Environmental Engineering

This section presents the requirements for programs in:

- **M.A.Sc. Environmental Engineering**
- **M.Eng. Environmental Engineering**
- **M.A.Sc. Environmental Engineering with Collaborative Specialization in Climate Change**
- **M.Eng. Environmental Engineering with Collaborative Specialization in Climate Change**
- **Ph.D. Environmental Engineering**

Program Requirements

M.A.Sc. Environmental Engineering (5.0 credits)

Study at the master's level can be pursued through a thesis leading to a M.A.Sc., a project option leading to a M.Eng., or a coursework option leading to a M. Eng. The requirements for coursework are specified in terms of credits. At Carleton University, 1.0 credit typically comprises three hours of lectures or seminars a week for two terms, or the equivalent. At the University of Ottawa, 1.0 course credit is one hour of instruction per week for one term. Thus 1.0 credit in Carleton University notation is equivalent to 6 course credits in the University of Ottawa notation. The requirements are:

Requirements - Thesis option:		
1. 2.5 credits in courses, with at least 0.5 credit from each of at least three of the areas of study listed below		2.5
2. Participation in the graduate seminar series:		0.0
ENVE 5800 [0.0]	Master's Seminar (participation in the graduate seminar series)	
3. 2.5 credits in:		2.5
ENVE 5909 [2.5]	Master's Thesis (including successful oral defence)	
Note: per Section 5.3 of the graduate regulations, no more than 1/3 of the coursework credits used towards the program requirements can be obtained from courses cross-listed with a 4000-level course or lower.		
Total Credits		**5.0**

M.Eng. Environmental Engineering (5.0 credits)

Requirements - Project option (5.0 credits)		
1. 4.0 credits in courses		4.0
2. 1.0 credit in:		1.0
ENVE 5900 [1.0]	Environmental Engineering Project	
3. Participation in the graduate student seminar series:		0.0
ENVE 5800 [0.0]	Master's Seminar	
Note: per Section 5.3 of the graduate regulations, no more than 1/3 of the coursework credits used towards the program requirements can be obtained from courses cross-listed with a 4000-level course or lower.		
Total Credits		**5.0**

Requirements - Coursework option (5.0 credits)		
1. Completion of a minimum of 5.0 credits by course		5.0
Note: per Section 5.3 of the graduate regulations, no more than 1/3 of the coursework credits used towards the program requirements can be obtained from courses cross-listed with a 4000-level course or lower.		
Total Credits		**5.0**

Breadth Requirement

In keeping with the objective of ensuring a breadth of knowledge for graduates of the program, students in the master's program are expected to take at least one graduate level course from each of at least three of the following areas of study:

- Air Pollution
- Water Resources Management, Groundwater Management and Contaminant Transport
- Management of Solid, Hazardous, and Radioactive Waste, and Pollution Prevention
- Water and Wastewater Treatment
- Environmental Impact Assessment, Sustainability and Climate Change

This requirement serves the objectives of educating graduate professionals who are not only specialized in one area but who are sufficiently familiar with problems and different approaches in the other areas to enable them to interact readily at a technical level with colleagues working in those areas. In addition to the courses associated with the individual areas, students will be encouraged to select courses from fundamental areas such as chemistry, numerical modelling, and applied statistics.

Master's candidates transferring from another university must take at least half their courses at the Institute.

M.A.Sc. Environmental Engineering with Collaborative Specialization in Climate Change (5.0 credits)

Requirements:		
1. 1.0 credit in:		1.0
CLIM 5000 [1.0]	Climate Collaboration	
2. 0.0 credit in:		
CLIM 5800 [0.0]	Climate Seminar Series	
3. 1.5 credits in courses, with at least 0.5 credit from two different areas of study listed below outside the area of EIA, Sustainability and Climate Change		1.5
4. 0.0 credit in:		
ENVE 5800 [0.0]	Master's Seminar (participation in the graduate student seminar series)	
5. 2.5 credits in:		2.5
ENVE 5909 [2.5]	Master's Thesis (in the specialization)	
Note: per Section 5.3 of the graduate regulations, no more than 1/3 of the coursework credits used towards the program requirements can be obtained from courses cross-listed with a 4000-level course or lower.		
Total Credits		**5.0**

M.Eng. Environmental Engineering with Collaborative Specialization in Climate Change (5.0 credits)

Requirements - Project pathway

1. 1.0 credit in:		1.0
CLIM 5000 [1.0]	Climate Collaboration	
2. 0.0 credit in:		
CLIM 5800 [0.0]	Climate Seminar Series	
3. 0.5 credit from:		0.5
ENVE 5105 [0.5]	Atmospheric Aerosols	
ENVE 5200 [0.5]	Climate Change and Engineering	
ENVE 5201 [0.5]	Geo-Environmental Engineering	
ENVE 5205 [0.5]	Sludge Treatment and Disposal	
ENVJ 5908 [0.5]	Anaerobic Digestion	
ENVJ 5212 [0.5]	Climate Change Impacts on Water Resources	
or approved Special Topics in the area of climate change		
4. 2.5 credits in courses, with at least 0.5 credit from two different areas of study listed below outside the area of EIA, Sustainability and Climate Change		2.5
5. 0.0 credit in:		
ENVE 5800 [0.0]	Master's Seminar	
6. 1.0 credit in:		1.0
ENVE 5900 [1.0]	Environmental Engineering Project (in the specialization)	
Note: per Section 5.3 of the graduate regulations, no more than 1/3 of the coursework credits used towards the program requirements can be obtained from courses cross-listed with a 4000-level course or lower.		
Total Credits		**5.0**

Requirements - Coursework pathway

1. 1.0 credit in:		1.0
CLIM 5000 [1.0]	Climate Collaboration	
2. 0.0 credit in:		
CLIM 5800 [0.0]	Climate Seminar Series	
3. 1.5 credits from:		1.5
ENVE 5105 [0.5]	Atmospheric Aerosols	
ENVE 5200 [0.5]	Climate Change and Engineering	
ENVE 5201 [0.5]	Geo-Environmental Engineering	
ENVE 5205 [0.5]	Sludge Treatment and Disposal	
ENVJ 5908 [0.5]	Anaerobic Digestion	
ENVJ 5212 [0.5]	Climate Change Impacts on Water Resources	
or approved Special Topics in the area of climate change		
4. 2.5 credits in courses, with at least 0.5 credit from two different areas of study listed below outside the area of EIA, Sustainability and Climate Change		2.5
Note: no more than 1.5 credits may be taken from the following: ENVE 5008, ENVE 5101, ENVE 5200, ENVE 5201, ENVE 5301		
Total Credits		**5.0**

Ph.D. Environmental Engineering (2.0 credits)

Ph.D. Environmental Engineering (1.5 credits)

1. 1.5 credits in courses		1.5
2. 0.5 credits in:		0.5
ENVE 7800 [0.5]	Ph.D. Seminar	
3. 0.0 credit in: Successful completion of the comprehensive examination, which consists of the successful defence of a PhD Thesis Proposal		
ENVE 6902 [0.0]	Ph.D. Comprehensive Examination	
4. 0.0 credits in:		0.0
ENVE 6909 [0.0]	Ph.D. Thesis (Including successful oral defence)	
Note: per Section 5.3 of the graduate regulations, no more than 1/3 of the coursework credits used towards the program requirements can be obtained from courses cross-listed with a 4000-level course or lower.		
Total Credits		**2.0**

Ph.D. candidates transferring from another university must take at least half of their courses at the Institute.

Graduate Courses

Course selection is subject to the approval of the adviser or the Advisory committee. Students may choose courses offered at either university from among those listed below.

The courses listed below are grouped by area of study. Master's students must complete at least one course in three of the five areas. The program's Associate Chair (graduate affairs), in consultation with the Institute's Director or Associate Director, will decide when a course offered outside the Institute or offered under a Special Topics or Directed Studies heading can be considered to meet the requirements of a given area. Course descriptions may be found in the departmental sections of the calendars concerned. Course codes in parentheses are for University of Ottawa (EVG, CVG and CHG), and those that begin with the prefix "ENVE" or "CIVE" are offered at Carleton. Only a selection of courses is given in a particular academic year.

Full course descriptions for courses offered at Carleton can be found in the relevant courses section of this calendar.

Air Pollution

ENVE 5101 (EVG 7101)	Air Pollution Control
ENVE 5105 (EVG 7105)	Atmospheric Aerosols
ENVE 5106 (EVG 7106)	Atmospheric Chemical Transport Modelling
ENVJ 5105 (CHG 8132)	Adsorption Separation Process

Water Resources Management, Groundwater Management, and Contaminant Transport

CIVJ 5502 (CVG 5112)	Numerical Modelling in Water Resources
CIVJ 5503 (CVG 5160)	Sediment Transport
CIVJ 5504 (CVG 5162)	River Hydraulics
CIVJ 5605 (CVG 5124)	Coastal Engineering

ENVE 5301 (EVG 7301)	Contaminant Hydrogeology
ENVE 5303 (EVG 7303)	Multiphase Flow in Soils
ENVJ 5182 (EVG 5182)	Water Resources Management
ENVJ 5183 (EVG 5183)	Mixing and Transport in Water Bodies
ENVJ 5301 (EVG 5301)	Soil and Water Conservation Engineering
ERTH 5403 (GEO 5143)	Environmental Isotopes and Groundwater Geochemistry
ERTH 5407 (GEO 5147)	Aqueous Inorganic Geochemistry and Modelling
ERTH 5503 (GEO 5153)	Computer Techniques in the Earth Sciences

Management of Solid, Hazardous, and Radioactive Waste and Pollution Prevention

CIVJ 5109 (CVG 5314)	Geotechnical Hazards
ENVE 5201 (EVG 7201)	Geo-Environmental Engineering
ENVE 5204 (EVG 7134)	Resource Industry Waste Management
ENVE 5205 (EVG 7132)	Sludge Treatment and Disposal
ENVJ 5906 (EVG 5133)	Solid Waste Management
ENVJ 5908 (EVG 5179)	Anaerobic Digestion

Water and Wastewater Treatment

ENVE 5004 (EVG 7144)	Advanced Wastewater Treatment
ENVE 5007 (EVG 7101)	Filtration and Membranes in Water Treatment
ENVE 5008	Wastewater Treatment Principles and Design
ENVJ 5001 (EVG 5001)	Biofilm Processes in Wastewater Treatment
ENVJ 5302 (EVG 5302)	Decentralized Wastewater Management
ENVJ 5502 (CHG 8192)	Membranes in Clean Processes
ENVJ 5900 (EVG 5130)	Wastewater Treatment Process Design
ENVJ 5901 (EVG 5132)	Unit Operations of Water Treatment
ENVJ 5902 (EVG 5138)	Advanced Water Treatment
ENVJ 5905 (EVG 5137)	Water and Wastewater Treatment Process Analysis
ENVJ 5907 (EVG 5134)	Chemistry for Environmental Engineering

Environmental Impact Assessment, Sustainability and Climate Change

ENVE 5200 (EVG 7200)	Climate Change and Engineering
ENVE 5206 (EVG 7206)	Energy and Resource Recovery from Waste
ENVJ 5212 (EVG 5212)	Climate Change Impacts on Water Resources
ENVJ 5700 (CVG 5139)	Environmental Assessment of Civil Engineering Projects
ENVE 5107 (EVG 7107)	Radiative Transfer and Remote Sensing
ENVE 5207 (EVG 7207)	Energy and the Critical Zone

To fulfill the requirements beyond the 1.5 credits of area courses, students may choose from the following:

Other Institute Courses

ENVJ 5333 (EVG 5333)	Research Methodology
ENVJ 5504 (CVG 8194)	Membrane Liquid Separation Processes and Materials
ENVJ 5505 (CHG 8195)	Advanced Numerical Methods in Chemical and Biological Engineering
ENVJ 5507 (CHG 8196)	Interfacial Phenomena in Engineering
GEOG 5804	Geographic Information Systems

Seminars, Directed Studies and Special Topics

ENVE 5701 (EVG 7001)	Topics in Environmental Engineering
ENVE 5702 (EVG 7002)	Topics in Environmental Engineering
ENVE 5704 (EVG 7004)	Topics in Environmental Engineering
ENVE 5703 (EVG 7003)	Topics in Environmental Engineering
ENVE 5705 (EVG 7005)	Topics in Environmental Engineering
ENVE 5800 (EVG 5800)	Master's Seminar
ENVE 5906 (EVG 6108)	Directed Studies 1
ENVE 6906 (EVG 6109)	Directed Studies 2
ENVE 7800 (EVG 5801)	Ph.D. Seminar
ENVJ 6300 (EVG 6300)	Special Topics in Environmental Engineering
ENVJ 6301 (EVG 6301)	Special Topics in Environmental Engineering
ENVJ 6302 (EVG 6302)	Special Topics in Environmental Engineering
ENVJ 6303 (EVG 6303)	Special Topics in Environmental Engineering
ENVJ 6304 (EVG 6304)	Special Topics in Environmental Engineering

Special Topics courses in Civil or Chemical Engineering will count as Institute courses only if approved by the program's Associate Chair (graduate affairs), in consultation with the Institute's Director or Associate Director.

Projects and Theses

ENVE 5900 (EVG 6001)	Environmental Engineering Project

ENVE 5909 (EVG 7999)	Master's Thesis
ENVE 6909 (EVG 9999)	Ph.D. Thesis

(EVG 9998) Comprehensive Examination

Non-Institute Courses

Students may also, subject to approval, select courses from the graduate programs in Civil, Chemical and Mechanical Engineering, as well as in Biology, Chemistry, Earth Sciences, Computer Sciences, Geography and Public Policy and Administration at both universities. Courses taken outside the Institute will not count towards the degree requirements unless approved by the adviser or the advisory committee and the program's Associate Chair (graduate affairs). In all programs, at least one half of the course work must be taken from the Institute.

Regulations

See the General Regulations section of this Calendar.

Regularly Scheduled Break

For immigration purposes, the summer term (May to August) for the M.Eng. Environmental Engineering (coursework and project pathways) is considered a regularly scheduled break approved by the University. Students should resume full-time studies in September.

Note: a Regularly Scheduled Break as described for immigration purposes does not supersede the requirement for continuous registration in Thesis, Research Essay, or Independent Research Project as described in Section 8.2 of the Graduate General Regulations.

Admission

The requirement for admission to the master's program in Environmental Engineering is a four-year bachelor's degree in Environmental Engineering, other related engineering disciplines (Civil, Chemical, Mechanical, etc.), or Environmental Science disciplines.

All students entering the program are required to have courses in mathematics, probability and statistics equivalent to courses required in undergraduate engineering programs. Students admitted without full equivalency in these areas are expected to take appropriate undergraduate courses early in their studies. These courses will be additional to the normal degree requirements.

For applicants to the M.A.Sc. program without a bachelor's degree in environmental, civil or chemical engineering, up to 3 undergraduate courses may be required in addition to the graduate program requirements. These may include a course in fluid mechanics, a course in environmental engineering fundamentals and a senior level undergraduate course in environmental engineering to be identified jointly by the supervisor, Associate Chair for Graduate Studies, and Director or Associate Director for OCIENE in the department.

For applicants to the MEng program without a bachelor's degree in environmental, civil or chemical engineering, up to 3 undergraduate courses may be specified in addition to the graduate program requirements at admission by the Director or Associate Director for OCIENE in the department. These will include a course in fluid mechanics, and course in chemical/biochemical kinetics and reactors if required.

Accelerated Pathway

The accelerated pathway in Environmental Engineering is a flexible and individualized plan of graduate study. Students in the final year of Bachelor of Engineering in Civil, Environmental, or Architectural Conservation and Sustainability Engineering with demonstrated excellent aptitude for graduate studies and research may qualify for this option.

Students with a CGPA of 10.0 or higher, going into their final year of undergraduate study, and intending to apply to a Master's degree in Environmental Engineering in the following academic year should consult with both the Undergraduate and Graduate Associate Chairs to determine if the accelerated pathway is appropriate for them and to confirm their selection of courses.

Upon approval for the accelerated pathway, students will replace a maximum of 1.0 credit of their engineering electives with 5000 level ENVE courses. Students will receive advanced standing for the approved 5000 level courses in which they receive a grade of A- or higher.

Admission

The normal requirement for admission into the Ph.D. Program in Environmental Engineering is completion of either a Master's degree in Environmental Engineering, or a Master's degree in an engineering discipline with an environmental specialization.

- Students wishing to enter the program who do not have either of these backgrounds will be evaluated on a case-by-case basis. Additional course requirements may be specified in some cases.
- Students who have been admitted to a master's program may be admitted into the Ph.D. program, without completing their master's program, if they demonstrate: (1) outstanding academic performance by completing at least 2.5 credits of course work that fulfil the breadth requirements as specified in the Master's degree requirements with a CGPA of A- or higher, and (2) significant promise for advanced research and the ability to defend their Ph.D. proposal in the first year of their Ph.D. program.

Environmental Engineering - Joint (ENVJ) Courses

ENVJ 5001 [0.5 credit] (EVG 5001)
Biofilm Processes in Wastewater Treatment

ENVJ 5105 [0.5 credit] (CHG 8132)
Adsorption Separation Process
Microporous materials and molecular sieves as adsorbents. Adsorption equilibrium and adsorption kinetics. Equilibrium adsorption of single fluids and mixtures. Diffusion in porous media and rate processes in adsorbers. Adsorber dynamics: bed profiles and breakthrough curves. Cyclic fluid separation processes. Pressure swing adsorption.

ENVJ 5182 [0.5 credit] (EVG 5182)
Water Resources Management
Global water supply and demand, integrated water resources management, modelling and optimization of water resources systems, reservoir management, uncertainty modelling, climate change and water, decision under uncertainty.
Also listed as CIVJ 5182.

ENVJ 5183 [0.5 credit] (EVG 5183)
Mixing and Transport in Water Bodies
Water resources systems models: rivers, lakes, estuaries; water quality parameters, conservative and non-conservative parameters, laminar and turbulent flows, dispersion, pollution sources; modelling: simplified, dilution, three-dimensional; advection-diffusion equation, analytical solution, numerical solution, non-conservative transport and multi-component systems.

ENVJ 5212 [0.5 credit] (EVG 5212)
Climate Change Impacts on Water Resources
Spatiotemporal distribution of water and its impact on human activities, including domestic and municipal consumption, hydropower generation, rain-fed and irrigated agriculture, design and operation of sewer systems, floodplain zoning, navigation, etc. Critical assessment of methodologies for climate change impacts estimation.
Also listed as CIVJ 5212.
Prerequisite(s): Theoretical knowledge and hands-on application experience needed to perform climate change analysis on a water resources system.

ENVJ 5301 [0.5 credit] (EVG 5301)
Soil and Water Conservation Engineering
Design, water quality and climate change impacts of soil and water conservation systems. Topics include: urban storm water management (including LID) erosion control practices, subsurface and surface drainage systems and irrigation technologies.

ENVJ 5302 [0.5 credit] (EVG 5302)
Decentralized Wastewater Management
Fundamental principles and practical design applications of decentralized wastewater treatment for domestic and industrial sources. Management of decentralized wastewater systems, pre-treatment systems, soil infiltration systems, advanced onsite technologies, constructed wetlands, alternative collection systems, wastewater reuse and septage management.
Also listed as CIVJ 5181.

ENVJ 5333 [0.5 credit] (EVG 5333)
Research Methodology
Key components and strategies required to build a robust scientific research program in environmental engineering including research questions, literature review, experiment design, data interpretation, scientific manuscripts, public speaking, ethics, and plagiarism.
Also listed as CIVJ 5333.

ENVJ 5502 [0.5 credit] (CHG 8192)
Membranes in Clean Processes
Membrane separations as clean and cleaning technologies. Reverse osmosis, ultrafiltration, vapour permeation and pervaporation to the treatment of industrial process and waste streams. Nanostructured membrane materials. Membrane fouling models, foulant-membrane material interactions, solvent resistant membranes, aqueous and non-aqueous separations.

ENVJ 5504 [0.5 credit] (CHG 8194)
Membrane Liquid Separation Processes and Materials

ENVJ 5505 [0.5 credit] (CHG 8195)
Advanced Numerical Methods in Chemical and Biological Engineering
Includes: Experiential Learning Activity

ENVJ 5507 [0.5 credit] (CHG 8196)
Interfacial Phenomena in Engineering

ENVJ 5700 [0.5 credit] (EVG 5139)
Environmental Assessment of Civil Engineering Projects
Procedures and methods for systematic evaluation of the environmental impact of civil engineering projects including wastewater disposal systems, solid waste disposal systems, and water resource development systems.

ENVJ 5900 [0.5 credit] (EVG 5130)
Wastewater Treatment Process Design
The physical, chemical and biological processes involved in the treatment of domestic and industrial wastes. Waste characteristics, stream assimilation, biological oxidation, aeration, sedimentation, anaerobic digestion, sludge disposal.

ENVJ 5901 [0.5 credit] (EVG 5132)
Unit Operations of Water Treatment
Unit operations and unit processes involved in the treatment of a water supply for various uses. Topics included are water quality, water microbiology, sedimentation, chemical treatment, disinfection, water chemistry, flocculation.

ENVJ 5902 [0.5 credit] (EVG 5138)
Advanced Water Treatment
Scope, limitations and design procedures for water treatment processes for removal of toxic and non-standard contaminants. Water treatment problems and regulations, activated carbon treatment, ion exchange, disinfection practices and oxidation via advanced oxidation processes, iron and manganese removal, recent developments in coagulation, membranes, air stripping.

ENVJ 5905 [0.5 credit] (EVG 5137)
Water and Wastewater Treatment Process Analysis
Mass balancing in complex systems. Reaction kinetics and kinetic data analysis: classical and computer based methods. Reactor design: ideal reactors and real reactors. Analysis of tracer tests. Interfacial mass transfer: common theories. Mass transfer models.

ENVJ 5906 [0.5 credit] (EVG 5133)
Solid Waste Management
Collection and disposal of solid wastes. Sanitary landfill, composting, incineration and other methods of disposal. Material and energy recovery.

ENVJ 5907 [0.5 credit] (EVG 5134)
Chemistry for Environmental Engineering
Dilute aqueous solution chemistry of water and wastewater treatment. Chemical kinetics and equilibrium. Carbonate, phosphate and chlorine chemistry. Precipitation and complex formation. Corrosion. Analytical techniques and applications.

ENVJ 5908 [0.5 credit] (EVG 5179)
Anaerobic Digestion
Design and application of anaerobic processes used for treatment of municipal and industrial wastewaters. Microbiology and biochemistry fundamentals, techniques for monitoring anaerobic digestion performance, municipal sludge stabilization, anaerobic composting, anoxic/anaerobic bioremediation, Andrew's dynamic model. Design of two-phase digestion; DSFF reactors; UASB; UBF, ASB reactors.

ENVJ 6300 [0.5 credit] (EVG 6300)
Special Topics in Environmental Engineering

ENVJ 6301 [0.5 credit] (EVG 6301)
Special Topics in Environmental Engineering

ENVJ 6302 [0.5 credit] (EVG 6302)
Special Topics in Environmental Engineering

ENVJ 6303 [0.5 credit] (EVG 6303)
Special Topics in Environmental Engineering

ENVJ 6304 [0.5 credit] (EVG 6304)
Special Topics in Environmental Engineering

ENVJ 8191 [0.5 credit] (CHG 8191)
Selected Topics in Chemical Engineering

Environmental Engineering (ENVE) Courses

ENVE 5004 [0.5 credit] (EVG 7144)
Advanced Wastewater Treatment
Fundamentals, applications, and design of biological, physical, and chemical treatment processes employed for advanced treatment of domestic and industrial wastewater. Reuse applications and guidelines.

ENVE 5007 [0.5 credit] (EVG 7101)
Filtration and Membranes in Water Treatment
Filtration is a key process for removal of contaminants from water sources. This course discusses various filtration processes including slow sand filtration, conventional filtration, biological filtration, and low and high pressure membrane applications in a lecture and seminar format. Previous water related course knowledge expected.

ENVE 5008 [0.5 credit]
Wastewater Treatment Principles and Design
Theoretical aspects of unit operations and processes for wastewater treatment with design applications. Topics include wastewater characteristics, flow rates, primary treatment, chemical unit processes, biological treatment processes, advanced wastewater treatment, disinfection, biosolids treatment and disposal. Laboratory procedures: activated sludge, anaerobic growth, chemical precipitation, disinfection.
Includes: Experiential Learning Activity
Also offered at the undergraduate level, with different requirements, as ENVE 4005, for which additional credit is precluded.

ENVE 5101 [0.5 credit] (EVG 7101)
Air Pollution Control
Air quality and pollution; definitions, measurement and monitoring methods. Criteria pollutants, air toxics, particulate matter, secondary pollutants. Pollutant formation mechanisms. Major sources and control methods. Meteorology and principles of dispersion modeling. Principles of receptor modeling. Indoor air quality.
Also offered at the undergraduate level, with different requirements, as ENVE 4003, for which additional credit is precluded.

ENVE 5105 [0.5 credit] (EVG 7105)
Atmospheric Aerosols
Atmospheric aerosol characterization and size distribution, theoretical fundamentals of physical and chemical processes that govern formation and transformation of aerosols in the atmosphere such as nucleation, coagulation, condensation/evaporation, and aerosol thermodynamics; interactions between aerosols and climate, aerosol sampling and measurement.

ENVE 5106 [0.5 credit] (EVG 7106)
Atmospheric Chemical Transport Modelling
Fundamentals of Eulerian atmospheric modelling; overview of global and regional atmospheric models, basic principles of numerical methods used in air quality models; applications of air quality models; uncertainty and sensitivity analysis in air quality modelling.

ENVE 5107 [0.5 credit] (EVG 7107)
Radiative Transfer and Remote Sensing
Exploration of interactions between light, Earth's surface, and the atmosphere. Topics include the radiative transfer equation, scattering and phase functions, and inverse theory. Applications to atmospheric science, climate, hydrology, and land use.

ENVE 5200 [0.5 credit] (EVG 7200)
Climate Change and Engineering
Survey of the physical science of climate change, impacts on the built environment, and climate adaptation in engineering. Greenhouse gases, global warming, paleoclimatology, and Earth system responses. Climate change impacts on structural, water, transportation, and energy systems. Climate vulnerability assessment, examples of design adaptation.
Also offered at the undergraduate level, with different requirements, as ENVE 4200, for which additional credit is precluded.

ENVE 5201 [0.5 credit] (EVG 7201)
Geo-Environmental Engineering
Landfill design; hydrogeologic principles, water budget, landfill liners, geosynthetics, landfill covers, quality control and quality assurance, clay/leachate interaction, composite liner design and leachate collection systems. Landfill operation, maintenance and monitoring. Design of environmental control and containment systems; slurry walls, grout curtains, Case studies.
Includes: Experiential Learning Activity
Also offered at the undergraduate level, with different requirements, as ENVE 4002, for which additional credit is precluded.

ENVE 5204 [0.5 credit] (EVG 7134)
Resource Industry Waste Management
Application of geotechnique and hydraulics to management of resource extraction residuals such as tailings, waste rock, and sludge from hard rock mines and bitumen extraction operations. Geotechnique of conventional and high density tailings disposal. Pipeline transport of concentrated suspensions. Closure technologies for mine waste impoundments.

ENVE 5205 [0.5 credit] (EVG 7132)
Sludge Treatment and Disposal
Aspects of sludge treatment, management, and disposal; sludge generation and characterization, thickening, preliminary treatment processes, aerobic and anaerobic digestion, lime stabilization, conditioning, dewatering, composting, land application and other disposal options, and thermal processes.

ENVE 5206 [0.5 credit] (EVG 7206)
Energy and Resource Recovery from Waste
Principles, design and application of biochemical and thermal processes for recovery of energy and value-added materials from different solid wastes and wastewater. Biochemical processes; biotransformation pathways, reactor analysis and chemical kinetics. Thermal treatment systems; process design, thermodynamics of material recovery.

ENVE 5207 [0.5 credit] (EVG 7207)
Energy and the Critical Zone
Survey of environmental impacts of energy development including groundwater and soil contamination and greenhouse gas emissions. Application of relevant theory (multiphase flow, mass transfer, fate and transport) to describe key environmental processes, detection, monitoring, and mitigation. Previous contaminant hydrogeology related course knowledge expected.
Includes: Experiential Learning Activity

ENVE 5301 [0.5 credit] (EVG 7301)
Contaminant Hydrogeology
Theory of flow through porous media; soil characterization, soil properties, anisotropy, heterogeneity. Contaminant transport. Well hydraulics and pump tests. Introduction to numerical modeling; finite difference, finite elements, conceptual model, boundary conditions. Site remediation and remediation technologies.
Also offered at the undergraduate level, with different requirements, as ENVE 4006, for which additional credit is precluded.

ENVE 5303 [0.5 credit] (EVG 7303)
Multiphase Flow in Soils
Theory of unsaturated flow and multiphase flow; capillary pressure-saturation relationships, relative permeability relationships, wettability, hysteresis, fluid entrapment, residual saturations, governing equations for flow and transport. Richard's Equation for unsaturated flow. Modeling of multiphase flow.

ENVE 5305 [0.5 credit]
Stormwater Management and Low Impact Development
The low impact development (LID) design approach is examined as a tool for sustainable urban planning and stormwater management. The course covers conventional (wet ponds), vegetated (green roofs, bioretention), infiltration (permeable pavements, exfiltration cells) and treatment (oil-grit separators) stormwater systems. Modelling approaches are introduced.

ENVE 5701 [0.5 credit] (EVG 7001)
Topics in Environmental Engineering
Courses in special topics in environmental engineering not covered by other graduate courses.

ENVE 5702 [0.5 credit] (EVG 7002)
Topics in Environmental Engineering
Courses in special topics in environmental engineering not covered by other graduate courses.

ENVE 5703 [0.5 credit] (EVG 7003)
Topics in Environmental Engineering
Courses in special topics in environmental engineering not covered by other graduate courses.

ENVE 5704 [0.5 credit] (EVG 7004)
Topics in Environmental Engineering
Courses in special topics in environmental engineering not covered by other graduate courses.

ENVE 5705 [0.5 credit] (EVG 7005)
Topics in Environmental Engineering
Courses in special topics in environmental engineering not covered by other graduate courses.

ENVE 5800 [0.0 credit] (EVG 5800)
Master's Seminar
M.A.Sc. and M.Eng (project option) students in the Environmental Engineering program are required to participate in these seminar series by attending all seminars and making at least one presentation during their graduate studies.
Registration in the course should be in the term that the presentation will take place.

ENVE 5900 [1.0 credit] (EVG 6001)
Environmental Engineering Project
Students enrolled in the M.Eng. program by project will conduct an engineering study, analysis, or design project under the general supervision of a member of the Department.
Includes: Experiential Learning Activity

ENVE 5906 [0.5 credit] (EVG 6108)
Directed Studies 1
Precludes additional credit for CIVE 5906.
Prerequisite(s): open only to students in an Environmental Engineering Master's program.

ENVE 5909 [2.5 credits] (EVG 7999)
Master's Thesis
Includes: Experiential Learning Activity

ENVE 6902 [0.0 credit]
Ph.D. Comprehensive Examination
Graduate students at the Doctoral level in the Environmental Engineering program are required to successfully complete a comprehensive examination which consists of a Ph.D. thesis proposal and successful defence of the proposal. Students should register in term they will defend their proposal.
Prerequisite(s): ENVE 6909 (taken concurrently).

ENVE 6906 [0.5 credit] (EVG 6109)
Directed Studies 2
Precludes additional credit for CIVE 6906.
Prerequisite(s): open only to students in the Environmental Engineering Ph.D. program.

ENVE 6909 [0.0 credit] (EVG 9999)
Ph.D. Thesis
Includes: Experiential Learning Activity

ENVE 7800 [0.5 credit] (EVG 5801)
Ph.D. Seminar
Ph.D. students in the Environmental Engineering program are required to participate in these seminar series by attending all seminars and making at least one presentation during their graduate studies.
Registration in the course should be in the term that the presentation will take place.