates in fluid mechanics and hydraulics find employment in a broad range of professional engineering fields, including consulting, university teaching and research, and state and federal government agencies.

Hydrology is a branch of geoscience concerned with the origin, distribution, movement, and properties of waters of the earth. The hydrologic cycle encompasses the atmosphere, the land surface, lakes and oceans, and the subsurface. Complex, interacting processes at varied time and space scales describe the hydrologic cycle. The concepts and practice of hydrology derive from an integration of field observations, laboratory investigations, and conceptual, mathematical, chemical, statistical, and probabilistic models.

The hydrology program at USU has strength in both theoretical and applied aspects of modern hydrology. Past and present research focuses on a broad spectrum of hydrologic problems. These range from climate modeling, rainfall processes, floods, droughts, terminal lake analyses, soil erosion, and stream water quality models to groundwater contamination characterization and remediation and watershed analyses. A particular emphasis of the program is on an understanding of the global water and energy cycles at nested scales from the hemisphere to the continent to the watershed from a holistic perspective that recognizes the two-way linkages between water reservoirs and fluxes through oceans, atmosphere, land surface and subsurface, and biota.

Groundwater engineering is concerned with the transport of fluids in the subsurface environment. It encompasses the theory of flow in porous media; groundwater hydrology and hydraulics; fate and transport of contaminants in subsurface; and analytical, numerical, and stochastic modeling of such processes. Emphasis is placed on the quantitative analysis of physical and chemical principles governing these processes and on the application of these principles to practical field problems, with all their difficulties related to the complex structure of subsurface formations. Examples of such problems include groundwater supply and management, subsurface cleanup technologies, and analysis and remediation of groundwater contamination. These problems are of a multidisciplinary nature, and their solutions require a multidisciplinary approach, involving, among others, soil and water chemistry, chemical engineering, and economics. The groundwater professional is an important team player in solving such problems.

The groundwater emphasis has a strong research component. Current research activities cover a well-balanced variety of topics, from theoretical (e.g., stochastic analysis of transport of contaminants in groundwater) to practical problems (e.g., design of cleanup technologies for gasoline-contaminated sites).

Water Resources Engineering prepares engineers to be lead members in water resources planning teams, often charged with coordinating the information and concepts supplied from other disciplines. This need for breadth requires considerable flexibility in the training and arrangement of degree programs.

Water resources engineers draw principles from hydrology, fluid mechanics, hydraulics, environmental engineering, economics, ecology, political science, and other disciplines in the design and operation of projects and nonstructural methods for water resources planning and management. They need a sound understanding of how water storage, delivery, and other management systems function; of criteria used in evaluating and selecting among alternatives; of the techniques of operations research that can be used in systems design; and of the institutional aspects of decision-making in the public sector. A focus area of the program is to develop decision support systems for sustainable water quantity and quality management in the United States and in developing regions of the world. Evolving information sources and tools, such as spatial data sets encoded in geographical information systems, climate forecasts, and cognitive models of the human decision process and societal group dynamics, are being integrated in representative institutional contexts.

An internationally-recognized specialized program has been developed in dam safety risk assessment. Students take classes in dam engineering; hydrology and hydraulics; geotechnical engineering; geology; decision analysis; risk assessment; probability and statistics; and natural resources economics, planning, and management. Students work on practical applications, as well as research projects, for improving the state-of-the art.

Environmental Engineering. The Division of Environmental Engineering is a multidisciplinary graduate program in the College of Engineering and provides coursework and research experience to enable engineers and scientists interested in the environment to obtain graduate degrees relating to potable water and waste treatment, toxic and hazardous wastes management, air quality management, natural systems engineering, and environmental impact assessment. The program provides an interdisciplinary educational approach to fundamental principles that can be applied to environmental phenomena. Research and training projects are a part of the program and provide the student with appropriate research experience leading to a thesis or dissertation.

Hazardous Waste Management. This specialization has been developed within the broader scope of the environmental engineering program to provide an integrated approach for students with a BS in engineering or natural sciences to deal with the complex issues of toxic and hazardous waste. Aspects of toxic/hazardous waste management, including characterization, treatment, disposal, control, monitoring, and environmental impacts, are dealt with in this program.

Natural Systems Engineering is the study of the interaction of engineered systems with nature, emphasizing impacts to aquatic ecosystems. Techniques include assessment of aquatic habitat through computer simulation and model verification, quantification of aquatic habitat using remote sensing systems, and data analysis and display through integrated statistical and GIS approaches. These tools are used to evaluate impacts on threatened and endangered species, habitat enhancement, instream flow assessments, fish habitat, stream sediment, and hydraulic features.

A *bioprocess engineering* program has been developed as a cooperative effort between the Division of Environmental Engineering and the Biological and Irrigation Engineering Department. This program provides students with specialized coursework and research experience in areas of bioreactor processing of environmental materials and engineering scale-up of biologically-based environmental reactions. Areas of specialization include waste to energy, fermentation, composting, and industrial waste (agricultural and chemical) reuse, recycling, and technologies based on biological processes, as well as engineering optimization of aquatic habitats.

Transportation Engineering. The graduate program in Transportation offers education and research opportunities in intermodal transportation systems planning, design, and management. It is designed to enable aspiring planners, engineers, and managers to obtain advanced degrees while specializing in infrastructure management, traffic network analysis, facility design, traffic operations, transportation economics and finance, and project appraisal. Up-to-date computer and laboratory facilities, as well as the Transportation Division's close links with local and state transportation agencies, enable students to gain hands-on experience and practical perspectives.

Past and present research undertaken by the Transportation Division faculty and researchers range from microscopic traffic flow simulation, dynamic route assignment, network reliability, and traffic accident modeling to rail system productivity, public transit service scheduling, and intermodal passenger terminal planning. The focus remains on efficient and effective intermodal solutions to transportation problems.

Transportation Division course offerings expose students to the theoretical and practical aspects of goods and passenger transportation. State-of-the-art analytical tools and new research findings are introduced into the courses through periodic revision of notes, examples, problem sets, and computer software. Students are encouraged to design their own programs of study according to their personal and professional goals. Due to the multi-disciplinary nature of transportation, students are encouraged to include in their program of study course offerings from other programs in CEE, as well as from Mathematics and Statistics, Environment and Society, Economics, Business Administration, and Sociology.

Financial Assistance

Both departmental and formal grant support are available to graduate students and are awarded on a competitive basis. Students requesting financial support should apply to the department by March 15 for the coming academic year.

A number of fellowships are available through the University and the department. Teaching assistantships are available through the department and research assistantships are available through the Utah Water Research Laboratory and departmental faculty members who have ongoing projects or who hold special research grants from the University, private companies, or state and federal agencies.

Acceptance to pursue graduate studies in the Civil and Environmental Engineering Department does not guarantee the student financial assistance. Inasmuch as funds are limited, the assistantships are awarded by the department to cover specific teaching assignments and by the faculty members to provide for research as funds are available.

Civil and Environmental Engineering Courses (CEE)

CEE 1880. Civil and Environmental Engineering Orientation and Computer Applications. Orients students to programs of the Department of Civil and Environmental Engineering, professional and academic advising, student services, professional societies, and engineering careers. Laboratory activities emphasize problem solving using computer applications, such as spreadsheets and the HP48 Scientific Calculator. (1 cr) (Sp)

CEE 2240. Engineering Surveying. Experience with a wide variety of common surveying equipment, including use and operation of levels, theodolites, total station equipment, and GPS. Prior to graduation, computer applications and field exercises prepare students for civil engineering employment early in their careers. (3 cr) (F,Su)

CEE 2250. Cooperative Practice I. Planned work experience in industry. Detailed program must have prior approval. Written report required. Prerequisite: Preprofessional enrollment in either the Civil or Environmental Engineering program. (3 cr) (F,Sp,Su)

CEE 2870. Sophomore Seminar. Supervised discussion and review of problems encountered by professional engineers. (1 cr) (Sp)

CEE 2890. Environmental Engineering Sophomore Seminar. Introduces students to the field of environmental engineering, emphasizing design, ethics, and leadership in the environmental engineering profession. Emphasizes creative thinking, organizational skills, team work, professional ethics, and social responsibility. Prerequisite: Sophomore standing in environmental engineering. (1 cr) (Sp)

CEE 3010. Mechanics of Materials. Includes principal stresses, combined loading and stresses, deflection of beams by direction integration, moment-area, conjugate beams and superposition, and deflection of frames and trusses by energy methods, columns, cables, and arches. Includes laboratories to demonstrate the mechanical behavior of materials. Prerequisites: Engr 2000 and 2040. (3 cr) (F)

CEE 3030. Uncertainty in Engineering Analysis. Principles of probability and statistics applied specifically to problems in civil and environmental engineering, including transportation, water quality, waste treatment, hydrology, and materials. (2 cr) (F,Sp)

CEE 3080. Design of Reinforced Concrete Structures. Design of reinforced concrete structural elements, simple and continuous reinforced beams, columns, joints, and one-way slabs. Includes concrete materials laboratory. Prerequisite: CEE 3010. (3 cr) (Sp)

CEE 3210. Introduction to Transportation Engineering. Introduction to basic concepts of roadway geometric design, and intersection and highway capacity analysis. Other topics include: traffic flow characteristics, traffic studies, signal design, and transportation project evaluation. Prerequisite: CEE 3030. (3 cr) (Sp)

CEE 3430. Engineering Hydrology. Processes and practical problems in: surface and groundwater hydrology, the hydrological cycle, rainfall-run-off and flood analysis, regional groundwater flow and well hydraulics, and the design of water supply systems. Prerequisite: CEE 3500 or AWER 3700 or Soil 5650. (3 cr) (Sp)

CEE 3500. Civil and Environmental Engineering Fluid Mechanics. Explores fluid properties, hydrostatics, fluid dynamics similitude, energy and momentum principles, closed conduit flow, open channel flow, and flow measurement. Includes laboratory exercises in flow measurement, open channel flow, pipe friction, physical modeling, and data collection. Prerequisites: Math 1220; Math 2210 or 2250; Engr 2000. (3 cr) (F,Sp)

CEE 3510. Civil and Environmental Engineering Hydraulics. Unsteady flow in open channel and closed circuits, nonuniform flow in open channels, combined energy losses in pipelines, and distribution in pipe networks. Includes laboratory and computer exercises in data collection, pipe networks, and unsteady and nonuniform flow. Prerequisite: CEE 3500. (2 cr) (F,Sp)

CEE 3610. Environmental Management. Introduction to environmental health, emphasizing relationships among environmental quality, public health, environmental and occupational health regulations, human health risk assessment, institutions, and engineered systems in environmental health management. Prerequisites: Chem 1210; Biol 1210 or Breadth Life Sciences course. Also taught as PubH 3610. (3 cr) (F)

CEE 3640. Water and Wastewater Engineering. Engineering analysis and design of processes for treatment of water and wastewater. Major topics include water quality evaluation; physical, chemical, and biological treatment systems; design of facilities for production of drinking water and for treatment and reclamation of municipal and industrial wastewater; and management of residuals from water and wastewater treatment facilities. Laboratory evaluation of physical and chemical treatment technologies. Computer applications for process modeling and analysis. Prerequisite: CEE/PubH 3610. (4 cr) (Sp)

CEE 3670. Transport Phenomena in Bio-Environmental Systems. Core course in both biological and environmental engineering. Students develop a detailed understanding of the principles, concepts, modes, and methods of calculating heat and mass transfer. Emphasis given to contaminant and nutrient flux, along with their state transformations, in order for the biological or environmental engineer to evaluate options for production, clean-up, and control of bio-environmental systems. Prerequisites: CEE 3500 and MAE 2400. Also taught as BIE 3670. (3 cr) (Sp)

CEE 3780. Solid and Hazardous Waste Management. Introduction to integrated management of municipal and industrial solid waste; household, commercial, and industrial hazardous waste; and resource recovery and recycling principles. Three lectures augmented by weekly laboratory to provide students with experience in wet laboratory, computer modeling, and field trip experiences related to modern solid and hazardous waste management principles. Prerequisite: Junior standing in environmental engineering. (3 cr) (F)

CEE 3870. Professional/Technical Writing in Civil and Environmental Engineering. Gives CEE students intensive practice with oral and written communication in business and technical CEE writing. Requires concurrent enrollment in CEE/PubH 3610. (2 cr) (F)

CEE 3880. Civil Engineering Design I. Introduction to senior engineering students' integrated design experience. Design project is identified and proposal for its com-

pletion during the senior year is produced. Emphasizes project scheduling, and completion of design proposal. Prerequisite: CEE 3870. (1 cr) (Sp)

CEE 3890. Environmental Engineering Design I. Introduction to senior environmental engineering students' integrated design experience. Design project identified and proposal for its completion during the senior year is produced, under mentoring of course instructor. Emphasizes project identification, project scoping, manpower and materials budgeting, project scheduling, and completion of design proposal. Prerequisites: CEE/PubH 3610; CEE 3640 and CEE/BIE 3670 (must be taken concurrently). (1 cr) (Sp)

CEE 4200. Engineering Economics. Applications of the mathematics of finance to engineering decision making. Prerequisite: Senior year of engineering or instructor's consent. (2 cr) (F)

CEE 4300. Engineering Soil Mechanics. Physical and mechanical properties of soils. Topics include: classification, permeability, soil stresses and settlement analysis, soil strength, slope stability, lateral earth pressures, introduction to foundations, numerical solutions, and computer applications. Prerequisites: CEE 3500 (taken concurrently) and Engr 2040. (4 cr) (Sp)

CEE 4790 (CI). Environmental Engineering Design II. Provides senior environmental engineering students with integrated design experience in two-semester sequence. Design projects proposed in CEE 3890 completed under mentoring of course instructor. Emphasizes team work, scheduling, design calculations, and completion of design report. Prerequisites: CEE 3890 and concurrent enrollment in environmental engineering technical elective course during fall semester. (2 cr) (F)

CEE 4870 (CI). Civil Engineering Design II. Provides senior engineering students with integrated design experience in two-semester sequence. Design projects proposed in Junior Design Proposal placed on team work, scheduling, design calculations, and completion of design report. Prerequisite: CEE 3880; senior design technical elective should be taken concurrently. (2 cr) (F)

CEE 4880 (CI). Civil Engineering Design III. Provides senior engineering students with integrated design experience in two-semester sequence. Design projects started in CEE 4870 will be completed with presentation, report, and defense of design project. Prerequisite: CEE 4870. (2 cr) (Sp)

CEE 4890 (CI). Environmental Engineering Design III. Provides senior environmental engineering students with integrated design experience in two-semester sequence. Completion of design projects begun in CEE 4790, with presentation, report, and defense. Prerequisite: CEE 4790. (2 cr) (Sp)

CEE 4930. Independent Study. Laboratory design or research project on problem selected by student. Requires review of literature, preparation of proposal describing project, completion of design or research project, and preparation of report.
(1-3 cr) (F,Sp,Su) ®

CEE 5010. Matrix Analysis of Structures and Introduction to Finite Elements. Analysis of structures using matrix methods. Application of software based on the stiffness method to practical analysis problems. Introduction of Finite Element method based on stiffness approach and mathematical derivation of simple finite elements, along with application to practical problems. Prerequisite: CEE 3010. (3 cr) (F)

CEE 5020. Finite Element Methods in Solid Mechanics I. Introduction to finite element methods and their application to the analysis and design of mechanical engineering systems. Prerequisite: MAE 3040. Also taught as MAE 5020. (3 cr) (F)

CEE 5050. Design of Wood and Masonry Structures. Design of beams, columns, joints, walls, and diaphragms in both wood and masonry materials. Current design codes will be utilized. Prerequisite: CEE 3080. (3 cr) (Sp)

CEE 5060. Mechanics of Composite Materials I. Stress-strain relations for nonisotropic composites, such as fiber-reinforced plastic laminates, properties and their uses, strength and life determination, and methods for design using composite materials. Prerequisite: MAE 3040 or CEE 3010. Also taught as MAE 5060. (3 cr) (F)

CEE 5070. Structural Steel Design. Structural steel design using load and resistance factor design (LRFD) method. Focuses on design of structural beams, columns, and connections utilizing steel design codes. Prerequisite: CEE 3080. (3 cr) (F)

CEE 5080 (d6080).[1] Numerical Methods in Elasticity. Elasticity theory, stress and strain analysis, and yield criteria. Governing equilibrium, kinematic, and compatibility equations. Generalized Hooke's law. Classical solutions of flex and torsion problems. Energy methods. Introduction to finite difference, finite element, and boundary element methods. Computer applications. Prerequisite: CEE 3010. (3 cr) (F)

CEE 5100. Infrastructure Evaluation and Renewal. Evaluation of existing structural systems and techniques to improve their performance. Focuses on structures which are seismically deficient. Prerequisites: CEE 3080, 5070. (3 cr) (Sp)

CEE 5190 (d6190). Geographic Information Systems for Civil Engineers. Introduction to GIS concepts addressing data structures, spatial entities, and queries. Topics include location referencing methods, data collection techniques, current applications, and institutional and organizational issues. (3 cr) (F)

CEE 5220 (d6220). Traffic Engineering. Topics covered include characteristics, measurements, and analysis of volume, speed, density, and travel time; capacity and level of service analysis; signalization and traffic control devices. (3 cr) (Sp)

CEE 5230 (d6230). Geometric Design of Highways. Principles of highway location and planning, with full consideration of economic, environmental, and other impacts. Capacity analysis of intersections and highways, passing-lane design, and risk-cost based horizontal and vertical alignment design. Introduction to design software through coursework and term projects. Prerequisite: CEE 3210. (3 cr) (F)

CEE 5240 (d6240). Urban and Regional Transportation Planning. Examination of travel demand forecasting, data collection, and survey data analysis techniques. Focuses on transportation-land use interactions and impact of market-based policies on travel demand. Theories and applications of traditional and advanced trip distribution, mode choice, and route assignment models. (3 cr) (F)

CEE 5250. Environmental Engineering Cooperative Practice. Applied environmental employment with primary focus of work experience related to one of the environmental engineering specialty areas. Prerequisites: Senior status and permission of instructor. (2 cr) (F,Sp,Su)

CEE 5350 (d6350). Foundation Analysis and Design. Applications of theories studied in soil mechanics. Design considerations for various foundation types, including shallow foundations, driven piles, drilled shafts, walls, soil anchorages, and mechanically-stabilized earth support systems. Field investigation techniques and computer applications. Prerequisite: CEE 4300. (3 cr) (F)

CEE 5380 (d6380). Earthquake Engineering. Covers wide variety of earthquake engineering topics, including seismology and earthquake source characterization, strong ground motion, seismic hazard analysis, wave propagation, soil dynamics, ground response, local site effects, liquefaction, seismic slope stability, soil improvement, vibrational analyses, and structural seismic design. Prerequisite: CEE 4300.
(3 cr) (Sp)

CEE 5430 (d6430). Groundwater Engineering. Basics of contaminant transport and fate in soil water and vapor, design of groundwater recovery systems, and subsurface contamination remediation, including interceptor wells, well fields, stream-aquifer interactions, soil vapor extraction, separate phase recovery, biodegradation of soluble plumes, and air emissions. (3 cr) (F)

CEE 5440 (d6440). Geographic Information Systems in Water Resources. Principles and operation of geographic information systems. Spatial hydrologic modeling done by developing a digital representation of the environment in the GIS, then adding functions simulating hydrologic processes. Includes term project on use of GIS in water resources. (3 cr) (F)

CEE 5450 (d6450). Hydrologic Modeling. Case studies of hydrologic modeling and decision methods: (1) Real-time flood warning; (2) extended streamflow prediction; (3) probabilistic water resource management; and (4) physical modeling of ungaged basins. Prerequisite: CEE 3430. (3 cr) (Sp)

CEE 5460 (d6460). Water Resources Engineering. Engineering design course covering a wide range of topics, including: surface and groundwater hydrology, statistical analysis, water law, hydroelectric power, water supply, irrigation, flood control, wastewater, drainage, dams and reservoirs, pipelines, open channels, and planning. (3 cr) (F)

CEE 5470 (d6470). Sedimentation Engineering. Explores river response, sediment transport, sediment and watershed yield, flow resistance, scour and erosion, and floodplain management. Prerequisite: CEE 3500. (3 cr) (Sp)

CEE 5540 (d6540). Fluid Mechanics. Intermediate-level fluid mechanics course, including fluid properties, governing equations, and applications. Brief study of viscous flows, including laminar and turbulent flow solutions. Detailed study of potential flow, including use of complex variable analysis and numerical solutions, and two- and three-dimensional flows. (3 cr) (F)

CEE 5550 (d6550). Hydraulics of Closed Conduits. Includes design and operation of piping systems; economics; feasibility and impact of pipelines; pipe, pump, and valve selection; transient and cavitation analysis; and pipeline operation and filling. Prerequisites: CEE 3500 and 3510. (3 cr) (Sp)

CEE 5560 (d6560). Environmental Hydraulics. Design of hydraulic structures, spillways, energy dissipators, fish passage, reservoir operation, ocean outfalls, and pumping stations. Includes principles of design and impact of structures on the environment, and the environmental properties and hydraulics of fluids. Prerequisite: CEE 3500. (2 cr) (F)

CEE 5610 (d6610). Environmental Quality Analysis. Familiarizes students with various methods used for analysis of chemical parameters in environmental samples (water, soil, and air). Provides students with skills enabling them to make proper selection/evaluation of analytical procedure and evaluate data generated. Prerequisite: Chem 1210. (3 cr) (F)

CEE 5620. Aquatic Chemistry. Provides students with understanding of principles of aquatic chemistry, emphasizing chemical equilibria, acid-base reactions, complex formation, oxidation-reduction reactions, complex formation, and dissolution chemistry. Prerequisites: Chem 1210, CEE 3640. Also taught as Soil 5620. (3 cr) (F)

CEE 5670. Hazardous Chemicals Handling and Safety. Provides students with necessary skills and knowledge for working safely in areas associated with hazardous chemicals. Topics covered include: regulations, exposure routes, toxicology, chemical and physical hazards, personal protective equipment, sampling, monitoring, decontamination, and emergency response procedures. Prerequisite: Chem 1210. (2 cr) (Sp)

CEE 5680 (d6680). Soil Based Hazardous Waste Management. Engineering management of hazardous wastes present in the vadose zone, including extraction, containment, and biological, chemical, and physical destruction technologies. Aspects include engineering characterization, problem definition, treatment, and monitoring. Analysis and design emphasized through problems, examinations, and report writing. Prerequisites: CEE/PubH 3610, CEE 3640, 3870, CEE/BIE 3670. (2 cr) (Sp)

CEE 5690 (d6690). Natural Systems Engineering. Application of modeling tools commonly utilized in water resources systems for assessment of environmental impacts associated with engineered systems. Topics include: water resources modeling; physical, chemical, and biological process effects; assessment methods; data integration techniques; and impact assessment. Taught second half of fall semester. Prerequisites: CEE/PubH 3610, CEE 3500, 3510, 3640. (2 cr) (F)

CEE 5700 (d6700). Field Sampling Techniques for Natural Systems Engineering. Provides students with hands-on approach to utilizing several of the most commonly applied spatial and temporal sampling techniques for data acquisition in support of natural systems modeling. Explores standard and advanced surveying techniques for water quality, stream geomorphology, and hydraulics, utilizing levels, total stations, laser levels, GPS, and hydroacoustic technologies. Integrative sampling strategies across spatial and temporal scales emphasized for multi-disciplinary studies. Taught first half of fall semester. Prerequisite: CEE 5690/6690. (2 cr) (F)

CEE 5710. Pollution Prevention and Industrial Ecology. Explores pollution prevention and waste minimization concepts, focusing on implementation of these concepts in design of production processes and products. Discussion of pollution prevention/waste minimization concepts, energy and materials conservation, Life Cycle Analysis, materials and process audits, industrial process design for waste minimization and energy conservation, packaging, and ISO 14000. Prerequisites: CEE/BIE 3670, CEE 3780, MAE 2400. (2 cr) (Sp)

CEE 5720 (d6720). Natural Systems Modeling. Provides hands-on approach to utilizing several of the most commonly applied modeling tools employed to estimate physical, chemical, and biological impacts of existing and proposed water resource systems. Focuses on utility and climitation of specific modeling approaches, while also stressing integrative multi-disciplinary nature of impact assessment frameworks. Prerequisite: CEE 5690/6690. (3 cr) (Sp)

CEE 5730 (d6730). Analysis and Fate of Environmental Contaminants. Provides students with understanding of methods used in analysis of environmental samples for organic contaminants. Examines various properties and processes determining the fate of organic contaminants in the environment. Taught first half of spring semester. Prerequisites: Chem 1210, 2300, CEE/Soil 5620. (3 cr) (Sp)

CEE 5740. Natural Systems Engineering Laboratory. Computer modeling techniques applied to water resources systems for assessment of environmental impacts associated with engineering activities. Corequisite: CEE 5690. Taught second half of fall semester. (1 cr) (F)

CEE 5750. Air Quality Measurements. Laboratory-based course designed to familiarize participants with federally-approved reference measurement techniques for embient and source air pollutants. Also provides understanding of temporal and spatial pollutant behavior. (2 cr) (Sp)

CEE 5760. Hydraulic Structures Field Course. Week-long course, with one day of in-class lectures and four days of field trips. Introduces students to field applications of hydraulic structures design. Field trips may involve backpacking to remote areas. (1 cr) (F,Su)

CEE 5790. Accident and Emergency Management. Introduction to fundamentals of accident, hazard, and emergency management. Topics include legislation; chemical safety fundamentals; fire, explosion, and spill fundamentals; contaminant air transport fundamentals; hazard and risk assessment; dispersion applications; and hazard and risk management applications. (3 cr) (Sp)

CEE 5810 (d6810). Biochemical Engineering. Fundamentals of bioreactor design and bioengineering. Emphasizes mathematical models of microbial and enzymatic processes in environmental and industrial biotechnology. Prerequisites: BIE 3200 and BIE/CEE 3670; *or* BIE/CEE 3670, CEE/PubH 3610, and CEE 3640. Also taught as BIE 5810/6810. (3 cr) (F)

CEE 5830 (d6830). Management and Utilization of Biological Solids and Wastewater. Focuses on production, management, and disposal of biosolids and wastewater generated in food processing and wastewater treatment. Emphasizes beneficial use of biosolids and wastewater for agricultural production, forest enhancement, and land reclamation. Prerequisite: BIE/CEE 3670. Also taught as BIE 5830/6830. (3 cr) (F)

CEE 5860. Air Quality Management. Introduction to air quality management. Explores sources and effects of conventional and toxic air pollutants, control techniques, and air dispersion modeling. Three lectures augmented by weekly laboratory, providing students with experience in wet laboratory, computer modeling, and field trip experiences related to conventional and toxic air pollution management principles. Prerequisites: CEE 3640, 3780, CEE/BIE 3670, MAE 2400. (3 cr) (F)

CEE 5870. Hazardous Waste Incineration. Provides introduction to hazardous waste incineration principles. Topics include: thermodynamics, stoichiometry,

thermochemistry, chemical kinetics, energy recovery, pollution control systems, and incinerator design principles. Prerequisites: CEE/BIE 3670, CEE 3780, MAE 2400; CEE 5860 (may be taken concurrently). (2 cr) (Sp)

CEE 5880. Remediation Engineering. Physical, chemical, and biological principles associated with remediation of hazardous waste contaminated soil, water, sediments, and air. Topics include: source removal and source control, product recovery, chemical treatment methods, biological remediation concepts, in situ processes, ex situ processes, and integrated process design. Prerequisites: CEE 3430, 3640, 3780, CEE/PubH 3610. (3 cr) (F)

CEE 5900. Cooperative Practice II. A planned work experience in industry. Detailed program must have prior approval. Written report required. (3 cr) (F,Sp,Su)

CEE 6010. Finite Element Methods in Solid Mechanics II. Advanced theory and applications of finite element methods to both static and dynamic solid mechanics problems. Prerequisite: MAE 5020. Also taught as MAE 6010. (3 cr) (Sp)

****CEE 6020. Structural Stability.** Elastic and inelastic buckling of columns; analysis of beam columns, thin-walled beams of open cross-section. Stability analysis of frame and plate structures. Large deflection theory. Historical notes on stability of structures. Computer applications. Prerequisite: CEE 3010. (3 cr) (F)

***CEE 6030. Structural Optimization.** Introduction to optimization techniques for linear and nonlinear, univariable, and multivariable functions with or without constraints. Computer applications, and applications to structural design. Prerequisite: CEE 3010 or instructor's consent. (3 cr) (Sp)

***CEE 6040. Structural Reliability.** Elements of probability theory and its application to structural engineering and mechanics. Statistical distribution of loads. Uncertainties in material parameters and their effects in design. Reliability-based safety analysis and computer applications. Prerequisite: Instructor's consent. (3 cr) (F)

****CEE 6050. Experimental Methods in Structural Engineering.** Experimental techniques used in research and design in structural engineering and mechanics. Structural models. Theory and practical applications. Development of principles used to design research projects. Prerequisite: Instructor's consent. Also taught as MAE 6050. (3 cr) (Sp)

CEE 6070. Mechanics of Composite Materials II. Second course in composite materials. Stress-strain states of laminated composite structures, including interlaminar stresses, failure criteria, and hygrothermal stresses. Prerequisite: MAE 5060. Also taught as MAE 6070. (3 cr) (Sp)

CEE 6080 (d5080). Numerical Methods in Elasticity. Elasticity theory, stress and strain analysis, and yield criteria. Governing equilibrium, kinematic, and compatibility equations. Generalized Hooke's law. Classical solutions of flex and torsion problems. Energy methods. Introduction to finite difference, finite element, and boundary element methods. Computer applications. Prerequisite: CEE 3010. (3 cr) (F)

CEE 6090. Theory of Plates and Shells. Introduction to plate and shell theories. Development of bending and buckling of plates and shells through classical theory. Prerequisite: MAE 3040 or CEE 3010. Also taught as MAE 6090. (3 cr) (Su)

CEE 6130. Structural Dynamics and Seismic Design. Development and solutions for equations of motion for single- and multi-degree of freedom systems. Dynamic analysis by Modal Superposition and Response Spectra. Design of structures for seismically active areas. Also taught as MAE 6130. (3 cr) (Sp)

CEE 6180. Dynamics and Vibrations. Fundamentals of two-dimensional and three-dimensional rigid body dynamics, including Newtonian, Lagrangian, and Leavit Energy Methods. Equations of motion, mode shapes, and natural frequencies for continuous media and multi degree-of-freedom systems. Prerequisite: MAE 5300 or CEE 6130. Also taught as MAE 6180. (3 cr) (F)

CEE 6190 (d5190). Geographic Information Systems for Civil Engineers. Introduction to GIS concepts addressing data structures, spatial entities, and queries. Topics include location referencing methods, data collection techniques, current applications, and institutional and organizational issues. (3 cr) (F)

CEE 6200. Pavement Design. Analysis and design of flexible and rigid pavements for highways and runways, including the design of overlays. Equal emphasis on current practice and advanced concepts of pavement management. Prerequisite: CEE 3010. (3 cr) (F)

CEE 6210. Transportation Systems Analysis. Introduces systems approach to analysis of transportation services and infrastructure. Focuses on basic and advanced concepts, including operations research techniques, simulation, and artificial intelligence. Topics include facility sizing and location, financial and economic analysis of investment projects, and privatization. Prerequisite: CEE 3030 or equivalent. (3 cr) (F)

CEE 6220 (d5220). Traffic Engineering. Topics covered include characteristics, measurements, and analysis of volume, speed, density, and travel time; capacity and level of service analysis; signalization and traffic control devices. (3 cr) (Sp)

CEE 6230 (d5230). Geometric Design of Highways. Principles of highway location and planning, with full consideration of economic, environmental, and other impacts. Capacity analysis of intersections and highways, passing-lane design, and risk-cost based horizontal and vertical alignment design. Introduction to design software through coursework and term projects. Prerequisite: CEE 3210. (3 cr) (F)

CEE 6240 (d5240). Urban and Regional Transportation Planning. Examination of travel demand forecasting, data collection, and survey data analysis techniques. Focuses on transportation-land use interactions and impact of market-based policies on travel demand. Theories and applications of traditional and advanced trip distribution, mode choice, and route assignment models. (3 cr) (F)

CEE 6250. Transportation Data/Safety Analysis. Statistical analysis of transportation data, including safety and risk assessment. Regression and multivariate analysis, such as discriminant analysis, canonical correlation, and factor analysis. In-depth study of selected methodologies for analyzing transportation safety and designing counter measures. Prerequisite: CEE 3210 or equivalent. (3 cr) (Sp)

CEE 6260. Public Transportation. Principles of planning, design, and operation of transit systems in urban and rural areas. Determination of optimal route alignments, schedules, and station/stop spacings. Exploration of innovations in financing and pricing, including cost-cutting techniques. (3 cr) (Sp)

CEE 6270. Traffic Operations Analysis. Traffic flow fundamentals, macroscopic and microscopic models of traffic flow, shock wave analysis, car following principles, queuing systems, and simulation. (3 cr) (Sp)

CEE 6290. Transportation Network Analysis. Analytical approaches and algorithms to the formulation and solution of the equilibrium assignment problem for transportation networks. Emphasis on user equilibrium, comparison with system optimal stochastic user equilibrium, origin-destination matrix estimation, and network design problems. (3 cr) (F)

CEE 6300. Earth Structures. Design and construction of earth and rockfill dams, embankments, excavations, and retaining structures. Prerequisites: CEE 4300, 5350/6350. (3 cr) (Sp)

CEE 6310. Environmental Geotechniques. Geotechnical aspects of environmental systems, with concentration on waste containment facilities. Prerequisite: CEE 4300. (3 cr) (F)

CEE 6320. Deep and Shallow Foundations. Analysis, design, and construction of deep and shallow foundations. Prerequisites: CEE 4300, 5350/6350. (3 cr) (Sp)

CEE 6330. Ground Reinforcement, Improvement, and Treatment. Theory, design, and construction methods for ground reinforcement, improvement, and treatment applications. Prerequisites: CEE 4300, 5350/6350. (3 cr) (F)

CEE 6340. Laboratory and Field Methods in Geotechnical Engineering. Subsurface investigation, field testing and instrumentation, and laboratory testing. Prerequisites: CEE 4300, 5350/6350. (3 cr) (F)

CEE 6350 (d5350). Foundation Analysis and Design. Applications of theories studied in soil mechanics. Design considerations for various foundation types, including shallow foundations, driven piles, drilled shafts, walls, soil anchorages, and mechanically-stabilized earth support systems. Field investigation techniques and computer applications. Prerequisite: CEE 4300. (3 cr) (F)

CEE 6360. Geotechnical Principles. Theoretical soil behavior. Hydraulic conductivity, compression, and shearing properties. Prerequisites: CEE 4300, 5350/6350. (3 cr) (F)

CEE 6370. Buried Structures. Analysis of structural performance of buried structures (pipes, tanks, silos, etc.) using principles of mechanics of materials and finite element methods. Prerequisite: CEE 4300. (3 cr) (Sp)

CEE 6380 (d5380). Earthquake Engineering. Covers wide variety of earthquake engineering topics, including seismology and earthquake source characterization, strong ground motion, seismic hazard analysis, wave propagation, soil dynamics, ground response, local site effects, liquefaction, seismic slope stability, soil improvement, vibrational analyses, and structural seismic design. Prerequisite: CEE 4300. (3 cr) (Sp)

CEE 6400. Physical Hydrology. Fundamentals of hydrologic cycle and hydrologic processes. Precipitation, infiltration, runoff generation, evaporation and transpiration, and snowmelt. Representation of hydrologic processes in hydrologic models. Prerequisite: CEE 3430. (3 cr) (F)

CEE 6410. Water Resource Systems Analysis. Systems formulation of decision problems. Solution by simulation and optimization, constrained and unconstrained optimization algorithms, case studies and applications to water supply, and quality and ecosystems management. (3 cr) (Sp)

CEE 6420. Engineering Risk Assessment and Risk Management. Comprises both quantitative risk assessment techniques and a range of issues in risk management. Examples drawn from various civil engineering subdisciplines such as: environmental engineering, geotechnical engineering, hydraulics and hydrology, structural engineering, transportation engineering, and water resource management. (3 cr) (Sp)

CEE 6430 (d5430). Groundwater Engineering. Basics of contaminant transport and fate in soil water and vapor, design of groundwater recovery systems, and subsurface contamination remediation, including interceptor wells, well fields, stream-aquifer interactions, soil vapor extraction, separate phase recovery, biodegradation of soluble plumes, and air emissions. (3 cr) (F)

CEE 6440 (d5440). Geographic Information Systems in Water Resources. Principles and operation of geographic information systems. Spatial hydrologic modeling done by developing a digital representation of the environment in the GIS, then adding functions simulating hydrologic processes. Includes term project on use of GIS in water resources. (3 cr) (F)

CEE 6450 (d5450). Hydrologic Modeling. Case studies of hydrologic modeling and decision methods: (1) Real-time flood warning; (2) extended streamflow prediction; (3) probabilistic water resource management; and (4) physical modeling of ungaged basins. Prerequisite: CEE 3430. (3 cr) (Sp)

CEE 6460 (d5460). Water Resources Engineering. Engineering design course covering a wide range of topics, including: surface and groundwater hydrology, statistical analysis, water law, hydroelectric power, water supply, irrigation, flood control, wastewater, drainage, dams and reservoirs, pipelines, open channels, and planning. (3 cr) (F)

CEE 6470 (d5470). Sedimentation Engineering. Explores river response, sediment transport, sediment and watershed yield, flow resistance, scour and erosion, and floodplain management. Prerequisite: CEE 3500. (3 cr) (Sp)

CEE 6480. Subsurface Flow and Transport Processes. In-depth coverage of unsaturated and saturated water flow, well hydraulics, salt water intrusion, and multiphase flow applicable to groundwater resources management and remediation. Includes basics of nonreactive and reactive mass transort processes due to various pollution events, and remediation strategies. Addresses special topics related to free-product recovery and migration, and vapor phase transport as applicable to remediation of hazardous-waste contaminated subsurface. (3 cr) (Sp)

CEE 6490. Integrated River Basin/Watershed Planning and Management. Reviews fundamental building blocks of water resource institutions, emphasizing creation of institutions which are sensitive to a particular culture, economic, and political environment. Addresses institutional mission and regulatory roles, public participation, property and water rights, and elements of production. (3 cr) (Sp)

CEE 6500. Open Channel Hydraulics with an Emphasis on Gradually Varied Flow. Theory and applications of steady uniform and gradually varied flow under both subcritical and supercritical flow conditions. Solutions to multiple-network canal systems by solving systems of combined ordinary differential and algebraic equations. Method for defining natural channel systems and solving steady-state flows in them. Prerequisites: CEE 3500, 3510. (3 cr) (F)

CEE 6510. Numerical and Statistical Methods for Civil Engineers. Engineering applications of approximation and interpolation, solution methods for ordinary differential equations, numerical solution of partial differential equations, nonparametric and parametric probability and regression estimation, and Monte Carlo and uncertainty analysis. (3 cr) (F)

CEE 6520. Applied Hydraulics. Basic fluid mechanics applied to wildland watershed systems and directed at nonengineering students. Explores nature of fluid state, fluid motion, and steady uniform and varied flow in open channels, under both subcritical and supercritical conditions. Surveys concepts of boundary layers, turbulence, convection, dispersal, and wave formation in unsteady flows. Emphasizes problem formulation and solving. Prerequisites: AWER 5490/4490; Math 2280 (recommended). Also taught as AWER 6520. (3 cr) (F)

CEE 6530. Unsteady Flows in Open Channels and Numerical Solutions of St. Venant Equations. Derivation and physical meaning of the St. Venant equations, types of water waves, solutions to unsteady free surface flows based on the characteristics, and direct and iterative implicit methods of solution. Emphasizes solving unsteady flow problems in channel systems. Prerequisite: CEE 6500. (3 cr) (Sp)

CEE 6540 (d5540). Fluid Mechanics. Intermediate-level fluid mechanics course, including fluid properties, governing equations, and applications. Brief study of viscous flows, including laminar and turbulent flow solutions. Detailed study of potential flow, including use of complex variable analysis and numerical solutions, and two- and three-dimensional flows. (3 cr) (F)

CEE 6550 (d5550). Hydraulics of Closed Conduits. Includes design and operation of piping systems; economics; feasibility and impact of pipelines; pipe, pump, and valve selection; transient and cavitation analysis; and pipeline operation and filling. Prerequisites: CEE 3500 and 3510. (3 cr) (Sp)

CEE 6560 (d5560). Environmental Hydraulics. Design of hydraulic structures, spillways, energy dissipators, fish passage, reservoir operation, ocean outfalls, and pumping stations. Includes principles of design and impact of structures on the environment, and the environmental properties and hydraulics of fluids. Prerequisite: CEE 3500. (2 cr) (F)

***CEE 6570. Potential Fluid Flow.** Application of the principles and methods of classical hydrodynamics to the solution of problems. Closed form solution to invisual fluid flows obtained using complex variables and conformal mappings. Prerequisite: CEE 3510 or MAE 3420. Also taught as MAE 6570. (2 cr) (F)

CEE 6580. Intermediate Fluid Mechanics. Survey of mathematical methods used in fluid mechanics, including: potential flow solutions (complex variables), laminar flow and turbulent flow solutions, boundary layer theory, and introduction to dispersion in fluid. (3 cr) (F)

CEE 6600. Environmental Chemistry of Inorganic Contaminants. Inorganics of environmental concern discussed in terms of processes affecting their behavior in soil and water systems. Laboratory-scale experiments and computer models used to evaluate this behavior. Explores remediation of environmental systems contaminated with inorganic pollutants. Taught second half of spring semester. Prerequisite: CEE/Soil 5620. (2 cr) (Sp)

CEE 6610 (d5610). Environmental Quality Analysis. Familiarizes students with various methods used for analysis of chemical parameters in environmental samples (water, soil, and air). Provides students with skills enabling them to make proper selection/evaluation of analytical procedure and evaluate data generated. Prerequisite: Chem 1210. (3 cr) (F)

CEE 6620. Field Sampling and Analysis of Environmental Systems. Explores applied field sampling, as well as field and laboratory techniques used in the monitoring of environmental media. Includes theory and practice of field site monitoring and measurement of physical, chemical, and biological processes in the environment. Prerequisite: Consent of instructor. (3 cr) (F)

CEE 6630. Process Dynamics in Environmental Engineering Systems. Fundamental principles used in analysis and simulation of environmental systems. Emphasizes reaction kinetics, mass transfer, reactor analysis and design, and development and solution of mathematical models to describe natural and engineered environmental systems. Taught first half of fall semester as prerequisite to CEE 6660. Prerequisites: CEE 3500, 3510. (2 cr) (F)

CEE 6640. Physical and Chemical Environmental Process Engineering. Principles of physical and chemical environmental engineering processes, including sedimentation, filtration, gas transfer, aeration, absorption, ion exchange, membrane processes, coagulation, flooculation, precipitation, oxidation, reduction, and disinfection. Process modeling and analysis applications in treatment of water, wastewater, industrial wastes, vapor treatment, and soil remediation. Prerequisites: CEE/Soil 5620, CEE 6630. Corequisite: CEE 6670. (3 cr) (Sp)

CEE 6650. Biological Processes in Environmental Engineering. Theory and design of biological processes used in environmental engineering. Stoichiometric, energetic, and kinetic analysis of biological treatment processes; modeling and design of suspended growth and fixed-film processes for treatment of municipal, industrial, and hazardous wastes; nutrient removal; and bioremediation. Prerequisites: CEE 6630, 6640, 6710. (2 cr) (Sp)

CEE 6660. Environmental Data Analysis and Experimentation. Data analysis and experimental design for environmental science and engineering. Graphical data analysis, parametric and nonparametric statistics, frequency distributions, hypothesis testing, propagation of variance, censored data, correlation and causation, parameter estimation, factorial experimental design and response surfaces, environmental monitoring and uncertainty. (2 cr) (F)

CEE 6670. Environmental Process Laboratory. Laboratory testing to demonstrate physical, chemical, and biological principles utilized in environmental engineering processes. Corequisites: CEE 6640, 6650. (2 cr) (Sp)

CEE 6680 (d5680). Soil Based Hazardous Waste Management. Engineering management of hazardous wastes present in the vadose zone, including extraction, containment, and biological, chemical, and physical destruction technologies. Aspects include engineering characterization, problem definition, treatment, and monitoring. Analysis and design emphasized through problems, examinations, and report writing. Prerequisites: CEE/PubH 3610, CEE 3640, 3870, CEE/BIE 3670. (2 cr) (Sp)

CEE 6690 (d5690). Natural Systems Engineering. Application of modeling tools commonly utilized in water resources systems for assessment of environmental impacts associated with engineered systems. Topics include: water resources modeling; physical, chemical, and biological process effects; assessment methods; data integration techniques; and impact assessment. Taught second half of fall semester. Prerequisites: CEE/PubH 3610, CEE 3500, 3510, 3640. (2 cr) (F)

CEE 6700 (d5700). Field Sampling Techniques for Natural Systems Engineering. Provides students with hands-on approach to utilizing several of the most commonly applied spatial and temporal sampling techniques for data acquisition in support of natural systems modeling. Explores standard and advanced surveying techniques for water quality, stream geomorphology, and hydraulics, utilizing levels, total stations, laser levels, GPS, and hydroacoustic technologies. Integrative sampling strategies across spatial and temporal scales emphasized for multi-disciplinary studies. Taught first half of fall semester. Prerequisite: CEE 6690/5690. (2 cr) (F)

CEE 6710. Environmental Engineering Microbial Ecology. Principles of microbial ecology applied to engineered and natural systems. Taught first half of fall semester. Prerequisites: Biol 3300, CEE/PubH 3610. (2 cr) (F)

CEE 6720 (d5720). Natural Systems Modeling. Provides hands-on approach to utilizing several of the most commonly applied modeling tools employed to estimate physical, chemical, and biological impacts of existing and proposed water resource systems. Focuses on utility and limitation of specific modeling approaches, while also stressing integrative multi-disciplinary nature of impact assessment frameworks. Prerequisite: CEE 6690/5690. (3 cr) (Sp)

CEE 6730 (d5730). Analysis and Fate of Environmental Contaminants. Provides students with understanding of methods used in analysis of environmental samples for organic contaminants. Examines various properties and processes determining the fate of organic contaminants in the environment. Taught first half of spring semester. Prerequisites: Chem 1210, 2300, CEE/Soil 5620. (3 cr) (Sp)

CEE 6740. Environmental Quality Modeling. Development and application of mathematical models for conventional and toxic pollutants in environmental systems. Description of advection, dispersion, sediment transport, partitioning, interphase transfer, and transformation kinetics applied to organic and inorganic pollutants. Equilibrium, steady state, and nonsteady systems. Prerequisite: CEE 6630. (3 cr) (Sp)

CEE 6750. Eco-Hydraulics for Natural Systems Engineering. Provides students with advanced multi-disciplinary modeling course in the application of hydraulics and water resource modeling in light of impact assessment frameworks for natural systems modeling. Focuses on application on one-dimensional and two-dimensional hydraulic modeling as basis for examining quantitative impacts on stream and riparian ecosystems under altered flow, as well as channel conditions with particular emphasis on fish and aquatic macro-invertebrates. Prerequisite: CEE 6690/5690. (4 cr) (F)

CEE 6800. Division of Environmental Engineering Seminar. Environmental engineering graduate seminar for faculty and student research presentations. (1 cr) (F,Sp)

CEE 6810 (d5810). Biochemical Engineering. Fundamentals of bioreactor design and bioengineering. Emphasizes mathematical models of microbial and enzymatic processes in environmental and industrial biotechnology. Prerequisites: BIE 3200 and BIE/CEE 3670; *or* BIE/CEE 3670, CEE/PubH 3610, and CEE 3640. Also taught as BIE 6810/5810. (3 cr) (F)

CEE 6830 (d5830). Management and Utilization of Biological Solids and Wastewater. Focuses on production, management, and disposal of biosolids and wastewater generated in food processing and wastewater treatment. Emphasizes beneficial use of biosolids and wastewater for agricultural production, forest enhancement, and land reclamation. Prerequisite: BIE/CEE 3670. Also taught as BIE 6830/5830. (3 cr) (F)

CEE 6840. Application of Technology Transfer for Teachers. Focuses on application of modern instructional strategies to the transfer of technology and science to the public education setting. Part of a series of six courses. Prerequisite: Participation in an In*Step Science Program in the public schools. (2 cr) (F,Sp,Su) ®

CEE 6900. Directed Reading. Prerequisite: Instructor's consent. (1-3 cr) (F,Sp,Su) ®

CEE 6930. Special Problems. Independent or group study of engineering problems not covered in regular course offerings. Prerequisite: Instructor's consent. (1-4 cr) (F,Sp,Su) ®

CEE 6970. Thesis Research. Prerequisite: Instructor's consent. (1-6 cr) (F,Sp,Su) ®

CEE 6990. Continuing Graduate Advisement. Prerequisite: Instructor's consent. (1-9 cr) (F,Sp,Su) ®

CEE 7050. Plasticity. Analysis of stresses, deformation, and collapse in devices constructed of plastic material. Prerequisite: MAE 6040 or CEE 6080/5080 or instructor's consent. Also taught as MAE 7050. (3 cr) (Sp)

CEE 7080. Advanced Plate and Shell Theory. Analysis of plate and shell structures by classical and numerical methods. Emphasis on numerical solutions. Prerequisite: Instructor's consent. Also taught as MAE 7080. (3 cr) (F)

****CEE 7110. Constitutive Modeling and Structural Response of Engineering Materials.** Constitutive modeling of reinforced concrete, metals, soils, and composite materials. Plasticity and endochronic theories. Finite element modeling and predictive analysis of two- and three-dimensional structures. Computer applications and implementations. Prerequisite: Instructor's consent. (3 cr) (F)

CEE 7120. Advanced Topics in Civil Engineering. Discussion of current research topics conducted by civil and other engineering faculty and staff at USU and elsewhere. Offered on either arranged or regular basis. Topics and times can be arranged with instructor and advisor. Prerequisite: Instructor's consent. (3 cr) (F,Sp,Su)

CEE 7200. Planning and Design of Airports. Aspects of airport location, financing, and marketing. Introduces demand forecasting techniques, airside and landside capacity analysis, and facility sizing techniques. Design of terminal building components, configuration, layout of concessions, and signing. Discussion of surface access issues and environmental aspects of airport development. Prerequisite: CEE 6240/5240. (3 cr) (Sp)

CEE 7270. Travel Demand and Supply Analysis. Fundamentals of demand and supply analysis. Theoretical aspects of travel demand modeling techniques. Modeling of performance characteristics and costs of transportation modes. Emphasis on theoretical aspects of discrete choice analysis and their applications in the modeling of transportation systems. (3 cr) (F)

CEE 7300. Theoretical Soil Mechanics. Advanced studies of stress distribution in soil masses, shear strength, consolidation, constitutive modeling, and finite applications. Prerequisite: CEE 6360. (3 cr) (Sp)

****CEE 7310. Fundamentals of Soil Behavior.** The influence of clay mineralogy, clay chemistry, and soil origin on the engineering properties of soil. Prerequisite: CEE 6360. (3 cr) (F)

****CEE 7320. Advanced Soil Dynamics.** Advanced studies in the response of soil structures and foundations to dynamic loads. Prerequisite: CEE 6360. (3 cr) (F)

*****CEE 7430. Stochastic Hydrology.** Stochastic description of hydrologic variability in time, space, and space-time. Markov processes, time series synthesis and forecasting, spectral analysis, spatial interpolation and random field simulation, data imputation, and parameter estimation for physical models. Lattice and Markov chain Monte Carlo methods, simulated annealing, and Gibbs processes. Applications to rainfall, streamflow, groundwater quality and quantity, and subsurface characterization. (3 cr) (Sp)

*****CEE 7440. Hydroclimatology.** Study of droughts and floods as determined by long-term climate fluctuations. Dynamics of low-frequency large-scale climate variability. El Nino Southern Oscillation and its hydrologic impacts. Global climate change issues. (3 cr) (Sp)

CEE 7460. Advanced Topics in Hydrology. Topics of prominent current interest for advanced MS and PhD students. Can be repeated for credit with consent of instructor. (3 cr) (Sp) ®

CEE 7520. Mathematical Methods for Civil and Environmental Engineers. Applications of advanced mathematical methods to analyze civil and environmental engineering problems, including analysis of dynamical systems, solutions to nonlinear and stochastic differential equations, Fourier analysis, and neural networks. (3 cr) (Sp)

CEE 7580. Advanced Finite Element Analysis in Fluid Mechanics. Application of the finite element method of analysis to problems in fluid mechanics. Use of higher order element to two- and three-dimensional flows. Prerequisites: CEE 3510, CEE/MAE 6570; or MAE 3420, 5020. Also taught as MAE 7580. (3 cr) (Sp)

CEE 7970. Dissertation Research. Prerequisite: Instructor's consent. (1-10 cr) (F,Sp,Su) ®

CEE 7990. Continuing Graduate Advisement. Prerequisite: Instructor's consent. (1-9 cr) (F,Sp,Su) ®

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[1]Parenthetical numbers preceded by *d* indicate a *dual* listing.

® Repeatable for credit. Check with major department for limitations on number of credits that can be counted for graduation.

*Taught 2002-2003.

**Taught 2003-2004.

***This course is taught alternating years. Check with department for information about when course will be taught.