

# Department of Civil and Environmental Engineering

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## Graduate Programs

### Master of Engineering/Master of Science Programs

Programs are offered leading to the ME degree in Civil and Environmental Engineering with the following specializations:

- Master of Engineering (ME); specialization, Civil Engineering (CE)
- Master of Engineering (ME); specialization, Environmental and Water Resources Engineering (EWRE)

Also offered is a program leading to the MS degree in Environmental Science with the following specialization:

- Master of Science (MS); specialization, Environmental Technology (ET)

The master's degree programs prepare students through course work and research giving them in-depth knowledge in the various fields of civil and environmental engineering. They provide students with significant research experience, and equip graduates with the necessary tools for professional practice and/or the pursuit of higher education.

## Doctor of Philosophy Programs

Two programs are offered leading to the PhD degree in Civil and Environmental Engineering with the following specializations:

- Doctor of Philosophy (PhD); specialization, Civil Engineering  
areas of concentration:
  - Structural and Materials Engineering
  - Geotechnical Engineering
  - Transportation Systems
- Doctor of Philosophy (PhD); specialization, Environmental and Water Resources Engineering (EWRE)

## Master of Engineering (ME), Specialization: Civil Engineering (CE)

### General Information

The Department of Civil and Environmental Engineering offers two graduate programs leading to the degree of Master of Engineering (ME) - specialization, Civil Engineering (CE): CE Thesis Program and CE Non-Thesis Program. The programs prepare students through course work (and research in the case of the Thesis Program) giving them in-depth knowledge in at least one of the following fields of civil engineering: structures, transportation, and geotechnical engineering. All graduate students must satisfy either the thesis program requirements or the non-thesis program requirements. The program will be indicated on the student's transcript.

### Admission Requirements

To be eligible for admission to the civil engineering graduate program a student must hold a bachelor's degree in civil engineering or its equivalent. Engineering graduate students in majors other than civil engineering may be admitted to the program and are required to take prerequisite courses set by the department. Students must also satisfy the requirements of the University and the Faculty of Engineering and Architecture for admission to graduate study, as specified in the relevant sections of this catalogue.

Graduates of universities other than AUB may be required to take undergraduate prerequisite courses to make up for deficiencies they may have. A minimum grade of 70, or its equivalent, is required in each of these courses. No credit, toward the graduate degree, is given for these courses.

### Thesis Program Requirements

In order to fulfill graduation requirements in the Thesis Program a student must complete a minimum of 24 credit hours of graduate courses and a thesis based on independent research, equivalent to at

least six credit hours. The required course work for the ME degree with a major in civil engineering (Thesis Program) is distributed as follows:

- A minimum of four courses (12 credit hours) in the field of specialty
- A maximum of two courses (6 credit hours) in a relevant field
- A maximum of two courses (6 credit hours) of free electives

Courses in the last two categories need to be approved by the department.

All students registered in the program must take CIVE 797, Civil Engineering Seminar (0 credit), whenever offered.

A minimum of one calendar year of residence is required for graduation. The student must satisfy all relevant FEA and AUB requirements.

### Non-Thesis Program Requirements

In order to fulfill graduation requirements in the Non-Thesis Program a student must complete a minimum of 33 credit hours of graduate courses. The required course work for the ME degree with a major in civil engineering (Non-Thesis Program) is distributed as follows:

- A minimum of five courses (15 credit hours) in the field of concentration
- A maximum of three courses (9 credit hours) in a relevant field
- A maximum of three courses (9 credit hours) of free electives

Courses in the last two categories need to be approved by the department.

All students registered in the program must take CIVE 797, Civil Engineering Seminar (0 credit), whenever offered.

A minimum of one calendar year of residence is required for graduation. The student must satisfy all relevant FEA and AUB requirements.

## Master of Engineering (ME), specialization: Environmental and Water Resources Engineering (EWRE)

### General Information

The Department of Civil and Environmental Engineering offers a graduate program leading to the degree of Master of Engineering (ME): major, Environmental and Water Resources Engineering (EWRE). The program prepares students through course work and research giving them in-depth knowledge in the fields of environmental and water resources engineering.

In order to fulfill graduation requirements, a student must complete a minimum of 24 course credit hours as well as a six credit hour thesis. This may be accomplished on either a full, or a part-time basis. A minimum of one calendar year of residence is required for graduation.

The ME program in Environmental and Water Resources Engineering offers two tracks with course requirements as listed below.

Track A	Track B
Major in Environmental Engineering	Major in Water Resources Engineering
Minor in Water Resources Engineering	Minor in Environmental Engineering

## Admission Requirements

- To be eligible for admission to the environmental and water resources engineering graduate program, a student must hold a bachelor's degree in any approved discipline of engineering and must satisfy the requirements of the University and the Faculty of Engineering and Architecture for admission to graduate study, as specified in the relevant sections of this catalogue.
- All students admitted to the program are required to take, or to have taken, the following courses, or their equivalent, as prerequisites.

MATH	202	Differential Equations	3 cr.
CIVE	340	Fluid Mechanics and Laboratory	3 cr.
CIVE	350	Environmental Engineering	3 cr.
CIVE	441	Hydrology	3 cr.
CIVE	450	Water and Wastewater Treatment and Laboratory	3 cr.

- A minimum grade of 70, or its equivalent, is required in each of these courses. Students required to take undergraduate prerequisite courses to make up for deficiencies will receive no credits toward the graduate degree.
- All students registered in the program must take ENSC 690, Seminar in Environmental Sciences (0 credit), whenever it is offered.

## Course Requirements

### Track A

**Course Type**                      **Major: Environmental Engineering**  
**Minor: Water Resources Engineering**

Core	Group A1	9
Electives I	Group A2+AB	9
Electives II	Group B1+B2	6
Thesis	CIVE 799	6
<b>Total</b>		<b>30</b>

### Track B

**Course Type**                      **Major: Water Resources Engineering**  
**Minor: Environmental Engineering**

Core	Group B1	6
Electives I	Group B1+B2+AB	12
Electives II	Group A1+A2	6
Thesis	CIVE 799	6
<b>Total</b>		<b>30</b>

Other relevant graduate courses from any faculty may be taken as Electives I (up to a maximum of two courses) with the consent of the academic adviser and the approval of the chairperson.

Group A1	Core Courses in Environmental Engineering		credits
CIVE	651	Environmental Chemistry and Microbiology	3
CIVE	654	Solid Waste Management I	3
CIVE	656	Air Pollution and Control I	3
Group A2	Electives in Environmental Engineering		
CIVE	650	Methods of Environmental Sampling and Analysis	3
CIVE	652	Environmental Management and Decision Making	3
CIVE	653	Water and Sewage Works Design	3
CIVE	655	Solid Waste Management II	3
CIVE	657	Air Pollution and Control II	3
CIVE	658	Industrial/Hazardous Waste Management	3
CIVE	659	Environmental Impact Assessment	3
CIVE	750	Wastewater Reclamation and Reuse	3
CIVE	751	Air Pollution Modeling	3
CIVE	752	Environmental Case Studies and Conflict Resolution	3
CIVE	753	Processes in Water and Wastewater Treatment	3

<b>Group B1 Core Courses in Water Resources Engineering</b>			
CIVE	640	Hydraulic Structures	3
CIVE	641	Surface Water Hydrology	3
CIVE	642	Ground Water Hydrology	3
CIVE	644	Coastal Engineering	3
CIVE	646	Water Resource Systems: Planning and Management	3
CIVE	647	GIS for Water Resources and Environmental Engineering	3
<b>Group B2 Electives in Water Resources Engineering</b>			
CIVE	643	Hydraulics of Open Channels	3
CIVE	645	Transport Phenomena in Surface and Subsurface Waters	3
<b>Group AB Common Requirements/Electives in Environmental and Water Resources Engineering</b>			
CIVE	796	Special Projects	3
ENSC	690	Seminar in Environmental Sciences	0
CIVE	798	Special Topics	3
CIVE	799	MS Thesis	6
CIVE	670	Computer Methods in Civil Engineering	3
CIVE	671	Numerical Modeling	3
ENMG	623	Stochastic Models of Applications	3

## Master of Science (MS), Specialization: Environmental Technology (ET)

The Department of Civil and Environmental Engineering offers a graduate program leading to the degree of Master of Science (MS): specialization, Environmental Technology (ET). The program, which is part of the Interfaculty Graduate Environmental Sciences Program (IGESP), is open to non-engineering students who hold a degree in basic sciences.

For more details on the Environmental Technology program refer to the Interdisciplinary Research Centers and Programs section of this catalogue, under IGESP.

## Doctor of Philosophy (PhD), Specializations: Civil Engineering (CE);

## Environmental and Water Resources Engineering (EWRE)

### General Information

Through the PhD programs offered by the CEE department, graduate students are trained to address and solve current challenges in civil and environmental engineering, and to develop theory, methodology, and adequate experimental skills to investigate emerging issues in this domain. In addition, PhD students are trained to be future educators, to participate in industrial research, and to work on interdisciplinary teams. The PhD programs provide training that equips graduate students with the maturity and ability to assume academic and professional leadership roles in various fields related to civil and environmental engineering. These programs address issues and provide solutions which directly contribute to societal progress and development in this part of the world. The objectives of the PhD program are to

- cultivate expertise in specialized concentration areas of civil and environmental engineering;
- develop research skills which include the formulation and study of original ideas as well as development of theory, methodology, and experimental skills;
- promote involvement in inter-disciplinary teams and activities and develop skills pertinent to group and collaborative efforts; and
- acquire teaching expertise through offering class lectures and assisting in courses and labs.

### Admission Requirements

Applicants to the PhD program are expected to have demonstrated distinct academic ability. To be eligible for admission to the program, a candidate must:

- hold a master's degree in civil engineering or a related discipline from AUB or another recognized institution of higher learning with a minimum cumulative average of 85 over 100 or its equivalent,
- provide scores for the General Exam part of the Graduate Record Examination (GRE).
- students from non-English-speaking countries must show proficiency in the English language (refer to catalogue section on English Language Proficiency Requirements).
- submit a complete application including a statement of interest, transcripts of academic record from all institutions attended after high school, a curriculum vita, and three letters of recommendation, and
- complete an interview, either in person or by phone.

The application to the doctoral program will follow the deadlines set by the Office of Admissions at AUB. Admission decision for the PhD program is made upon the recommendations of the CEE department and the FEA Graduate Studies Committee, with the approval of the AUB Board of Graduate Studies.

## Program Requirements

### Course Requirements

The PhD program requires a minimum of 24 credit hours of course work beyond the master's degree and 24 credit hours of dissertation work. The course work consists of a minimum of 12 credits in the area of concentration within a major, six credits in a related area and six credits in an area other than the candidate's field of research, which can be taken inside or outside the department. Courses selected must be approved by the graduate student's adviser. It is expected that the student will be involved in setting a plan of course work with the help of the dissertation adviser that is consistent with the area of research.

## Candidacy Requirements

### Comprehensive Exam

All students admitted to the PhD program must successfully complete a written comprehensive examination administered by the department. The purpose of the comprehensive exam is to ascertain the student's knowledge in his/her field of specialization and related areas. The written exam will cover major topics from within the concentration area and related fields. A student must take the comprehensive exam not later than 12 months after enrollment in the PhD program. Students who do not pass the comprehensive exam may, upon the recommendation of the department, take it for a second time after an interval of at least 3 months. Failure on the second attempt will result in the student's discontinuation from the graduate program.

### Qualifying Exam

All students must successfully complete a qualifying examination, which is to be taken at least two semesters prior to the final defense of the PhD dissertation. The qualifying exam, administered by the dissertation committee is an oral exam in which the student presents his/her research proposal. This proposal should include the projected research methodology and anticipated outcomes, as well as the preliminary results. The objective of the oral exam is to determine whether the candidate's proposal and methodology are adequate for a PhD dissertation. The candidate must show positive preliminary results and considerable promise of original research. It is the responsibility of the student to inform and update the dissertation committee members about his/her research progress, especially during the period between the comprehensive and qualifying exams. Students who do not pass the qualifying exam are allowed to take it for a second time after an interval of three months. Failure on the second attempt will result in the student's discontinuation from the graduate program.

### Admission to Candidacy

Students enrolled in the program must be admitted to candidacy at least two semesters before obtaining their PhD degree. To be eligible for candidacy, students must

- pass the qualifying and comprehensive examinations, and
- complete at least 24 credits of course work with a minimum cumulative grade average of 85.

## Dissertation Requirements

In partial fulfillment of the requirements for the degree of doctor of philosophy, a student must submit a dissertation (equivalent to 24 credit hours) that is expected to make a significant and original contribution to his/her field of research. The research work is to be carried out under the supervision of a full-time faculty member from the Civil and Environmental Engineering department.

### Dissertation Committee

The dissertation work will be supervised by a committee of at least four members that includes the primary dissertation adviser, two faculty members from within the same department, and a member from outside the department. The dissertation committee will be chaired by the dissertation adviser. All committee members must hold professorial rank. One of the committee members must be from outside the research group with which the candidate is associated. Qualified experts whose work is relevant to the research topic may be selected as additional members, from within or outside of AUB. It is advisable that the dissertation committee include one member from outside AUB. The PhD dissertation committee must be approved by the department and by the AUB Board of Graduate Studies.

An external reviewer, who is an authority on the dissertation subject, will be selected by the chair of the department in consultation with the dissertation adviser to review the dissertation and judge the scholarly level of the research work. The external examiner may also attend the dissertation defense and participate in the final deliberations.

### Dissertation Defense

All PhD candidates must defend their dissertation in public. The candidate will be examined by the dissertation defense committee chaired by one of the members of the dissertation committee other than the dissertation adviser. A grade of pass or fail will be reported for the PhD dissertation. If a grade of fail is reported, the student may resubmit the dissertation and defend it after a period of at least four months.

## Residence Requirements

To satisfy the minimum residence requirements for the PhD degree, all students must register and be in residence for at least three years beyond the completion of the master's degree. The requirements for the degree of doctor of philosophy must be completed within a period of six years after joining the PhD program. Extension beyond the six-year period will require the approval of the AUB Board of Graduate Studies.

## Graduation Requirements

To earn a PhD degree in the Department of Civil and Environmental Engineering, a student must fulfill the following graduation requirements:

- Attain a minimum grade of 80 in 24 credits taken at the PhD level;

- Attain a minimum cumulative average of 85 in 24 credits of course work taken at the PhD level;
- Pass the PhD dissertation defense;
- Satisfy the minimum residence requirements;
- Present evidence of a paper submittal to a leading international journal, based on the PhD research;
- Have at least one accepted refereed conference paper, based on the PhD research
- Satisfy all pertinent AUB regulations.

## Sample Study Program

A typical program of study for a PhD student is shown below.

Year	Semester	Course	Credits	Total	Timeline
1	Fall	Major course	3		
		Major course	3		
		Minor course	3	9	Thesis Adviser Selection
	Spring	Major course	3		
		Major course	3	15	
Comprehensive Exam					
2	Fall	Minor Course	3		
		Thesis	6	24	
	Spring	Minor course	3		
		Thesis	6	33	
Thesis Proposal and Committee selection					
3	Fall	Minor course	3		
		Thesis	6	42	
	Spring	Thesis	6	48	
		Qualifying Exam			
4	Fall	Thesis	0		
	Spring	Thesis	0	48	
Thesis Defense					

## PhD in Civil Engineering (CE)

The concentration areas and specialized tracks of the PhD programs in CE and EWRE are consistent with the fields of expertise and research interests of the faculty members, and the existing teaching, research, and laboratory facilities, and relevant to local and regional needs.

The PhD program in CE will be offered in the following three areas of concentration:

## Structural and Materials Engineering

- Advanced design and behavior of concrete, steel structures, and fiber-reinforced composites
- Strengthening and rehabilitation of structural systems; and structural health monitoring
- Advanced concrete technology including plain, hot-weathered, and high-strength concrete
- Petrographic, chemical, and mechanical properties of sands and aggregates
- Seismic evaluation and assessment, and earthquake engineering design
- Numerical modeling and computer-aided structural engineering

## Geotechnical Engineering

- Land reclamation and site improvement
- Geographic Information Systems (GIS) used in decision making and expert tool applications
- Geo-environmental engineering with reference to waste disposal and site contamination
- Geotechnical earthquake engineering, geo-hazards and risk assessment

## Transportation Systems

- Intelligent Transportation Systems (ITS) - traveler information systems and behavior
- Public and urban transport planning and operations
- Transport operations management
- Transport infrastructure planning and management
- Air quality linkages and modeling

## PhD in Environmental and Water Resources Engineering (EWRE)

The PhD program in EWRE provides courses and research opportunities along the following specialized tracks:

- Water and wastewater treatment systems
- Solid and industrial waste management
- Air pollution control and air quality management
- Environmental and water resources management and planning
- Water resource optimization and conflict management

- GIS and IT applications in water resources
- Risk assessment, mass emergency and disaster, with particular emphasis on dam safety
- Hydrologic systems analysis and watershed modeling and management
- Hydraulic systems analysis

## Course Descriptions

### Structural Sequence

#### **CIVE 610      Advanced Structural Analysis      3 cr.**

A course that offers a review of matrix algebra; basic principles of structural analysis: stiffness, flexibility, and energy methods; direct stiffness method for plane and space trusses and frames; linear and non-linear problems; special problems; and computer programming. *Prerequisite: CIVE 410. Annually.*

#### **CIVE 620      Plain Concrete      3 cr.**

A course that examines portland cements; aggregates; fly ash and silica fume; admixtures for concrete; proportioning normal concrete mixtures; pumping concrete; consolidating, finishing, and curing concrete; durability; testing hardened concrete; high-strength concrete; light and heavy weight concretes; hot and cold weather concreting. *Annually.*

#### **CIVE 621      Special Topics in Concrete      3 cr.**

A course that reviews reinforced concrete design; wind load on structures; seismic design of structures; design of shear walls; brackets, corbels, and deep girders; torsion in concrete members; circular, rectangular, and elevated water tanks; spherical, conoidal, and ellipsoidal domes. *Prerequisite: CIVE 421. Annually.*

#### **CIVE 622      Prestressed Concrete      3 cr.**

A course on material characteristics, prestress losses, working strength design procedures, composite construction, ultimate flexural strength and behavior, shear design, and continuous prestressed concrete members. *Prerequisite: CIVE 421. Alternate years.*

#### **CIVE 623      Bridges      3 cr.**

A course that discusses types of bridges; influence lines; loads and their distribution on bridges; serviceability of bridges; methods of design of bridge deck, superstructure, and substructure. *Prerequisites: CIVE 410 and CIVE 421. Alternate years.*

#### **CIVE 624      Steel Design      3 cr.**

A course that examines loads on structures; philosophies of design: LRFD versus ASD; behavior, analysis, and design (according to AISC) of tension members, bolted connections, welded connections, compression members, and beams. *Prerequisite: CIVE 410. Alternate years.*

#### **CIVE 625      Strengthening and Rehabilitation of Concrete Structural Systems      3 cr.**

A course on assessment of structural deficiency using analytical and field test methods; strengthening materials; strengthening of structural members in flexure, shear, and axial load; upgrading of gravity load-designed members for earthquake load resistance. *Alternate years.*

#### **CIVE 626      Earthquake Engineering      3 cr.**

A course that examines the nature of earthquake ground motion; seismic hazard evaluation in engineering practice; response analysis of structures and effect of soil conditions on structural response and behavior under earthquake ground motion; and the design of structures under earthquake loading. *Alternate years.*

#### **CIVE 632      Reliability Based Design of Civil Systems      3 cr.**

A course that covers applications of reliability theory with regard to assessing the safety and reliability of civil systems in the presence of uncertainty; decision making and risk analysis; definition of the probability of failure; modeling uncertainty in resistance and load; limit states and limit state functions; approximate and exact methods for assessing reliability; load and resistance factor design (LRFD) in structural and geotechnical engineering; basics of design code calibration; reliability assessments of existing structures, updating reliability with load tests. *Prerequisite: Advanced standing level. Alternate years.*

#### **CIVE 710      The Finite Element Method      3 cr.**

A course on matrix algebra; energy theorems; analysis of discrete member systems; interpolation functions; numerical integration; plane stress and plane strain problems; axisymmetric problems; problems in three dimensions; plate bending. *Prerequisite: CIVE 610. Alternate years.*

#### **CIVE 711      Advanced Mechanics of Solids      3 cr.**

A course that covers theories of stress and strain; stress-strain relations, generalized Hook's law; modes of failure, failure criteria; energy principles and applications; torsion; beams on elastic foundations; introduction to the theory of plates; thin-wall and thick-wall cylinder. *Prerequisite: CIVE 310. Alternate years.*

#### **CIVE 712      Structural Dynamics      3 cr.**

A course on analysis of vibration of single degree, multi-degree, and infinite degree of freedom systems; free and forced vibration response; analysis of dynamic response by approximate methods; introduction to earthquake engineering.

#### **CIVE 720      Behavior of Reinforced Concrete Members      3 cr.**

A course on building codes; limit state design; mechanical characteristics of concrete and steel reinforcement; creep and shrinkage; flexure: moment-curvature and force-deformation relationships; columns: axial force-moment-curvature relationships; shear: mechanisms of shear resistance, and truss analogy; bond and anchorage of reinforcement. *Prerequisite: CIVE 421. Alternate years.*

#### **CIVE 722      Advanced Steel Design      3 cr.**

A course that investigates stability, column strength, beam-columns, composite steel-concrete construction, plate buckling, plate girders, torsion, and combined torsion and bending. *Prerequisite: CIVE 624.*

#### **CIVE 723      Introduction to Offshore Structures      3 cr.**

A course on types of offshore structures, components comprising fixed offshore structures, components comprising jack-ups, components comprising Floating Production Storage and Offloading Units (FPSOs), loading on offshore structures, design and analysis of fixed offshore structures, design and analysis of Mobile Jack-up structures, and design and analysis of Floating Production Storage and Offloading (FPSOs) structures. *Prerequisite: Advanced standing level. Alternate years.*

## Geotechnical Sequence

**CIVE 630 Applied Foundation Engineering 3 cr.**  
A course on braced excavations, retaining structures, deep foundations, slope stability, and computer applications. *Prerequisite: CIVE 530. Alternate years.*

**CIVE 631 Environmental Geotechnics 3 cr.**  
A course on geotechnical practice in environmental protection and restoration; methods of soil and site characterization for sifting of waste repositories and site restoration; influence of physical and chemical processes in soils on the evaluation of contaminant distribution; design of waste containment systems including landfills, slurry walls, and soil stabilization; the applicability and use of geosynthetics; and technologies for site restoration and cleanup. *Prerequisite: CIVE 431.*

**CIVE 633 Soil Behavior 3 cr.**  
A course on soil mineralogy, soil formation, and composition; influence of geological factors on properties; colloidal phenomena in soils; soil structure; analysis of conduction phenomena (hydraulic, diffusive, thermal, and electrical); compressibility, strength, and deformation properties. *Prerequisite: CIVE 431.*

**CIVE 634 Soil and Site Improvement 3 cr.**  
A course that covers compaction, admixture stabilization, foundation soil treatment, reinforced soil and composite materials, and material sites reclamation. *Alternate years.*

**CIVE 731 Earth Dams 3 cr.**  
A course that examines hydraulic dams, rolled earth dams, homogenous dams, thin core dams, filters, causes of dam failures, seepage control, and seismic stability of dams.

**CIVE 732 Geotechnical Earthquake Engineering 3 cr.**  
A course on causative mechanisms of earthquake, earthquake magnitudes, ground motion; influence of soil conditions on site response; seismic site response analysis; evaluation and modeling of dynamic soil properties; analysis of seismic soil-structure interaction; evaluation and mitigation of soil liquefaction and its consequences; seismic code provisions and practice; seismic earth pressures, seismic slope stability and deformation analysis, seismic safety of dams and embankments, seismic performance of pile foundations, and additional current topics. *Prerequisite: CIVE 431.*

## Transportation Sequence

**CIVE 660 Pavement Design 3 cr.**  
A course that examines highway and airport pavement design; flexible and rigid pavement types and wheel loads; stresses in flexible and rigid pavements; pavement behavior under moving loads; soil stabilization. *Prerequisite: CIVE 461. Alternate years.*

**CIVE 661 Urban Transportation Planning I 3 cr.**  
An introductory course on methods and models used in transportation planning with emphasis on the urban context. *Prerequisite: CIVE 461. Alternate years.*

**CIVE 662 Traffic Engineering 3 cr.**  
A course outlining traffic engineering studies; traffic control of signalized and unsignalized intersections; signal control hardware and maintenance; arterial performance and operations; and network optimization. *Prerequisite CIVE 461. Alternate years.*

**CIVE 663 Transportation Systems Analysis 3 cr.**  
A course on transportation and traffic problems in modern society. Among the topics covered are travel forecasting problems and methods; theoretical techniques for traffic flow description and management; highway, railway, and runway capacity and performance characteristics; economic considerations; and cost functions. *Alternate years.*

**CIVE 664 Design and Management of Transport Operations 3 cr.**  
A course that covers the application of quantitative techniques from operations research and probabilistic analysis to transportation problems. Applications covered include: pickup and delivery systems, emergency urban services, facility location, and network problems. *Prerequisite: STAT 230 or equivalent.*

**CIVE 665 Transportation Economics 3 cr.**  
A course that investigates the application of economic principles to the evaluation of projects and policies in the transport sector such as transport project benefits, costs and financing, and pricing in the transport sector. *Alternate years.*

**CIVE 666 Transport Operations 3 cr.**  
A course that introduces probabilistic and optimization methods for designing efficient operations in freight carrier, airline, transit, and traffic modes. Topics include crew and vehicle scheduling in freight, airline, and transit modes; vehicle routing problems in carrier systems; runway and air traffic operations; operations control in transit services; and fundamental relations and models of traffic flow. *Prerequisite CIVE 461.*

**CIVE 760 Public Transportation 3 cr.**  
A course on public transportation modes and services; single route, network, and strategic planning; tasks involved in system operations; management of public transportation; privatization issues. *Pre- or co-requisite: CIVE 661.*

**CIVE 761 Urban Transportation Planning II 3 cr.**  
A course examining advanced topics in urban transportation planning; transportation systems management techniques; travel demand analysis; and discrete choice modeling of travel demand. *Prerequisite: CIVE 661.*

**CIVE 762 Traffic Flow Theory 3 cr.**  
A course on characteristics of traffic flow, density, and speed; models describing traffic flows; hydrodynamic analogue; and computer simulation models. *Prerequisite: CIVE 461 or equivalent.*

## Environmental and Water Resources Sequence

**CIVE 640 Hydraulic Structures 3 cr.**  
A course that covers closed conduit flow, water distribution systems, transient analysis, open channel flow, flood control, culvert hydraulics, design of various hydraulic structures. *Prerequisite: CIVE 440. Alternate years.*

**CIVE 641 Surface Water Hydrology 3 cr.**  
A course on design-storm, rainfall-runoff modeling, overland flow, flood routing, reservoir routing, simulation models, hydrologic design, urban hydrology, and stochastic hydrology. *Prerequisite: CIVE 441 or equivalent. Annually.*

**CIVE 642 Groundwater Hydrology 3 cr.**  
A course that deals with properties of groundwater, groundwater movement, general flow equations, steady-state well hydraulics, seepage forces, unsteady well hydraulics, infiltration, and groundwater modeling. *Prerequisite: CIVE 441. Annually.*

**CIVE 643 Hydraulics of Open Channels 3 cr.**  
A course that examines gradually varied flow theory and analysis, spatially varied flow, and numerical modeling of unsteady flow in open-channels. *Prerequisite: CIVE 440. Alternate years.*

**CIVE 644 Coastal Engineering 3 cr.**  
A course on small-amplitude wave theory; finite-amplitude wave theory; conoidal waves; solitary wave theory; wave refraction, diffraction, and reflection; wave forces; and design of maritime structures (e.g., breakwaters). *Prerequisite: CIVE 440. Alternate years.*

**CIVE 645 Transport Phenomena in Surface and Subsurface Waters 3 cr.**  
A course on advection, diffusion, and dispersion of pollutants; transport in rivers and estuaries; transport in groundwater; numerical modeling; design of wastewater discharge system.

**CIVE 646 Water Resource Systems: Planning and Management 3 cr.**  
A course that introduces the main concepts and principles of water resource planning and management; logical steps in engineering planning and decision making; water resource systems analysis, modeling, simulation, and optimization; economic and financial analysis; flood protection and reservoir operation; and water resource management case studies. *Alternate years.*

**CIVE 647 GIS for Water Resources and Environmental Engineering 3 cr.**  
A course that introduces the concepts and principles of Geographic Information Systems (GIS) from the perspective of water resources and environmental engineering. It provides coverage of state-of-the-art GIS methods and tools, specifically targeting water resources and environmental applications including: spatial and terrain analysis, geostatistical analysis, watershed delineation and identification of river networks, representation of groundwater and aquifer systems, time series analysis, and development of GIS integrated water and environmental models. *Alternate years.*

**CIVE 650 Methods of Environmental Sampling and Analysis 3 cr.**  
A course on sampling techniques and instrumental methods in environmental sciences; determination of pollutants in water, air, and soil; analytical techniques; adaptation of procedures to specific matrices; case studies. *Alternate years.*

**CIVE 651 Environmental Chemistry and Microbiology 3 cr.**  
A course that deals with organic, inorganic, and physical chemistry; chemical equilibrium; reaction kinetics; acidity and alkalinity; composition, morphology, and classification of microorganisms; energy, metabolism, and synthesis; growth, decay, and kinetics; biological water quality indicators. *Prerequisite: CHEM 202, BIOL 210, or equivalent. Alternate years.*

**CIVE 652 Environmental Management and Decision Making 3 cr.**  
A course that deals with mathematical programming techniques, multi-objective optimization, and the generation of alternatives, as these are used in environmental systems analysis and management; as well as introducing how considerations such as economics, uncertainty, equity, and other sociopolitical parameters may influence environmental management and decision making. *Alternate years.*

**CIVE 653 Water and Sewage Works Design 3 cr.**  
A course that examines the design of water and wastewater schemes, including design reports and a literature search on the development of conventional treatment processes. *Prerequisite: CIVE 450. Alternate years.*

**CIVE 654 Solid Waste Management I 3 cr.**  
A course on the nature and effects of solid wastes including hazardous wastes; engineering management principles, practices, and techniques for management of solid wastes administration; solid waste generation, storage, collection and transport, processing, resource recovery, and disposal; and a trip to a local facility. *Annually.*

**CIVE 655 Solid Waste Management II 3 cr.**  
A course on the design of solid waste disposal schemes, including design reports and a literature search on the development of conventional treatment and disposal processes. *Prerequisite: CIVE 654 or consent of instructor. Alternate years.*

**CIVE 656 Air Pollution and Control I 3 cr.**  
An introductory course on air pollutants, sources, and effects; emission estimates, regulations, and monitoring techniques; particulate matter characterization; meteorology and atmospheric dispersion; and air pollution control processes. *Prerequisite: CHEM 202 or equivalent. Annually.*

**CIVE 657 Air Pollution and Control II 3 cr.**  
A course that examines process analysis, operational limitations, cost and performance, and evaluation of control process and equipment; case studies, field visits, and inspection of industrial installations. *Prerequisite: CIVE 656 or consent of instructor. Alternate years.*

**CIVE 658 Industrial/Hazardous Waste Management 3 cr.**  
A course that deals with sources, quantity, and quality of industrial wastes; basic industrial waste treatment processes; major industries, types of waste, and existing treatment practices; disposal and fate of industrial wastes. *Prerequisites: CIVE 450 and CIVE 651, or consent of instructor. Alternate years.*

**CIVE 659 Environmental Impact Assessment 3 cr.**  
A course that outlines theories and procedures of assessing environmental impact; analysis of the impact of development on various measures of environmental quality; and benefit-cost considerations in environmental impact assessment. *Prerequisites: CIVE 450, CIVE 654, and CIVE 656; or consent of instructor. Alternate years.*

**CIVE 750 Wastewater Reclamation and Reuse 3 cr.**  
A course that examines environmental issues in water reuse, risk assessment, water reclamation technologies, storage of reclaimed water, usage of reclaimed water, and planning of wastewater reclamation and reuse. *Prerequisites: CIVE 651 and CIVE 450, or CIVE 652. Alternate years.*

**CIVE 751 Air Pollution Modeling 3 cr.**  
A course that deals with mathematical models, air pollution meteorology, plume rise, dispersion and atmospheric chemistry, meteorological models, as well as Gaussian, statistical, and other special application models. *Prerequisite: CIVE 656 or consent of instructor.*

**CIVE 752 Environmental Case Studies and Conflict Resolution 3 cr.**  
A course on case studies in environmental management: pesticide application, air pollution, solid waste land filling, wastewater treatment facilities, oil exploration, ocean dumping, deep well injection, reservoirs, and water resources. *Prerequisites: CIVE 450, CIVE 654, and CIVE 656; or consent of instructor. Alternate years.*

**CIVE 753**                    **Processes in Water and Wastewater Treatment**                    **3 cr.**  
A course on sedimentation, filterability, permeability and fluidization, ion exchange, aeration, flotation, membrane filtration, and aerobic digestion. Experimental applications of processes.  
*Prerequisite: CIVE 450 or consent of instructor. Alternate years.*

## Common Courses

**CIVE 670**                    **Computer Methods in Civil Engineering**                    **3 cr.**  
A course on the use of the computer for analysis, design, and decision making in civil engineering, including programming, numerical, and CAD methods and applications. *Prerequisites: EECE 230 and CIVE 370. Alternate years.*

**CIVE 671**                    **Numerical Modeling**                    **3 cr.**  
A course that deals with ordinary differential equations: initial-, boundary-, and characteristic-value problems; partial differential equations: steady state, time dependent, and oscillatory problems; techniques: Runge-Kutta, shooting, iterative, finite difference, and finite element methods. *Alternate years.*

**CIVE 672**                    **Introduction to Geographic Information Systems**                    **3 cr.**  
An introductory course on Geographic Information Systems (GIS) and their applications in the planning and engineering fields, alternatives in computer-based graphics, data concepts and tools, network data management and planning applications, and implementation issues. This course can be taken as an elective for credit in all graduate engineering programs. *Annually.*

**CIVE 673**                    **Infrastructure Systems Management**                    **3 cr.**  
A course on modeling and optimization methods and their application to inspection, performance prediction and maintenance decision making for the management of infrastructure systems. *Annually.*

## Special Courses and Thesis

**CIVE 796**                    **Special Projects**                    **3 cr.**

**CIVE 797**                    **Civil Engineering Seminar**                    **0 cr.**  
A seminar that consists of current research or applied projects presented by faculty members, students, or invited speakers.

**ENSC 690**                    **Seminar in Environmental Sciences**                    **0 cr.**  
A seminar that consists of current research or applied projects presented by faculty members, students, or invited speakers.

**CIVE 798**                    **Special Topics**                    **3 cr.**

**CIVE 799**                    **Thesis**                    **6 cr.**

**CIVE 898**                    **Advanced Topics in Civil and Environmental Engineering**                    **3 cr.**

**CIVE 899**                    **PhD Dissertation**