

**CIVIL AND  
MINERAL  
ENGINEERING**

**SELF-STUDY**

**2017**



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# EXECUTIVE SUMMARY

## Progress and Key Achievements: 2012-17

Civil engineering and mining engineering were among the first professional engineering programs offered through the Ontario School of Practical Science during the early years of formation of the University of Toronto. The present day Department of Civil Engineering has continued to serve this esteemed institution as a core member of the Faculty of Applied Science and Engineering, widely recognized as one of the top 10 engineering schools in the world.

Through our ongoing efforts to offer educational programs of the highest calibre, and to advance impactful research, we strive to make meaningful contributions towards the growth, development and elevation of our Faculty, and the University.

Over the past five years we have:

- achieved 16% growth in our faculty complement, constituting a 28.6% expansion in gender diversity
- doubled our number of NSERC Industrial Research Chairs and tripled our number of Tier 2 Canada Research Chairs
- seen an increase in our research funding pool in excess of \$3.4-million, and realized growth in our share of research overhead by nearly \$1-million
- launched the University of Toronto Transportation Research Institute (UTTRI), and strengthened our presence in Faculty-wide collaborative initiatives (such as in the Institute for Water Innovation)
- significantly improved the integration of the Civil Engineering and Lassonde Mineral Engineering undergraduate programs
- developed and successfully launched the Master of Engineering in Cities Engineering and Management (MEng CEM) program
- increased enrollment in our Master of Engineering program by 51.1%
- increased our PhD student enrollment by 14.3%
- increased our graduate student funding allocation by \$2.8-million
- completed more than \$7-million in renovations to research labs, faculty office space, and graduate student office space
- embarked on the governance process to formally change the name of the Department from the "Department of Civil Engineering" to the "Department of Civil and Mineral Engineering", to properly recognize the undergraduate programs offered by the Department, as well as to ensure and fortify inclusiveness for all members of our community.

## Academic Programs Summary

### *Undergraduate Programs*

The Department of Civil and Mineral Engineering currently offers two distinct undergraduate degree programs: the Civil Engineering Program (Civil BASc) and the Lassonde Mineral Engineering Program (LME BASc). Both programs are accredited, and rigorously reviewed on a cyclical basis by the Canadian Engineering Accreditation Board (CEAB). During our last accreditation review in 2012, the Civil Engineering program received the maximum accreditation of six years with no serious issues identified. The Lassonde Mineral Engineering program received a three-year accreditation. The Department fully addressed all outstanding concerns, and a further three-year extension was granted in June 2015. Data collection and analysis in preparation for our next review, which will take place in fall 2018, is currently underway.

There are presently 491 students registered in the Civil Engineering (BASc) program and 89 students registered in the Lassonde Mineral Engineering (LME BASc) program. We generally admit approximately 100 to 125 students into the Civil BASc program and 25 to 30 new students into the LME BASc program each year.

The academic qualification of applicants seeking admission to our undergraduate programs has been on an upward trend, with the mean high school averages of students applying to Civil BASc growing from 86.5% in 2009 to 92% in 2016. This progression has been slightly more dramatic in the case of the Lassonde Mineral Engineering Program, with applicant grade averages growing from 83.4% in 2009 to 92.2% in 2016. On the other end of this spectrum, the final year student achievement within both the Civil and Lassonde Mineral Engineering programs is consistently on par with students across the Faculty. For example, in the 2015-16 academic cycle the average final year achievement for Civil Engineering students was 75.6%, and for Lassonde Mineral Engineering students it was 74.6%. The cumulative Faculty average that year was 76.3%.

Our undergraduate curriculum complements technical training with learning opportunities, introducing fundamental engineering concepts and elements of design during the first two years, and then branching into in-depth exploration of engineering practices and specializations throughout the senior years. Courses are sequenced so that students can also take advantage of the minors and certificate programs offered by the Faculty. Practical experience is reinforced through opportunities to participate in ancillary activities such as the Professional Experience Year (PEY) Internship Program, or through mentorship opportunities that arise through external relations.

For the most part, our undergraduate students have signaled satisfaction with their academic experience and with the quality of our programs. However, through dialogues conducted in association with this quality assurance exercise we have identified a need to direct attention toward enhancing our student support resources, such as student meeting facilities and access to counselling services, especially in the area of career counselling. We also recognize that, as part of our ongoing curriculum review, it is imperative that we now place some emphasis on optimizing our course offerings. We must explore areas where we might be able to amalgamate courses in order to bring concepts closer together. Provided that we continue to meet all CEAB and Faculty academic guidelines, we will endeavor to open up room within the curriculum to allow greater opportunity for students to incorporate technical electives at an earlier stage in their program.

With respect to student experience, we are intensifying our efforts to provide opportunities for students to network and build relationships with industry partners and alumni. This includes development of a cohesive rebranding plan, establishing a series of networking events geared towards bringing students together with alumni on a more regular basis, and working with students and alumni to develop a formalized mentorship program.

## *Graduate Programs*

The Department currently offers two professional graduate programs, the Master of Engineering (MEng) in Civil Engineering and the Master of Engineering in Cities Engineering and Management (MEng CEM), and two doctoral-stream programs, the Master of Applied Science (MASc) in Civil Engineering and the Doctor of Philosophy (PhD) in Civil Engineering. Admission to all graduate programs is conducted in accordance with the guidelines set out by the School of Graduate Studies (SGS), which has established a minimum GPA requirement at a B- average in the last year of the applicant's undergraduate program. However, the majority of applicants for our doctoral-stream programs are at an A average, and MEng applicants are at the A- level, so the quality of our graduate candidates is reasonably high. Current registration in all of our graduate programs is near capacity, with 238 students undertaking doctoral-stream programs (124 PhD, 114 MASc), and 204 students registered in the professional programs (180 MEng, 24 MEng CEM).

The standard time to completion of the MEng and MEng CEM programs is 12 to 16 months. The MASc can normally be completed within 24 months, and although the target for completion of the PhD is 48 months, or 4 years, in our experience the median average for completion has been steadily increasing over the past five years, reaching an average of 5.67 years in 2016-17. While some portion of this extended time can be understood as an inherent aspect of undertaking in-depth research investigations, we are currently exploring potential internal mechanisms that may help to facilitate program progression, to bring this more in line with established parameters.

Although interest in all of our graduate programs from international applicants is very strong, until recently, the cost of admitting an international student into our doctoral-stream programs had been roughly 38% higher than that of domestic candidates. Doctoral-stream students are fully funded, and for the most part the funding is provided through their academic supervisor's research funds. As such, this cost differential presented a challenge to supervisors in terms of being able to commit to engaging international PhD students. To address this, the University of Toronto has reduced international tuition for PhD students to domestic levels. The funding requirement for supervisors is still higher for international students than domestic students, reflected in the lower funding per international student transferred to the Department from the University. We recognize that we must take aggressive action to expand our internal scholarship base to allow us to offer competitive graduate funding packages. This is identified as a major priority for the Department.

Other challenges facing us within our graduate programs portfolio include growing the number of domestic applicants to our MASc program, clarifying the structure and definition of the program specializations available through the MEng program, and accommodating the demand for our professional programs within a reality of static space and stretched human resources.

## **Faculty and Research**

The Department has a complement of 42 full-time tenure and tenure-stream academic staff. Since 2012, we have more than doubled our number of female faculty members, such that our gender diversity now rests at a ratio of 71.4% male to 28.6% female. We continue to seek to further opportunities to improve upon this.

All of our faculty have received formal recognition for their achievements over the course of their careers, with more than 50% receiving additional major awards within the past five years, and approximately 42% currently holding a named research designation.

In the QS Rankings for Civil and Structural Engineering the Department ranked first in Canada in 2014 and second in Canada from 2015 to 2017, scoring marginally behind UBC (by less than 0.5%).

Globally we currently rank 31st in these rankings. We placed fourth in Canada in the QS Rankings for Mining and Mineral Engineering in 2017, and 17th in the QS global ranking for this subject area.

Our collective research spans a wide range of specializations and a number of affiliated centres and institutes have evolved out of these diverse areas of investigation. This includes the Institute for Sustainable Energy, the Centre for Resilience of Critical Infrastructure, the Lassonde Institute of Mining, the University of Toronto Transportation Research Institute (UTTRI), the Institute for Water Innovation, and most recently, the Building Tall Research Centre.

The Department's contribution to research operating funding approximates 8-10% of the total amount of research funding secured across the Faculty per year, consistent with other FASE departments of comparable size. In 2016, Tri-Council funding (via NSERC) represented 36.7% of the Department's total research funding, institutional initiatives comprised a total of 18.5%, and 17.8% was derived from other government sources. Funding acquired from corporate sources accounted for 9.4%, and not-for-profit was on par with institutional initiatives at 17.5%. The funding base available through government sources has been steadily decreasing over the past several years, while competition for these awards has steadily increased, and as such a concerted effort to build upon our contractual research support through the corporate and non-for-profit sectors will be a focal point for the Department over the coming years.

With the Faculty's stated commitment to further innovative research in the areas of water, sustainability and AI advanced learning, all key areas of active research within the Department, we are confident that we are well positioned to continue our work on solid funding ground.

## Organization and Financial Structure

The Department has managed to keep pace with its administrative portfolio with limited organizational change and minimal growth of our administrative complement over many years, and we greatly appreciate the long-serving dedication of our staff. However, the workloads respective to each administrative area have not remained static over time, and this has placed additional pressure on our administrative team and resources. For example, the size of our graduate student population within the MEng program has grown by approximately 51.1% and the introduction of an internship component in the MEngCEM program has added an intensive element to program administration. The demand for administrative support to faculty, especially as concerns financial management of research funds, has grown exponentially with the growth in our faculty complement, as well as in the complexity involved in the administration of large-scale collaborative research initiatives.

Although we do not envision a need for any major administrative restructuring, or for creation of any new administrative positions in the short-term, we do plan to undertake an organizational review to respond to changes that will arise through planned retirements that will be coming up over the next few years.

## Resources and Infrastructure

The Department occupies approximately 12% of the total space currently allocated to the Faculty of Applied Science and Engineering (FASE). We are responsible for ensuring the ongoing maintenance, and for provision of any development costs associated with renovations and/or upgrades made to these facilities. With the assistance of several infrastructure renewal funding partnerships, such as the Dean's Strategic Fund (DSF), the Canada Foundation for Innovation (CFI) and the Federal Government Post Secondary Strategic Innovation Fund (SIF), since 2012 we have made capital

investments totaling in excess of \$7-million, bringing significant improvement and/or revitalization to our assigned facilities over the past five years.

Perhaps our greatest challenge, shared with a majority of our cognate departments within FASE, is securing additional space that will allow room for growth. We are hopeful that opportunities for growth and further renewal of our assigned facilities will arise through the reallocation of space associated with the opening of the Faculty's "Centre for Engineering Innovation and Entrepreneurship", currently under construction and scheduled for occupancy in 2018.

## External Relations

The Department of Civil and Mineral Engineering is fortunate to have strong ties, established with industry over the years, and with our graduates who have moved on to professional careers. Many long-standing, effective outreach initiatives are well in place, but as our programs and research directions have grown, the need to extend our outreach and strengthen our relationships with alumni and industry has likewise increased. We recognize that more opportunities for mentorships and work placements, as well as incentives through scholarships are needed, and that we must redouble our efforts to cultivate and expand in this area. As such, growing and maintaining excellent relations with our alumni and industry partners will remain a high priority for the Department throughout the coming years.

## The Direction Forward: 2018-2023

The change in our Department name, from the 'Department of Civil Engineering' to the 'Department of Civil and Mineral Engineering', currently progressing through the formal approval channels of University governance, offers us opportunity to embark on a rebranding process that will serve to rejuvenate and revitalize our community in many ways. This will strengthen connections among our undergraduate students, solidify our ties with a greater number of alumni, and build on our relationships with industry. This fully aligns with the path we have set for ourselves for the next five years, which also includes:

- progressing our commitment to ongoing curriculum review and embracing innovations in teaching and experiential learning to sustain and elevate our undergraduate and graduate programs
- developing initiatives to enhance our outreach and ensure success in our recruitment of top doctoral-stream students
- undertaking an organizational review and identifying areas for optimization of administrative systems in the Department, thereby providing improved support for the education and research mission of the Department
- strengthening our external relations with alumni and industry to increase opportunities that will enrich the student experience and raise our research impact through academic-industry partnerships ■

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# 1. INTRODUCTION AND CONTEXT

The Faculty of Applied Science and Engineering at the University of Toronto is consistently ranked as the #1 engineering school in Canada and is among the top 10 in the world and the Department of Civil Engineering has served as a pivotal cornerstone of this esteemed Faculty for over 130 years.

Founded in 1873 as the Ontario School of Practical Science, the initial institution was dedicated to the training of professional engineers in mining, civil engineering, mechanics and manufacturing. The Department has undergone several periods of growth and restructuring since those early years and currently offers a dynamic compendium of research and academic programs. Our mandate now spans a wide range of modern day applications in professional practice, encompassing the built environment and its infrastructure, transportation engineering and planning, structural engineering, environmental engineering, mining, and geomechanics.

A central endeavour currently underway within the Department is a proposal to change our department name from the “Department of Civil Engineering” to the “Department of Civil and Mineral Engineering”.

The foremost factor compelling this action is to reflect the two distinct undergraduate programs offered by the department: Civil Engineering and the Lassonde Mineral Engineering programs.

The current department name is misleading as there is no mention of the mineral focus, and we feel that it is vitally important to have a department name that is inclusive for all students, alumni and affiliated professors. In addition to recognizing the presence of the Lassonde Mineral Engineering program in the Department, this name change will bring consistency with the branding of the Department on social media platforms where “civmin” is used as the identifiable name (i.e., CIVMIN Connect, @civmin).

As background to this, in the 2012 University of Toronto Quality Assurance Process (UTQAP) external review of the Department of Civil Engineering, the review team recommended that a change in the name of the department to include Mineral Engineering be considered. The Department consulted with faculty members on the proposed name change at town hall meetings held in conjunction with this current UTQAP review. Subsequently, at a departmental Council meeting held in early January 2018, we received unanimous support from the attendant faculty and students to proceed with pursuing this name change. This motion was approved at the Faculty's February 27, 2018 Council meeting and is currently undergoing consideration within the various levels of University governance.

It is to be clearly signalled that this motion is ultimately subject to approval by the University's Academic Board, with confirmation by the Executive Committee of its Governing Council. However, to denote the vested involvement of all members of our community in this review process, and to ensure inclusivity for the purposes of this report, we have taken the liberty of pre-identifying the Department by our proposed new name, the Department of Civil and Mineral Engineering.

The Department defines itself through the following statement:

*The vision of the Department of Civil and Mineral Engineering at the University of Toronto is to uphold and strengthen its position as a preeminent leader in education and research in systems-based approaches to developing sustainable solutions for the global community across the spectrum from mineral engineering to urban infrastructure.*

Our strengths are rooted within our long history of service to the University and the community, the quality of our teaching, the broad scope of our research, the dedication of our faculty and staff, the diversity of our student composition, and the support of our alumni. Our location within the downtown core of one of Canada's largest urban centres provides our students with access to numerous opportunities for hands-on study, practice and mentorship, and garners our faculty with a wealth of possibilities for collaboration and research.

Our challenges are presented through the limitations inherent in on-going growth within the context of a confined space allocation and aging infrastructure, the increased competition for research funding within a reality of shrinking research funding sources, and keeping pace with the exigent adaptations required to respond to today's unstable environmental conditions and rapidly changing societal patterns.

## 1.1 Programs

The Department currently offers six distinct programs:

- Undergraduate Bachelor of Applied Science (BASc) in Civil Engineering
- Undergraduate Bachelor of Applied Science (BASc) in Lassonde Mineral Engineering
- Master of Applied Science (MASc) in Civil Engineering
- Doctor of Philosophy (PhD) in Civil Engineering
- Master of Engineering (MEng) in Civil Engineering
- Master of Engineering in Cities Engineering and Management (MEng CEM)

Each of these programs will be fully outlined and examined within the pertinent sections of this report.

Since our last review in 2012, the Department set out to build on the strengths that were identified, and to strengthen those areas that were noted as in need of greater attention. Since 2012 the Department has:

- hired nine new faculty members (seven of whom are women), increasing our faculty complement from 36 to 42 (with one retirement within this period), with three of the recent hires cross-appointed with other FASE departments
- increased the number of Tier 2 Canada Research Chairs from 1 to 4
- increased the number of NSERC Industrial Research Chairs from 2 to 4
- increased the annual research funding from \$4,317,881 in 2012 to \$7,765,386 in 2017, and annual research overhead from \$830,860 in 2012 to \$1,820,682 in 2017
- increased graduate student funding from \$4.1-million in 2011-12 to \$5.7-million in 2015-16, and \$6.9-million in 2016-17
- launched the University of Toronto Transportation Research Institute (UTTRI)
- collaborated with other FASE departments in the launch of the Institute for Water Innovation
- completed ~\$7-million of renovations to research labs, faculty office space, and graduate

student office space

- improved integration between the Civil and Lassonde Mineral Engineering programs through creation of a common undergraduate studies committee
- enhanced the visibility of the Lassonde Mineral Engineering program and the Lassonde Institute of Mining through the appointment of a new communications position dedicated to strengthening the branding
- rolled out the Master of Engineering in Cities Engineering and Management program
- increased enrollment in our Master of Engineering program by a factor of 51.1% (exclusive of enrollment in the MEng CEM program)
- increased the number of PhD students from 96 in September 2012 to 112 in September 2017 (14.3%).

As we move forward into the next cycle of growth and development, we are energized by our plans to:

- increase research funding from industry
- increase our outreach to industry in the civil and mining areas
- provide more experiential learning opportunities
- take advantage of the opportunities for new pedagogical methods possible via the Faculty's new Centre for Engineering Innovation and Entrepreneurship (CEIE)
- continue to improve our undergraduate curricula in the context of the recently defined graduate attributes
- continue to enrich our graduate course offerings, particularly in areas related to sustainability and the expertise of new faculty members
- increase enrollment of excellent domestic and international PhD students
- continue to improve branding of the Department and its programs
- increase involvement of alumni in the Department
- increase our outreach to industry in the civil and mineral engineering areas, and
- further our fundraising campaign to raise \$1.5-million dedicated toward improving the facilities at the University's Gull Lake Camp.

## 1.2 Overview of Self-Study Process

In preparing this report, opinion and input was sought from all sectors of the Civil and Mineral Engineering community: faculty, students, administrative and research staff, alumni and external partners, employing a number of methodologies for information gathering. We began in early March, 2017 by establishing a core steering committee comprised of the Department chair and associate chairs, senior administrative staff, and departmental communications personnel, with additional guidance provided by the Dean's Office. The role of the steering committee was to determine the parameters for the report and to steer the process through to completion.

The members of the steering committee were:

Brent Sleep	Department Chair
Heather McLean	Associate Chair – Research
Susan Andrews	Associate Chair – Graduate Studies
Evan Bentz	Associate Chair – Undergraduate, Civil Engineering
John Harrison	Associate Chair – Undergraduate, Lassonde Mineral Engineering
Michelle Deeton	Director, Administration and Finance
Renzo Basset	Director, Technical Services
Nelly Pietropaolo	Director, Student Services and External Relations
Keenan Dixon	Communications Coordinator, Civil Engineering
Rachel Wallace	Communications Coordinator, Lassonde Institute of Mining
Teresa Miniaci	Executive Assistant to the Department Chair

In consultation with:

Nataliya Pekar	Chair, Undergraduate Civ Club
Simonne Varela	Vice-Chair, Undergraduate Civ Club
Marko Lopac	Chair, Undergraduate Min Club
Valeria Baranova	VP-Academic, Undergraduate Min Club
Pablo Orozco	Civil Engineering Graduate Students Association

The UTQAP data provided by the Office of the Provost was distributed throughout the Department in mid-March and the Self-Study exercise was introduced and discussed at a departmental Council meeting at the end of that month. This was followed up with a series of town hall meetings with faculty, held throughout the months of June – October, 2017. The agenda for each town hall meeting was set to address specific topical areas.

Town hall meetings were also held with both the Civil and Mineral undergraduate students in the early fall, while input from graduate students and student club leaders was sought via a series of focus group meetings. Administrative staff were consulted in conjunction with their regularly scheduled group meetings. Additional opinion was gathered through a series of surveys distinctly targeted to each of our stakeholder groups, including alumni, industry partners, and research specialization consortia.

A draft report was then circulated throughout the Department in early December, and revisions stemming from the departmental feedback gathered through review of the draft were then incorporated into the report. The revised report was then submitted to the Dean's Office in December, 2017. A further revision, including the Dean's input, was circulated throughout our community for additional feedback in February 2018, and the final report was published in March 2018.

Detailed information pertaining to the programs, research activities, and structure of the Department can be found on our website at: <http://civil.engineering.utoronto.ca/> ■

# 2. FACULTY

## 2.1 Faculty Composition

The Department currently has 39 full-time tenure and tenure-stream academic staff and three cross-appointed tenure-stream faculty members, for a total complement of 42. Of these, 23 are full professors, 11 are associate professors and eight are at the assistant professor rank. Over the five-year period assessed within the context of this report this represents an increase of seven new faculty members. Of these five, or 71.4%, are female. The Department currently does not have any teaching stream faculty assigned.

Cross-appointed faculty are those who hold an appointment that is shared between two (or more) academic units, with the budgetary commitment funding the position appropriately divided among the departments involved. Generally, cross-appointments are structured as a combination of primary and secondary appointments, apportioned as 51% primary and 49% secondary. Of the three cross-appointed faculty members within our department, two hold their primary appointments in Civil and Mineral Engineering and the third holds her primary appointment in the Department of Mechanical and Industrial Engineering.

All faculty appointments are reviewed and assessed on an annual basis in conjunction with the University's "Progression through the Ranks" (PTR) promotion process, a comprehensive exercise in which academic performance is assessed on the basis of teaching, service, research, creative professional achievement and professional development activities. This annual review, conducted via the Department's PTR Committee, is integral to ensuring that our faculty continue to strive for excellence in all aspects of their professional life, and that their contributions and service to the University, Faculty and the Department surpass baseline expectations. The PTR Committee is comprised of a mix of senior and early career professors so that the early career professors can acquire insights into the PTR review process.

All faculty members appointed to the Department of Civil and Mineral Engineering hold graduate membership status with the School of Graduate Studies.

A full list of faculty members indicating their rank and primary appointment is attached in appendix (Appendix A), as is a list depicting the Department's SGS graduate membership (Appendix B). Copies of individual CVs can be viewed at <http://uoft.me/CivE2018Review>.

To ensure that our courses are current with the most up-to-date developments in professional practice, the Department generally employs three or four sessional instructors from industry each year. The contracted instructors and the assigned courses change on a regular basis according to the timeliness of the subject and the needs of the Department, and all hiring is done within the parameters of the University's guidelines governing sessional appointments.

It is also our practice to assign a few senior PhD students to teach or co-teach some of our first to third year undergraduate courses each year in order to give them full-scale teaching experience. This approach to course delivery has proven to be extremely effective, as the student instructors generally receive very high ratings in their teaching evaluations. The students are hired according to CUPE3902 (University of Toronto Education Workers) Unit 1 guidelines.

To facilitate the dynamics of our broad range of research, the Department currently has 16 adjunct faculty involved in ongoing research programs, primarily serving on graduate student supervisory committees. For details regarding our sessional and adjunct faculty members, please see the table in appendix (Appendix C).

The Department has 26 emeritus professors, some of whom generously continue to support the Department through various forms of participation, such as serving as examination chairs for departmental PhD exams and assisting with alumni outreach. Two of these professors continue to hold research grants and supervise graduate students, as well as provide mentorship to junior colleagues.

Table 2.1 shows all faculty appointed to the Department in order of seniority, along with their primary area of research. The majority of our current faculty have been hired post 2000, with the largest complement of new hires occurring between 2012 and 2017. These hires were open positions, generated in conjunction with interdisciplinary searches coordinated in the Faculty, and for special opportunities.

**Table 2.1** List of Faculty Appointed to the Department of Civil and Mineral Engineering in Order of Seniority

Faculty	Year of Appointment (in order of seniority)	Primary Research Area
Michael Collins	1969	Structural Engineering
Jeffrey Packer	1980	Structural Engineering
Eric Miller	1983	Transportation Engineering and Planning
Bryan Karney	1985	Environmental Engineering
Frank Vecchio	1985	Structural Engineering
R. Douglas Hooton	1986	Building Engineering
Shamim Sheikh	1989	Structural Engineering
Kim Pressnail	1990	Building Engineering
Brent Sleep	1990	Environmental Engineering
Murray Grabinsky	1992	Mining and Geomechanics
Robert Andrews	1993	Environmental Engineering
Brenda McCabe	1997	Building Engineering
Baher Abdulhai	1998	Transportation Engineering and Planning
Amer Shalaby	1998	Transportation Engineering and Planning
Evan Bentz	2000	Structural Engineering
Tamer El-Diraby	2000	Building Engineering
Heather L. MacLean	2000	Environmental Engineering
Susan Andrews	2001	Environmental Engineering
Constantin Christopoulos	2002	Structural Engineering
D. Paul Gauvreau	2002	Structural Engineering
Matthew Roorda	2005	Transportation Engineering and Planning
Giovanni Grasselli	2006	Mining and Geomechanics
Kaiwen Xia	2006	Mining and Geomechanics
Ronald Hofmann	2007	Environmental Engineering
Oh-Sung Kwon	2010	Structural Engineering
Daman Panesar	2008	Building Engineering
Karl Peterson	2008	Building Engineering
John Hadjigeorgiou	2009	Mining and Geomechanics
John Harrison	2010	Mining and Geomechanics
Oya Mercan	2010	Structural Engineering
Khandker Nurul Habib	2010	Transportation Engineering and Planning
Kamran Esmaeili	2012	Mining and Geomechanics
Jennifer Drake	2013	Environmental Engineering
Jeffrey Siegel	2013	Building Engineering
Elodie Passepport	2014	Environmental Engineering
Mason Ghafghazi	2015	Mining and Geomechanics
Marianne Hatzopoulou	2015	Transportation Engineering and Planning
Fae Azhari	2016	Structural Engineering
Shoshanna Saxe	2016	Environmental Engineering
Marianne Touchie	2016	Building Engineering
Lesley Warren	2016	Mining and Geomechanics
Daniel Posen	2017	Environmental Engineering

## 2.2 Awards and Recognition

We have substantive reason to take pride in the achievements of our faculty, who are consistently recognized for their innovation, academic integrity and professionalism. The Department has an Awards Committee to assess nominations for departmental awards, and a member of this committee sits on the Faculty Scholarships and Awards Committee. Table 2.2 below details the major awards and professional recognitions accorded to our faculty between 2011 and 2017.

**Table 2.2 Professional Recognitions and Awards Won by Faculty Members of the Department of Civil and Mineral Engineering during the period 2011 – 2017**

Faculty	Award	Organization	Year Awarded
Abdulhai, Baher	Inventor of the Year Award	University of Toronto	2014
	Fellow	Engineering Institute of Canada	2016
*Adams, Barry	Camille A. Dagenais Award	Canadian Society of Civil Engineering	2011
Andrews, Robert	Julian C. Smith Medal	Engineering Institute of Canada	2011
	Albert E. Berry Medal	Canadian Society of Civil Engineering	2016
	Fellow	Canadian Academy of Engineering	2017
Andrews, Susan	George Warren Fuller Award	Ontario Water Works Association	2013
Bentz, Evan	Faculty Teaching Award	University of Toronto - FASE	2012-13
	Design Award*	American Concrete Institute	2016-17
*Birkemoe, Peter	Lifetime Achievement Award	American Institute of Steel Construction	2014
Christopoulos, Constantin	Inventor of the Year Award	University of Toronto	2011
Collins, Michael	Fellow	Canadian Academy of Engineering	2009
	Fellow	Royal Society of Canada	2011
	Honourary Membership	American Concrete Institute	2012
	Doctor of Engineering	University of South Wales	2012
	Design Award*	American Concrete Institute	2016-17
*Hauer, Ezra	Outstanding Career Centennial Road Safety Award	Transportation Association of Canada	2014
Hooton, R. Douglas	Fellow	Engineering Institute of Canada	2011
	Arthur R. Anderson Medal	American Concrete Institute	2011
	V.M. Malhotra Award	International Congress on Concrete Durability	2012
	Fellow	Canadian Academy of Engineering	2013
	Research and Development Medal	Professional Engineers Ontario (PEO)/Ontario Society of Professional Engineers	2013
	Frank E. Richart Award	ASTM International	2013
	Fellow	Réunion Internationale des Laboratoires et Experts des Matériaux	2014
	Wason Medal for Meritorious Paper	American Concrete Institute	2015
	George C. Hoff Award for Concrete Technology	American Concrete Institute	2015-16
	Julian C. Smith Medal	Engineering Institute of Canada	2016
Karney, Bryan	Fellow	Institute of Concrete Technology	2016-17
	Erskine Fellowship	University of Canterbury, New Zealand	2012
	Camille A. Dagenais Award	Canadian Society of Civil Engineering	2016
	Hart Teaching Innovation Fellowship	University of Toronto	2016-17

Faculty	Award	Organization	Year Awarded
MacLean, Heather	Fellow	Engineering Institute of Canada	2016
	Albert E. Berry Medal	Canadian Society of Civil Engineering	2017
	Fellow	Canadian Academy of Engineering	2017
McCabe, Brenda	Clean50	Corporate Knights	2012
	Recognition Award	Senior Women Academic Administrators of Canada	2013
	Joan E. Foley Quality of Student Experience Award	University of Toronto	2015
Miller, Eric	Professor of the Year	Civil Engineering Undergraduate Students	2016
	Margolese National Design for Living Prize	University of British Columbia	2012
Packer, Jeffrey	Sir Casimir Gzowski Medal	Canadian Society of Civil Engineering	2011
	Shortridge Hardesty Award	American Society for Civil Engineers	2012
	Fellow	Canadian Academy of Engineering	2012
	Fellow	Canadian Society of Civil Engineering	2016
	Fellow	American Association for the Advancement of Science	2016
Passeport, Elodie	Fellow	Technology Enhanced Active Learning - University of Toronto	2016-17
Pressnail, Kim	Clean50	Corporate Knights	2012
	Fellow	Engineers Canada	2011
Sheikh, Shamim	Fellow	Canadian Academy of Engineering	2012
	Fellow	Engineering Institute of Canada	2013
	Ontario Volunteer Service Award	Professional Engineers Ontario	2017
Siegel, Jeffrey	J. Neils Thompson Centennial Teaching Fellow in Civil Engineering	University of Texas	2017
	Fellow	International Society of Indoor Air Quality & Climate	2016-17
	Fellow	American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)	2017
Sleep, Brent	Fellow	Engineering Institute of Canada	2012
	Fellow	Canadian Society of Civil Engineering	2016
	Connaught Global Challenge Award: Engineering Education for Sustainable African Cities	University of Toronto	2016-17
Touchie, Marianne	Fellow	Technology Enhanced Active Learning - University of Toronto	2016-17
	E. Whitman Wright Award	Canadian Society of Civil Engineering	2011
Vecchio, Frank	Fellow	Canadian Society of Civil Engineering	2015
	Horst Leipholz Medal	Canadian Society of Civil Engineering	2015
	Research and Development Medal	Professional Engineers Ontario (PEO)/Ontario Society of Professional Engineers	2015
	Joe W. Kelly Award	American Concrete Institute	2016
	Fellow	American Association for the Advancement of Science	2011
*Young, R. Paul	Queen Elizabeth II Diamond Jubilee Medal	Government of Canada	2013
	Fellow	Institute of Materials, Minerals and Mining	2016

Data Source: Awards & Honours Database (Office of Vice-President, Research and Innovation); Updated per departmental records.

Notes:

1. Database includes records from 2011 to 2017 (data extracted June 2017).
2. American Concrete Design Award 2016-17 awarded to Professors Evan Bentz and Michael Collins, along with graduate students Giggio Proestos and Phillip Quach, as a team.
3. \* Indicates professors who have recently retired and now hold emeritus status
4. For data regarding CRC, NSERC, and other research related awards please see Section 4: Research.

## 2.3 Diversity

We have made good progress towards our mandate goal to establish greater diversity within our faculty composition in terms of male to female ratio. Since 2012, we have more than doubled the number of female faculty members in the Department, moving from six of 36 (or 16.7%) in that year, to 12 of 42 (or 28.6%) in 2017. With the increase in numbers of women now pursuing careers within STEM based disciplines, combined with targeted succession appointments as senior faculty members retire, we expect to see even greater parity in diversity developing within the Department over the coming years.

## 2.4 Work Load

To guide us in our effort to ensure a collegial and fair distribution of work among our faculty, the Department prescribes to the terms outlined in our “Workload Policy and Procedures” document (see Appendix D), as defined within the three key components comprising academic workload: Research, Teaching and Service. The Teaching and Service elements addressed in the policy are relative to those aspects of workload that are assignable by the Department Chair, and as Research is viewed as a primarily self-directed aspect it is fully recognized as a component but not specifically detailed within the policy.

Workload assignments are reviewed on an annual basis and, where appropriate, adjustments are made in order to ensure that workload balance is maintained across-the-board. The Department Chair is responsible for ensuring that each faculty member is engaged in service in a way that allows the Department to function optimally, encouraging faculty to contribute and lead in the operation of the Department, and allowing each faculty member to thrive in all aspects of their work.

## 2.5 Professional Development

The Department has several mechanisms in place to facilitate the professional development of its faculty members. For newly appointed faculty, a senior faculty member is assigned to serve as a mentor to apprise of policies, procedures, and processes, and to assist with their general onboarding to the Department and the University. New faculty are also provided with a copy of the “Instructor’s Handbook”, a consolidated resource that provides information regarding University policies, guidelines for processes such as best practices, technology transfer and course instruction, copies of departmental policies and procedures, a listing of departmental resources, and links to institutional student support resources.

An ongoing practice within the Department is to enlist junior faculty to participate in the departmental PTR Committee, which not only helps them to develop an understanding of the processes involved with progression through the ranks, but also helps them to gain insights into the development of a strong tenure review file. It is also worth noting that all pre-tenure faculty benefit from a reduced workload in their first two years, and in the year before their tenure assessment, to facilitate the development of their tenure file.

With respect to pedagogical development, the Department retains Emeritus Professor David James to serve as a teaching mentor for all new faculty members. Additionally, all faculty are encouraged to connect with and participate in the workshops provided through the University’s Centre for Teaching Support and Innovation (CTSI), a hub for teaching and learning that provides leadership and support on all teaching-related and student engagement issues (<http://teaching.utoronto.ca/>). The University’s School of Graduate Studies also provides a number of workshops each year to help coach faculty on matters related to graduate student supervision.

To support faculty in the development of their research programs, we have changed our workload policy since our last review to allow newly hired-faculty a reduced teaching load during the first two years of their appointment, thereby providing them with time and opportunity to focus on applying for grants and establishing their research groups. Workshops on the preparation of successful grant applications are provided at both the Faculty and the institutional level, and mechanisms are in place for peer review of research proposals available to faculty within the Department.

Through mechanisms such as the FASE Dean's Strategic Fund (DSF), in which the Faculty provides financial support for new educational and research programs, our faculty are well supported and encouraged to embrace innovation and engage in interdisciplinary collaborations. This has resulted in the establishment of numerous interdisciplinary initiatives, outlined more fully within the research section of this report (see Section 4: Research).

One concern expressed by our faculty is that there is a general lack of awareness regarding the diversity of research occurring across the Department, and within the various research specializations. To address this, each year the Department sponsors a robust Distinguished Lecture Series, in which we invite top international scholars and global leaders to visit, speak to a pertinent aspect of their research, meet informally with our colleagues and students, and view our facilities and resources. Faculty members are invited to nominate speakers, and from this a program roster is determined by committee.

The annual program usually comprises a series of eight lectures, with one lecture held in each month, and normally takes place throughout the main academic session (September-April). To ensure breadth and relevancy for all of our constituents, each lecture features a speaker who represents one of our identified research themes. For example, in 2017-18 our Distinguished Lecture Series program includes the following presentations:

- Professor Emeritus Suzanne Lacasse of the Norwegian Geotech Institute, who spoke on “Risk and Reliability in Geomechanical Practices”
- Professor Tami Bond of the University of Illinois who provided a talk entitled “Systems, Surroundings, Crosstalk, and Critical Mass: Prospects for Improving Indoor Solid-fuel Burning”
- Professor Markos Papageorgiou of the Technical University of Crete, speaking on “Traffic Management for the 21<sup>st</sup> Century”
- Professor Anu Ramawami of the University of Minnesota speaking on “Urban Infrastructure Transitions for Sustainable Health Cities”
- Professor Allen Davis of the University of Maryland speaking on “Sustainable Stormwater using Bioretention: Engineering, not Black Boxes”
- Professor Jason Weiss of Oregon State University, speaking on “Behaviour of Cement and Concrete at early Ages”
- Professor Sue Harrison of the University of Cape Town, speaking on “Microbial Processes in Mine Waste Management”

In 2015 and 2016, the Department sponsored an annual “Lassonde Research Day” to provide a forum to highlight student research relative to mining and mineral engineering, and to encourage informal collegial exchange. The event comprised a student poster session and presentations by faculty, students, and alumni (e.g., Dr. Bryan Tatone, NSERC Industrial R&D Fellow with Geomechanica Inc.) and was also attended by the Lassonde Advisory Board and people invited from the mining industry.

The Department has also organized the “Lassonde Leaders in Mining/Frontiers in Mining Speaker Series” in partnership with the Rotman MBA Energy and Natural Resources Student Group. This series has featured a number of esteemed keynotes such as:

- Ammar Al-Joundi, President, Agnico Eagle Mines Ltd. (2015)
- Jennifer Maki, CEO, Vale Canada (2016)
- The Honourable Bob Rae speaking on corporate social responsibility (2016)
- Rob McEwen, Chairman and Chief Owner, McEwen Mining Inc. (2017).

In 2017, we launched the “Lassonde Pivot Point Event Series”, a colloquium for examining the mining industry and future trajectories of business models, technology and innovation. The inaugural event featured a special presentation by Pierre Lassonde and keynote speaker George Hemingway, Partner and Head of Innovation with the Stratalis Group. In April 2018, we will welcome philanthropist and accomplished entrepreneur Zita Cobb, O.C., and additional events in conjunction with this series are in the planning stages.

Commencing in May 2018, we plan to expand our events portfolio to mount a Department-wide research day that will encompass representation from all areas of research specialization.

The Department has now hired two full-time Communications personnel dedicated to promoting our collective achievements and events, furthering our external community outreach, and liaising with Engineering's Strategic Communications and Advancement offices. This vital support ensures that we will continue to develop new communication tools and generate additional innovations for special events to engage our faculty and all members of our community, which will serve to strengthen our mutual awareness and communal interaction over the coming years. ■

# 3. ACADEMIC PROGRAMS

## 3.1 Overview

Civil engineering exists at the intersection of the built and natural environments. Our engineers have historically been the professionals leading the design, construction, maintenance and eventual decommissioning of society's physical infrastructure. Although not an exhaustive representation of the branches embodied in the practice of civil engineering, civil engineers work in transportation, structures, materials, building science, water and wastewater treatment, geotechnical engineering, and water resources. There is a natural crossover between civil engineering and mineral engineering in the area of geotechnical engineering and geomechanics, and environmental management.

Although civil and mineral engineering are highly technical professions, responsible engineering today also requires that engineers understand the impact of their decisions and their constructed works on society-at-large, including issues of environmental stewardship, sustainability, and public policy. As such, the overarching objective of all programs offered through the Department of Civil and Mineral Engineering is to provide the highest calibre of education and training to future engineers, enabling them to make meaningful contributions to society and enhance the global quality of life. This is accomplished through the creation of sustainable systems, and the application of innovative and resilient best practices.

The Department currently offers the following suite of undergraduate and graduate programs:

- Undergraduate Bachelor of Applied Science (BASc) in Civil Engineering
- Undergraduate Bachelor of Applied Science (BASc) in Lassonde Mineral Engineering
- Master of Applied Science (MASc) in Civil Engineering
- Doctor of Philosophy in Civil Engineering (PhD) in Civil Engineering
- Master of Engineering (MEng) in Civil Engineering
- Master of Engineering in Cities Engineering and Management (MEng CEM)

## 3.2 Program Objectives

The stated goal of the University of Toronto is to be an internationally significant research university, with undergraduate, graduate and professional programs of excellent quality.

The shared vision of the Faculty of Applied Science and Engineering (FASE) is to be the premier engineering school in Canada and to ensure its standing among the world's best through excellence in engineering education and research, preparing the next generation of engineering leaders to address the world's most critical challenges.

The vision of the Department of Civil and Mineral Engineering at the University of Toronto is to uphold and strengthen its position as a preeminent leader in education and research in systems-based approaches to developing sustainable solutions for the global community across the spectrum from mineral engineering to urban infrastructure.

The programs offered by the Department of Civil and Mineral Engineering align with these resolute statements through our academic rigour, state of the art research facilities, commitment to high quality teaching, and proactive student engagement.

### 3.3 Undergraduate Programs

The Department of Civil and Mineral Engineering currently offers two distinct undergraduate degree programs: the Civil Engineering Program (Civil BASc) and the Lassonde Mineral Engineering Program (LME BASc). Admissions are governed by the academic ranking and targets as set out by the Faculty as a whole. The process is managed by the Faculty's Admissions Committee, for which a departmental faculty representative is appointed, assisted by our recruitment and admissions coordinator. The Registrar's office is responsible for handling the associated administrative processes on behalf of all departments. Academic admission requirements are consistent with those of our peer Canadian institutions – six final year high school credits: English (ENG4U), Calculus and Vectors (MCV4U), Chemistry (SCH4U), Physics (SPH4U) Advanced Functions (MHF4U), and one additional U or M level course. Proof of English facility is also required.

Applications to the Civil BASc have steadily increased, growing by a factor of 27.6% since 2009. However, our yield on registrations has slightly declined by 4.5%, moving from 38.4% in 2009 to 33.9% in 2016. This minimal decline is largely attributable to the institution of the Faculty's "TrackOne" option for first year enrollment, introduced in 2007-08, in which students enter a general first year and postpone decision on their chosen field of study until second year.

Table 3.1 shows the comparison of applications against offers, and resultant registration yields, over the past eight years. The current yield for the Civil BASc is consistent with the Faculty's 2016 rate, which rested at 33.7%.

**Table 3.1 Enrollment Data for the Civil Engineering Program over the Last Eight Years**

Civil Engineering	Fall 2009	Fall 2010	Fall 2011	Fall 2012	Fall 2013	Fall 2014	Fall 2015	Fall 2016
Applications	955	971	1,085	1,133	1,194	1,267	1,194	1,219
Offers	310	316	260	277	245	248	247	242
Year 1 Reg	119	110	91	105	87	97	93	82
Registered / Offered Yield	38.4%	34.8%	35.0%	37.9%	35.5%	39.1%	37.7%	33.9%

Conversely, applications to the LME BASc Program have been somewhat erratic over the years, but have nonetheless increased by 37.5% since 2009 (Table 3.2). The yield on registrations in the program spiked to a peak of 39.7% in 2013, and has since levelled off to a rate of 24.7% in 2016, still representing an increase of 3.9% over 2009 numbers. In this case, entrance scholarships available exclusively to LME BASc students have proven to be a significant draw to the program.

**Table 3.2 Enrollment Data for the Lassonde Mineral Engineering Program over the Last Eight Years**

Lassonde Mineral Engineering	Fall 2009	Fall 2010	Fall 2011	Fall 2012	Fall 2013	Fall 2014	Fall 2015	Fall 2016
Applications	72	76	94	104	185	165	148	99
Offers	48	80	102	137	78	77	102	89
Year 1 Reg	10	21	30	48	31	29	37	22
Registered / Offered Yield	20.8%	26.3%	29.4%	35.0%	39.7%	37.7%	36.3%	24.7%

After first year, FASE students have the option to transfer between the nine programs in the Faculty, which on average nets an additional 10 students into the Civil BASc.

In addition, TrackOne students choose the program they wish to join for their remaining three years. A challenge to the Department is to more effectively promote our undergraduate programs to capture a greater share of the TrackOne students. In 2014, the Faculty began to tabulate the movement of the TrackOne students. Table 3.3 shows the breakdown of transfers by department since that time. While we do see incremental growth in the number of TrackOne students choosing Civil Engineering (from 4% in 2014 to 7% in 2017) this is very low relative to the number of students available for program transfer.

**Table 3.3 Student Transfers from TrackOne (2014 – 2017)**

Program	2014	2014 (%)	2015	2015 (%)	2016	2016 (%)	2017	2017 (%)
Chemical Engineering	17	9%	15	8%	12	6%	7	4%
Civil Engineering	7	4%	16	8%	15	7%	13	7%
Computer Engineering (ECE)	32	18%	54	27%	57	26%	56	30%
Electrical Engineering (ECE)	36	20%	29	15%	37	17%	39	21%
Engineering Science	0	0%	0	0%	1	0%	0	0%
Industrial Engineering (MIE)	30	17%	29	15%	32	15%	27	15%
Mechanical Engineering (MIE)	53	29%	52	26%	60	28%	37	20%
Lassonde Mineral Engineering	2	1%	1	1%	0	0%	0	0%
Materials Science Engineering	4	2%	4	2%	4	2%	6	3%
<b>Total</b>	<b>181</b>		<b>200</b>		<b>218</b>		<b>185</b>	

Data compiled by FASE Registrar's Office, May 2017

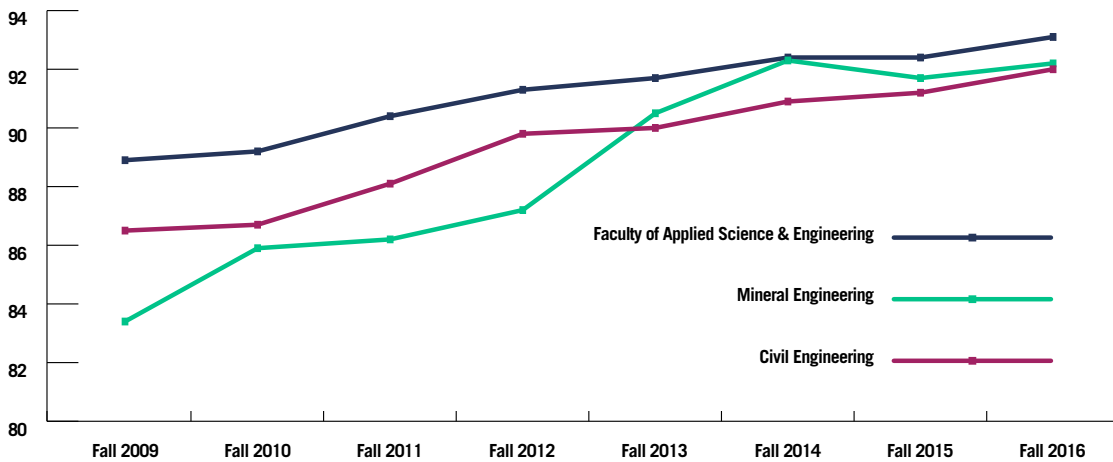
As FASE students confirm their chosen program of study following a foundation year, a more telling indicator for application to yield ratios, and student retention, are the second year enrolment numbers, as shown in Table 3.4 below. Our second year target for Civil BASc is 100-110 each year, and for LME BASc the target is 20-25 students.

**Table 3.4 Civil and Mineral Engineering Second Year Enrollments 2009-2016**

Program	2009	2010	2011	2012	2013	2014	2015	2016
Civil	129	130	148	113	137	103	125	119
LME	16	15	27	40	34	31	20	16

The academic qualification of applicants seeking admission to our undergraduate programs has continually increased over the same period, with the mean high school averages of students applying to Civil BASc growing from 86.5% in 2009 to 92% in 2016, closely on par with the current Faculty-wide average of 93.1. In the case of the Lassonde Mineral Engineering Program, this upward trend is significantly more dramatic, with grade averages growing from 83.4% in 2009 to 92.2% in 2016. Figure 3.1 demonstrates the increase in academic standing of applicants to the Civil and LME programs as compared to the Faculty as a whole.

**Figure 3.1 Department of Civil and Mineral Engineering by Program, Faculty of Applied Science and Engineering, Entering Averages**



Notes:

1. Entering averages based on annual Admissions Committee reports to Faculty Council (November).
2. Mean Entering Averages for Ontario secondary school students (only) are based on final grades in Chemistry, Calculus & Vectors, Physics, English (if required), Advanced Functions/Mathematics of Data Management/Biology/Earth & Space Science and sixth best grade 12 U/M course.
3. Students with no entering average data are excluded from the table above (e.g., international students, non-Ontario high school students, etc.).

Academic standing is never a sole determinant for offer of admission to our undergraduate programs. In fulfilling our objectives to steer future engineers towards global stewardship and to be leaders and exemplary contributors to society, factors such as extra-curricular and volunteer activities, personal interests and hobbies, and previous practical experience are equal in importance to our assessment of applicants. Additionally, for the past three years the Faculty has piloted an enhanced broad-based admissions process in which trained alumni serve as volunteer assessors to review applicant responses to targeted questions, probing cognitive and non-cognitive characteristics such as critical and logical thinking, the ability to clearly articulate thoughts and ideas, adaptability, and perseverance. This approach has proven to be an extremely effective aid to our efforts to identify applicants who purposefully seek challenges and therefore will thrive in our top-notch programs.

Internally, our undergraduate programs are academically supported by the Associate Chair-Undergraduate (Civil Engineering), the Associate Chair – Undergraduate (Lassonde Mineral Engineering), a student services team comprised of the Director of Student Services and External Relations, the Undergraduate Program Administrator/Student Counsellor, the Student Recruitment and Admissions Coordinator, and the Student Services Administrative Assistant. In addition, the LME BSc is further supported by the LME Strategic Development and Communications Coordinator, responsible for activities specifically associated with LME student engagement, extra-curricular professional development and industry relations.

While the Civil and Lassonde Mineral Engineering students share several courses over the second and third years of their programs, each program also offers a series of core courses specific to each field of study. Civil Engineering courses are identified by the code “CIV###”, Lassonde Mineral Engineering courses are identified by the code “MIN###” and shared courses are identified by the code “CME###”.

All undergraduate engineering programs at UofT are cyclically reviewed and accredited through the Canadian Engineering Accreditation Board (CEAB). These reviews provide opportunity for in-depth analysis of our courses, and serve as the impetus for curriculum revitalization. During our last accreditation review in 2012, the Civil BSc received approval for a full six-year accreditation and the Lassonde Mineral Engineering Program received a three-year accreditation with a further three-year extension granted in June 2015. Both the Civil and Mineral Engineering Programs will be undergoing their next accreditation review in the fall of 2018.

In 2012, the CEAB added a new dimension to the accreditation process through the introduction of “Graduate Attributes”, a series of learning objectives or outcomes that define the qualities and skills graduating students should possess by completion of their program. While CEAB has specified the characteristics of the graduate attributes in generic terms, responsibility for identifying the unique corresponding curricular indicators or quality measures rests with the school and department offering the program. The Civil and Mineral Engineering Department has identified the appropriate graduate attributes associated with each course through the consultative development of a curriculum map (respective to each undergraduate program offered), which connects course components to key attributes. This is detailed further within the appropriate sections of this report.

### *3.3.1 Bachelor of Applied Science (BASc) in Civil Engineering*

The undergraduate Bachelor of Applied Science (BASc) program in Civil Engineering is designed to complement traditional technical training with exposure to aspects of broad-based generalized design, including networking in a multidisciplinary team-based environment, responsible use of renewable and non-renewable resources, articulation of good engineering design, and legal and ethical aspects of professional engineering design. The fundamental strength of the BASc program in Civil Engineering is encompassed under four guiding pillars: hands on learning, professional development, focus on sustainability and comprehensive design experiences.

All undergraduate students in the Faculty of Applied Science and Engineering share a comparable foundation year and branch into a curriculum specific to their chosen field in second year. Civil Engineering students are provided with a unique experience at the commencement of their second year via our CIV201 “Introduction to Civil Engineering” course, a three-day intensive course that provides students with opportunity to gain hands-on insight into the civil engineering profession and to observe demonstrations of the application of concepts central to the practice. The course involves embarking on a series of structured thematic tours, both throughout the city and to key large-scale engineering facilities at remote sites, and culminates in an overnight stay at Gull Lake Camp in Minden, Ontario. Students record their experiences and observations in a field book, graded immediately following the course by the assigned teaching assistants. The student’s report is formally summarized through a partner communications component, CIV282 “Engineering Communications I”. This experience not only makes for a dynamic, interactive program start for our students, but also serves as a useful vehicle for students to establish meaningful bonds with their peers, setting a tone for collegiality and team spirit that carries throughout the remaining years of their undergraduate program.

The curriculum is designed to complement technical training with learning opportunities and is structured to initially introduce civil engineering concepts and elements of design, then branch into in-depth exploration of engineering practices and specializations.

Courses are deliberately sequenced so that students can take advantage of the minors offered by the Faculty in Bioengineering, Environmental Engineering or Sustainable Energy, or its established certificate programs in Preventative Engineering and Social Development, and Entrepreneurship, Innovation and Small Business. Information regarding these programs can be found on the Faculty website at: <http://discover.engineering.utoronto.ca/programs/minors-certificates/>

Practical experience is reinforced through opportunities to participate in ancillary activities such as the Professional Experience Year (PEY) Internship Program, in which students suspend their studies to take on a one-year work placement in a sponsor organization, or through mentorship opportunities that arise through external relations activities.

Another long-standing, but equally unique element of our BAsC program in Civil Engineering (and Lassonde Mineral Engineering) is CME358 “Survey CAMP (Civil and Mineral Practicals)”, in which all students in third year attend an intensive two-week field-based session at the Gull Lake Camp facility. Through this activity students gain hands-on experience in the use of the various field instruments commonly used by civil and mineral engineers, and carry out a series of exercises to reinforce their practice in conducting route, topographic and construction surveys. The Survey CAMP experience also contributes to the added-value aspects introduced in CIV201 of team-building, peer support, and collegial cooperation.

The fourth year capstone group design course is a team-based design experience integrating mathematics, basic sciences, engineering sciences, aspects of complementary studies, and detailed design aspects of the various civil engineering sub-disciplines. During the external review conducted in 2012 the reviewers put forward a recommendation to encourage a more fulsome interdisciplinary approach to assigned projects. The Department embraced this recommendation and, through a series of consultations between the course team and the Faculty’s NSERC Chair in Multidisciplinary Design, the Multidisciplinary Capstone Program (MCP) was made available as an option to students commencing in the 2013-14 academic cycle. Since then, the scope of project assignments has expanded to allow increased opportunities for multidisciplinary capstone experiences, although the majority of projects offered still do not incorporate a strong civil engineering component. As such, student participation in the MCP to date has been incremental. This has been identified as a curricular challenge for the Department and we plan to develop and lead a sampling of MPC projects, and redouble our efforts to promote participation in the MCP to our students.

The Civil Engineering Undergraduate program outline as it appears in the 2017-18 academic calendar is attached in Appendix E along with a curriculum map depicting the CEAB's key Graduate Attributes (Appendix F) inherent in each course. Complete information regarding our undergraduate Civil Engineering program is available on our departmental website at <http://civil.engineering.utoronto.ca/> and additional information can be found on the FASE website at <http://www.engineering.utoronto.ca/>.

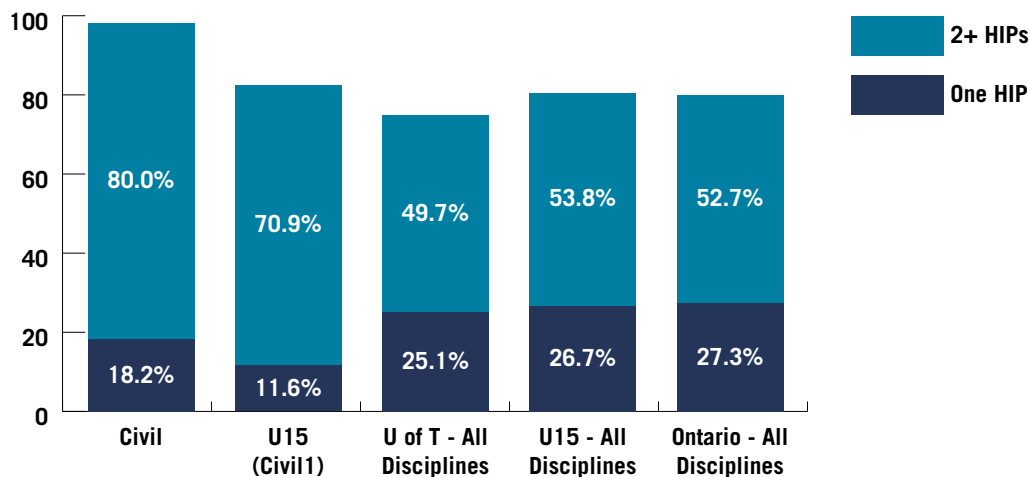
Continual examination and review of the quality and relevance of our programs and the academic experience we provide to our students is essential to ensuring that our programs remain at the top rank, and that our graduates embark on their careers fully equipped with the knowledge and skills necessary to excel in their field. These factors can be meaningfully understood through analysis of qualitative measures such as the National Survey of Student Engagement (NSSE), which examines key dimensions of student engagement and satisfaction. In the 2014 survey of U15 Engineering schools, Civil and Mineral Engineering at U of T held its position at the top rank in academic challenge, but ranked slightly below the U15 averages in the areas of “Experiences with Faculty”, and “Campus Environment”, as illustrated in Table 3.5 below.

These ratings, however, in this table do not fully correlate to the results found in other metrics summarized in the survey, such as high-impact practices (HIP), which measures activities that facilitate learning outside of the classroom, require meaningful interactions with faculty and fellow students, or encourage collaboration with others. In this respect, our undergraduate programs outpace the U15 averages, suggesting that our students perceive their program experience as dynamic, and with 74.5% indicating that, if they were to start over again, they would choose to take their Civil and Lassonde Mineral Engineering program at U of T (compared to an average of 68.5% for the U15 schools,) as illustrated in Figure 3.2.

**Table 3.5 2014 NSSE Results for the Department of Civil and Mineral Engineering, University of Toronto**

Engagement Indicator (0 to 60 scale)	NSSE	Civil	U15 (Civil1)	U of T All disciplines	U15 All disciplines	Ontario All disciplines
<b>Academic Challenge</b>						
1. Higher-Order Learning (HO)	2014	34.4	34.6	38	36.4	38.0
2. Reflective and Integrative Learning (RI)	2014	29.3	28.8	35.4	35.2	36.6
3. Learning Strategies (LS)	2014	33.7	31.1	35.7	35.1	35.2
4. Quantitative Reasoning (QS)	2014	33.5	35.6	25.5	26.7	27.0
<b>Learning with Peers</b>						
5. Collaborative Learning (CL)	2014	40.8	43.8	29.2	32.8	33.3
6. Discussions with Diverse Others (DD)	2014	43.1	41.1	42.3	40.3	41.7
<b>Experiences with Faculty</b>						
7. Student-Faculty Interaction (SF)	2014	12.3	17.0	17.5	17.2	18.9
8. Effective Teaching Practices (ET)	2014	28.1	32.2	35.3	34.9	35.8
<b>Campus Environment</b>						
9. Quality of Interactions (QI)	2014	34.0	38.6	37.2	39.0	39.6
10. Supportive Environment (SE)	2014	24.3	26.2	26.2	27.8	28.9

**Figure 3.2 Percent of Senior Year Students who Participated in High-Impact Practices**



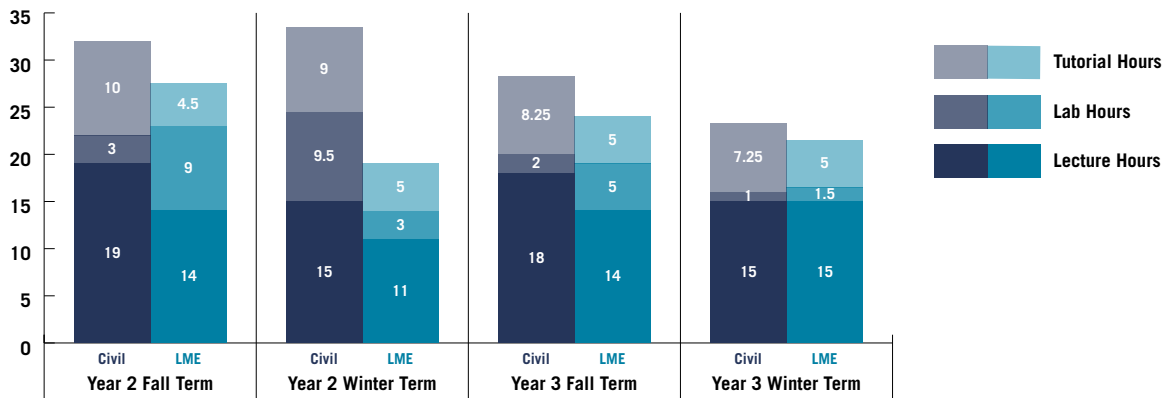
To update our reflections on the quality and meaningfulness of our programs with current student opinion, we conducted an internal survey of all students in the Civil and Lassonde Mineral Engineering programs in Years 2, 3 and 4. We also held focus groups with second and third year students, and town halls with fourth year students. The result of these dialogues confirm the NSSE data: our students are largely satisfied with their academic experience and with the quality of our programs, but that student support resources, such as student meeting facilities and access to counselling services, especially in the area of career counselling, require attention.

Another challenge that we recognize, echoed by our students, is the number of contact hours contained in the curriculum, particularly in the second and third years of Civil BAsC. From the students' perspective, they are required to balance eight courses in the fall terms of Years 2 and 3, and six engineering courses plus Complementary Studies or Humanities/Social Services electives in the winter terms of each year. The reality of this is that some of the course activities are not full-term activities, and some are conducted, or can be taken outside of the standard September-April academic session. For example, in the fall term of second year, CIV201: Introduction to Civil

Engineering, is a three-day field experience held at the start of fall term classes that counts for one half-course equivalent (0.05 FCE). Similarly, CIV282: Engineering Communications I is a companion course that accounts for 0.20 FCE, and requiring only one hour of lecture and one hour of tutorial each week (in which students primarily work on their course assignments). Students in third year count CME358: Survey CAMP (Civil and Mineral Practicals) as a term course, but this is actually a two-week field based activity, taken in August prior to the commencement of their fourth year. Students also have the option of taking some of their Complementary Studies/Humanities-Social Sciences electives in the summer terms.

Nevertheless, it is true that the Civil BAsC requires slightly more in-class time than the Lassonde Mineral Engineering Program. For example, Year 2 Civil Engineering requires a total of 19 lecture, 3 laboratory and 10 tutorial hours in the fall term, while Lassonde Mineral Engineering requires 14 lecture, 9 laboratory and 4.5 tutorial hours. In the winter term, the Year 2 Civil Engineering schedule calls for 15 lecture, 9.5 laboratory, and 9 tutorial hours, while the Lassonde Mineral Engineering Program has 11 lecture, 3 laboratory and 5 tutorial hours. In comparing Year 3 of both programs, Civil Engineering fall term contains 18 lecture, 2 laboratory and 8.25 tutorial hours, and 15 lecture, 1 laboratory and 7.25 tutorial hours in the winter term. Comparatively, Lassonde Mineral Engineering has 14 lecture, 5 laboratory and 5 tutorial hours in the Fall term, but the winter term schedule is comparable to that of Civil Engineering with 15 lecture, 1.5 laboratory and 5 hours of tutorial (See Figure 3.3).

**Figure 3.3 Comparison of Civil and Lassonde Mineral Engineering Program Class Hours**



Students also feel that, in some subjects, course content and lab content do not seem to align, and across all years of the program Civil Engineering students have difficulty perceiving the value of their lab experiences. They also challenge a perceived redundancy of some course content. In response to this, we are diligently examining the content of all of our courses in connection with our current preparations for our CEAB accreditation review in the fall of 2018. Additionally, we have begun to examine areas where we might amalgamate some courses to bring concepts more closely together, and to open up room within the curriculum to allow greater opportunity to incorporate technical electives.

The full NSSE 2014 survey results are attached in Appendix I, along with the summary reports and samples of our 2017 departmental surveys (Appendix J).

### 3.3.2 Bachelor of Applied Science (BASc) in Lassonde Mineral Engineering

Through the visionary leadership and generous philanthropy of Dr. Pierre Lassonde, the Lassonde Mineral Engineering Program (LME BASc) was initiated in 2006, replacing the Geological and Mineral Engineering Program. The LME BASc is designed to train future engineers to address the most pressing challenges facing the mining industry today, from new technologies to extract value from low-grade ores to innovations that improve the sustainability, economics and social impact of mining. The primary strength of the BASc in Lassonde Mineral Engineering is encapsulated under the following four guiding educational pillars: hands on learning, professional development, field experiences, and low student-faculty ratio.

As with all undergraduate programs offered by the Faculty, the Lassonde Mineral Engineering students share a comparable foundation year curriculum and then transfer into the LME BASc program in second year. Through 27 core technical courses offered throughout the upper years, students build on their expertise in all aspects of the mining industry, from exploration and extraction to processing, refining, upgrading and waste management. Similar to the Civil Engineering second year “Introduction to Civil Engineering” and third year “Survey CAMP” courses, the Lassonde Mineral Engineering program places a strong emphasis on experiential learning through its second year MIN225 course “Introduction to the Resource Industries”, which includes a field trip to explore an operating mine at Kirkland Lake, Ontario. In third year, students attend the Gull Lake Camp along with the Civil Engineering students for CME358, and in fourth year they participate in an in-depth nine-day field study through MIN400 “Geology Field Camp for Mineral Engineers”, which is held in the mining hub region surrounding Sudbury, Ontario. These hands-on, team-building experiences accelerate opportunities for the Lassonde Mineral Engineering students to develop friendships and strengthen bonds with their fellow students, which endure well beyond their years at university.

It is important to note that, through the generosity of Dr. Pierre Lassonde, the Lassonde Mineral Engineering Program provides the largest amount of scholarship assistance per undergraduate student of all undergraduate engineering programs in the Faculty of Applied Science and Engineering. The fourth year field camp also receives financial support provided by the Lassonde Fund.

The outline for the Lassonde Mineral Engineering Program as it appears in the 2017-18 academic calendar is attached in Appendix G and can be referenced on the departmental website at <http://civil.engineering.utoronto.ca/> or the Faculty website at <http://www.engineering.utoronto.ca/>. The curriculum map, as defined by the CEAB Graduate Attributes is also attached in Appendix H.

When the Lassonde Mineral Engineering Program was last reviewed in 2012 the reviewers observed that the program did not appear to be well-integrated into the Department, and that its students did not share an equal sense of affiliation. This sense of alienation was largely because the amalgamation of the program into the organizational structure of the Department was still in the early stages of development. Since that time, the Department has taken several steps to strengthen the program, clarify the organizational structure, and improve our relationship with the students. For example, the Department is currently undergoing the governance process to formally change its name to the “Department of Civil and Mineral Engineering” to reflect inclusion of the LME BASc. In 2013, a LME harmonization task force was struck to undertake a full review of the program and to address the external reviewer comments. To aid assessment of the fit of the LME BASc program within the Department, the academic planning committees for the Civil Engineering and the Lassonde Mineral Engineering Programs merged as the Undergraduate Studies Committee, and an Associate Chair Undergraduate – Lassonde Mineral Engineering was appointed in parallel with the Associate Chair Undergraduate – Civil Engineering. Several new faculty members were hired specifically to oversee the program, facilitate the revitalization of the curriculum, and develop a new suite of dedicated courses, such that the program is now more broadly based and integrates material from chemical, civil, materials, mechanical and computer engineering. To help students enjoy a strong sense of community and support, LME BASc class sizes are generally smaller, which provides greater opportunity for

one-on-one discourse with instructors. Further, a series of town hall meetings have been held in each ensuing academic cycle to receive continual feedback and input from students.

While the LME BASc students generally agree that significant in-roads have been made towards addressing their concerns regarding integration and program quality, the focus is now being directed to develop their relationships with industry partners and alumni. To address this, a strategic communications coordinator has been added to the Department's administrative team, with a specific mandate to provide assistance to the LME BASc program and the Lassonde Institute of Mining. This individual assists LME students, as well as the newly appointed director of the Lassonde Institute of Mining, to develop a cohesive rebranding plan, establish a series of networking events geared towards bringing students together with alumni on a more regular basis, and work with students and alumni to develop a formalized mentorship program.

### *3.3.3 Undergraduate Curriculum and Program Delivery*

Civil engineering is widely recognized as one of the first of the engineering disciplines, encompassing much of what defines modern civilization and impacting our quality of life in multiple ways. Civil engineers are concerned with the design and construction of buildings, bridges and other large-scale structures, public works, roads, railroads and public transportation systems, sanitation systems, water supply and water treatment processes, natural resource remediation, and issues of environmental stewardship. The Civil Engineering undergraduate program is designed to complement technical training with learning opportunities to address these challenges. The curriculum ensures core competency in the areas of physical chemistry, calculus, communications, and linear algebra, and introduces concepts in urban engineering, construction management, hydraulics and hydrology, water and wastewater treatment processes, steel and timber design, urban transportation, building science, and geotechnical engineering. Throughout, courses dedicated to exploration of materials, examination of environmental factors, and development of sustainable energy systems enhance student knowledge and understanding. In second year students take a course that focuses on understanding how technology functions within human life, society and the biosphere. In-depth technical elective courses offered in the fourth year of the program provide students with opportunity to focus in their selected area of specialization.

Mineral engineering encompasses those activities necessary to extract and process natural mineral resources. The Lassonde Mineral Engineering Program encompasses the entire scope of minerals engineering: geology and mineral exploration, analysis and design of surface and underground excavations, mechanical and explosive excavation of geological materials, planning and management of mines and quarries, processing of metallic and nonmetallic minerals, safety and environmental protection, and financial aspects of minerals operations. The program is truly interdisciplinary, using concepts and techniques from mathematics, physics, chemistry, geology and economics; in the setting of the University of Toronto it is thus both interdepartmental and interfaculty, with the Departments of Civil Engineering, Earth Sciences, and Materials Science & Engineering contributing to the program. As Toronto is a world centre for mining and mining finance, the program is able to maintain close links with the minerals industry, and thus invites recognized experts from various branches of the industry to deliver state-of-the-art treatment of specialized topics within the curriculum.

In the engineering profession, Civil and Mineral engineers often rely on each other for their various expertise. Civil Engineers cannot construct the underground infrastructure of a city without consulting the experts in underground space; similarly, Mineral Engineers require experts in environmental engineering, structures, transportation and a variety of other Civil disciplines to build the systems that provide us with mineral resources safely, sustainably, and economically. As a result, students in the Civil and Lassonde Mineral Engineering Programs share a number of core courses, and can

choose to specialize even more in their upper years with technical electives in both civil and mineral engineering.

Curriculum revision is an ongoing process in the Civil and Mineral Engineering department, conducted under the umbrella of the Department's Undergraduate Studies Committee (USC). An integral aspect of our approach to curriculum review is the identification of specific criteria required by the CEAB, referred to as "Graduate Attributes", which assists us in ensuring that there are strong connections between program components and learning objectives, good links between courses, and that the CIV and LME programs have an appropriate balance of required and elective elements.

The USC also has a mandate to explore and introduce new methodologies that will help increase student-faculty interaction and hands-on learning, especially within the context of delivery of our larger undergraduate courses. Several methodologies have been implemented to date. These include the inverted classroom approach, in which background material is provided in pre-recorded on-line lecture format, thus freeing up in-class time to allow faculty to more dynamically engage and interact with students (CIV235); employing the use of clickers to encourage student participation and involvement in lectures (CIV385); and, development of on-line courses (APS160).

A recent innovation in our approach to course delivery is the creation of TEAL (Technology Enabled Active Learning) classrooms for lectures and tutorials. Assisted by technology and strategic design, instructors teaching in a TEAL facility are able to combine lectures with lab work, and simulations with presentations, to provide a more active and engaged learning experience.

### 3.3.4 *Assessment of Learning*

The Province of Ontario's Quality Assurance Framework requires Ontario universities to describe degree level expectations for all undergraduate and graduate degrees as a measure of quality. The FASE's undergraduate degree level expectations (UDLEs) describe competencies, knowledge and skills expected of students graduating from our undergraduate programs (Appendix K.1). The UDLEs are regularly assessed by our Undergraduate Studies Committee.

As stated earlier, since 2012 the CEAB accreditation review has included an assessment of how well students are achieving learning outcomes, referred to as Graduate Attributes (GAs). The GAs map very closely to the FASE UDLEs, thus a successful accreditation review ensures that our programs meet the FASE UDLEs.

An outline of the generic definitions of the CEAB graduate attributes is attached in Appendix K.2. The following lists the UDLEs and corresponding CEAB graduate attributes.

**Depth and Breadth of Knowledge:** This is related to the GA "knowledge base for engineering", which requires "Demonstrated competence in university-level mathematics, natural sciences, engineering fundamentals, and specialized engineering knowledge appropriate to the program." This is assessed across the curricula of the Civil and Lassonde Mineral engineering programs.

**Knowledge of Methodologies:** This is related to the GA "problem analysis" which requires "An ability to use appropriate knowledge and skills to identify, formulate, analyze, and solve complex engineering problems in order to reach substantiated conclusions." This UDLE/GA is introduced in first year (CIV100), developed in second year (e.g. in Solid Mechanics I, Engineering Mathematics I, and Structural Analysis I) and applied in third and fourth year (e.g. in Geotechnical Engineering II, Sustainable Energy Systems, capstone Group Design Project).

**Application of Knowledge:** This is related to the GA "design" that requires "An ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, and economic, environmental, cultural and societal considerations." Design is introduced in first year, developed in third year, and applied in the fourth year capstone Group Design Project (for Civil) and Mineral Project Design I and II (for Mineral).

**Communication Skills:** This is directly related to the GAs "communication skills" and requires "An ability to communicate complex engineering concepts within the profession and with society at large. Such ability includes reading, writing, speaking and listening, and the ability to comprehend and write effective reports and design documentation, and to give and effectively respond to clear instructions." Communication skills are introduced in first year (Engineering Strategies and Practice I), developed in first and second years (Engineering Strategies and Practice I, Engineering Communications I, Civil Engineering Graphics), and applied in a number of third and fourth year courses. This includes the Civil Engineering Communication Portfolio, Survey CAMP, Engineering Economics and Decision Making, Mineral Reserve and Mineral Resource Estimation, Mineral Economics, and the capstone Group Design Project.

**Awareness of Limits of Knowledge:** This is related to the GA "lifelong learning", and requires "An ability to identify and to address their own educational needs in a changing world in ways sufficient to maintain their competence and to allow them to contribute to the advancement of knowledge." This is introduced in first year in "Engineering Strategies and Practice I and II", developed in "Introduction to Civil Engineering", and developed in third year in Survey CAMP.

**Autonomy and Professional Capacity:** This is related to several GAs, including "professionalism", "impact of engineering on society and the environment", "ethics and equity", and "economics and project management". The introduction occurs in first year in Engineering Strategies and Practice I and II and is developed in a number of second and third year courses.

**Quantitative Reasoning:** This is related to the GAs "investigation" and "problem analysis", and met by the numerous lab experiments conducted by students in courses. The investigation GA is introduced in first year in Engineering Strategies and Practice I, developed in Engineering Strategies and Practice II, Introduction to Civil Engineering, Urban Engineering Ecology, Mineral Economics, and applied in Survey Camp and Mineral Project Design I and II.

**Information Literacy:** The Faculty requires all students to develop an advanced understanding of how to obtain, manipulate and evaluate information; how to bring diverse sources together to develop a comprehensive understanding of specific issues, and how to solve problems or apply the scientific method to create further knowledge in the discipline. This is met by many aspects of the Civil and Mineral curricula, but particularly emphasized in the 400- and 500-level courses and the fourth year design projects.

Our primary method of learning assessment is through traditional grades that follow the standard University protocol. Seventy-five percent of the grades are "closely supervised" (quizzes, midterms, final exams), including a minimum of 35% for a final exam. Not closely supervised work is comprised of course assignments and project reports. Courses that introduce, develop, or apply communication skills typically will also have grades assigned for oral presentations. Final year student achievement within the Civil and Lassonde Mineral Engineering programs is also consistently on par with students across the board in the Faculty, as shown in Table 3.6. The average final year achievement for Civil Engineering students in 2015-16 was 75.6%, 74.6% for students in the Lassonde Mineral Engineering Program, and 76.3% cumulatively within the Faculty.

**Table 3.6 Department of Civil and Mineral Engineering Final Year Academic Achievement**

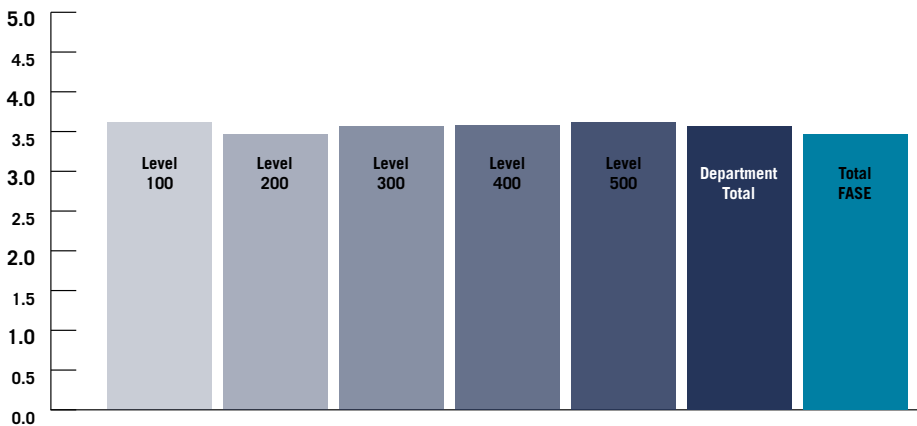
		2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16
<b>Civil Engineering</b>	<b>#</b>	87	88	104	104	111	140	135	105
	<b>Avg Grade</b>	72.9	74.4	73.7	74.0	74.5	74.4	75.5	75.6
<b>Lassonde Mineral Engineering</b>	<b>#</b>	11	16	13	21	13	17	30	28
	<b>Avg Grade</b>	72.2	69.3	72.1	72.8	73.2	74.0	75.1	74.6
<b>Faculty of Applied Science and Engineering</b>	<b>#</b>	830	922	899	961	966	937	1,020	1,050
	<b>Avg Grade</b>	75.2	74.6	74.8	75.3	75.4	75.8	76.2	76.3

Source: FASE Divisional Reporting

### 3.3.5 Student Satisfaction

Student satisfaction in their learning experience can be quantified from results arising through annual course evaluations conducted over all levels of the undergraduate program. Figure 3.4 below corresponds to the specific metric assessing student opinion regarding the quality of their overall learning experience, and demonstrates that the general view of Civil and Mineral undergraduate students across all years hovers between good and very good, consistent with the viewpoint of students across all departments of the Faculty.

**Figure 3.4 Comparison of Aggregate Undergraduate Student Satisfaction in Learning Experience, Department of Civil and Mineral Engineering against Faculty of Applied Science and Engineering**

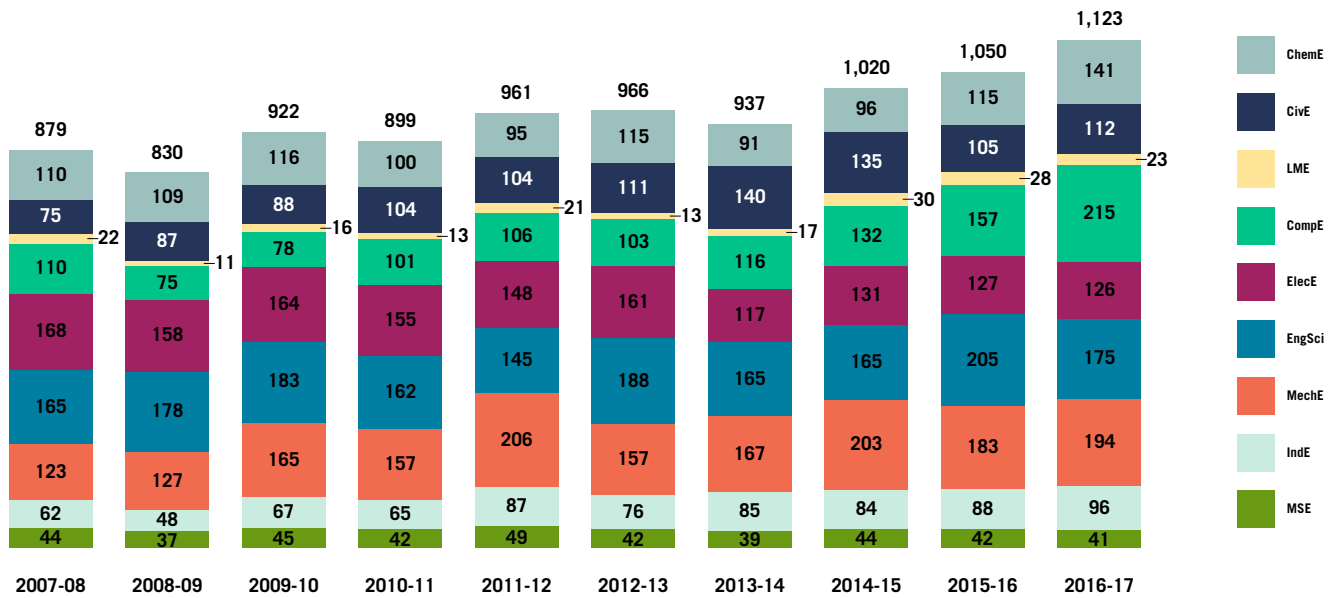


Notes:

1. Data presented is based on students' online course evaluation ratings.
2. All statistics are weighted by student.
3. Data is an aggregate of responses for all courses owned by the Department
4. This report contains data for the 2015-16 academic year (Fall 2015, Winter 2016, Summer 2016).
5. Data includes responses from both Civil and Lassonde Mineral Engineering undergraduate programs

### 3.3.6 Retention Rates and Graduation

Retention rates and graduation indicators are demonstrated through tabulation of undergraduate degrees awarded by program, as codified by the Faculty. Civil Engineering informally anticipates an average of 100-125 students entering second year in each academic cycle, while the average for Lassonde Mineral Engineering students entering second year is anticipated at 20-25 students. On this basis, Figure 3.5 shows that an equal number of students achieve successful completion in each of our undergraduate programs on a comparable basis.

**Figure 3.5 Undergraduate Degrees Awarded by Program, 2007-2008 to 2016-2017**


### 3.4 Graduate Programs

The Department offers two professional stream (MEng and MEngCEM), and two doctoral-stream (MAsc, PhD) graduate programs. Professional stream programs are largely course based, while doctoral-stream programs are more deeply involved in research and require completion of a fully developed thesis. Doctoral-stream programs are funded, and students are guided through their programs by an academic supervisor. Professional stream programs are usually self-funded, although students may apply for internal or University-wide scholarships that are available to all graduate students. Express academic supervision is generally not assigned to students in professional programs, although may be offered in conjunction with a specified research-based design project.

The research portfolio of the Department of Civil and Mineral Engineering is broadly organized under five primary thematic areas: Structural Engineering, Transportation Engineering, Environmental Engineering, Building Engineering and Construction Management, and Mining and Geomechanics. Doctoral-stream students are typically based in one of these five sections, while professional stream students may choose to participate in one of eight areas of specialization: Building Science, Concrete, Construction Management, Geomechanics, Environmental Engineering, Sustainable Urban Systems, Structural Engineering, Transportation Engineering and Planning<sup>1</sup>, the program emphasis in Advanced Water Technologies, or in the MEngCEM program.

#### 3.4.1 Graduate Programs Applications and Admissions

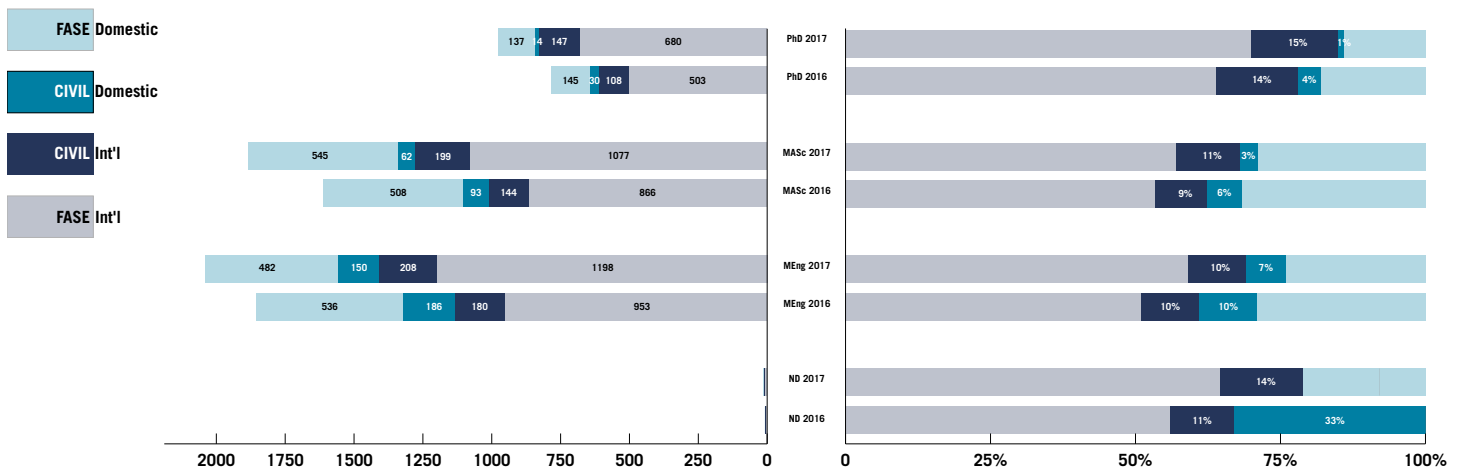
Admission to all graduate programs is managed within the Department, and is conducted in accordance with the guidelines set out by the School of Graduate Studies (SGS). The SGS minimum GPA requirement is set at a B- average in the last year of the applicant's undergraduate program. However, the quality of applicants compared to available spaces within a given graduate program generally exceed this minimum, with the majority of graduate applicants for doctoral-stream programs

<sup>1</sup> The Department is currently working toward reclassifying the eight areas of specialization available to the Master of Engineering students to program emphases, similar in structure to the program emphasis in Advanced Water Technologies.

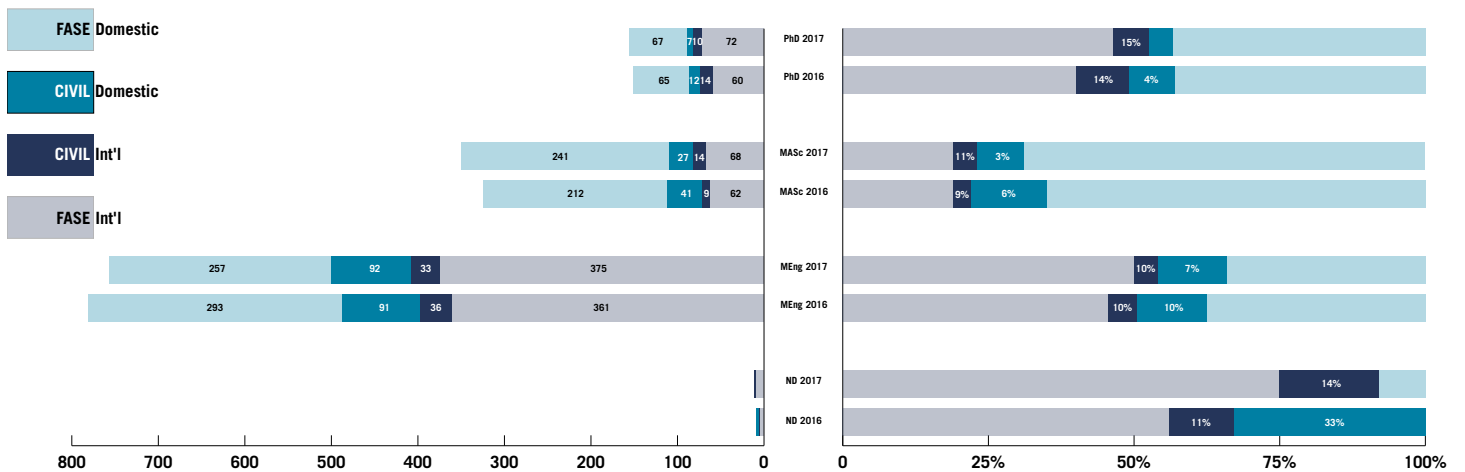
coming in with an A average, and generally at an A- average for MEng students. As such, an offer of admission is predicated on a highly competitive applicant assessment, with differing parameters set according to the type of program. For example, assessment of applicants to the MEng programs may be more dependent on GPA as a primary measure, while applications to the MASc and PhD programs involve a broader assessment of the applicant's academic standing and prior experience within a research-based context.

However, one aspect of analysis that greatly aids our understanding of the demand for our graduate programs, and the composition of our graduate student population, is in examining comparators between domestic and international applications, and comparison of registrations by program. Although we have only recently begun to track this information, it is key to our assessment of which programs position most strongly within the Department, and which programs require more concerted recruitment effort. Figure 3.6 and Figure 3.7 demonstrate how the graduate programs in Civil Engineering compare to the Faculty as a whole.

**Figure 3.6 Comparison of Applications to Graduate Programs 2016 and 2017**



**Figure 3.7 Comparison of Admissions to Graduate Programs 2016 and 2017**



Tables 3.7 shows the number of applications and resulting admissions for each of our internal programs from the two most recent admissions cycles (i.e., 2016 and 2017.) Although this timeframe is too short to establish any substantive understanding of trends, we can see a change in positioning emerging that we had previously only tacitly surmised, and which warrants attention.

**Table 3.7 Comparison of Applications to Civil Engineering Graduate Programs 2016 and 2017**

Applications 2016: Total 745	# Dom	%Dom	# Int'l	% Int'l	Applications 2017: Total 782	# Dom	%Dom	# Int'l	% Int'l
PhD	30	4.1%	108	14.6%	PhD	14	1.8%	147	18.8%
MASc	93	12.5%	144	19.4%	MASc	62	8.1%	199	25.4%
MEng	186	25.0%	180	24.3%	MEng	150	19.2%	208	26.7%
NDg	3	0.05%	1	0.0%	NDg	0	0.0%	2	0.0%
<b>Percentage of Total</b>	312	41.7%	433	58.3%	<b>Percentage of Total</b>	226	29.1%	556	70.9%

Table 3.7 shows that applications to our programs went up by a modest increase (5%) in 2017, but the change in the number of domestic to international applicants has dramatically shifted. In 2016, international applications accounted for 58.3% of the total received. In 2017 this grew to 70.9%.

We also see a significant decline in the number of domestic applications to our PhD and MASc programs, with applications to both programs down by nearly 50% from the previous year. Domestic applications to our MEng program have also gone down by 24% over 2016.

Conversely, the number of international applications across the board has gone up. International applications to the PhD program in 2017 rose by 36%, applications to the MASc program went up by 38%, and applications to the MEng program are up by 15.6% over the 2016 counts.

In Table 3.8, we compare admissions over these same two cycles. We see a decline in the number of domestic admissions to our PhD and MASc programs, although domestic admissions to the MEng program went up by a modest 1%.

We also see a decline in the numbers of international admissions to some programs. Again, in comparing only the two most recent admission cycles we see that International admissions to the PhD and MEng programs declined, while international admissions to the MASc went up by 55.6%.

**Table 3.8 Comparison of Admissions to Civil Engineering Graduate Programs 2016 and 2017**

Admissions 2016: Total 207	# Dom	%Dom	# Int'l	% Int'l	Admissions 2017: Total 185	# Dom	% Dom	# Int'l	% Int'l
PhD	12	5.8%	14	6.8%	PhD	7	3.7%	10	5.6%
MASc	41	19.9%	9	4.5%	MASc	27	14.6%	14	7.5%
MEng	91	44.0%	36	17.5%	MEng	92	49.7%	33	17.8%
NDg	3	1.5%	1	0.00%	NDg	0	0.00%	2	1.1%
<b>Percentage of Total</b>	147	71.2%	60	28.8%	<b>Percentage of Total</b>	126	68.0%	59	32.0%

While applications and admissions in this short-term analysis indicate a slight decrease overall, it is clear that the greatest area of growth is attributable to our MEng program. From this we understand that greater emphasis on recruitment to our doctoral-stream programs overall is essential.

Additional metrics for comparison of applications to registration yields are contained within the specific program sections below.

### 3.4.2 Master of Applied Science (MASC) in Civil Engineering

The Master of Applied Science (MASC) program is a full-time, two-year program comprised of a base of preparatory graduate courses followed with a research thesis. The program serves as both an excellent stand-alone program, and very often as an entry point to the PhD program.

Students receive a full funding package comprised of departmental fellowship, research assistantship, and teaching assistantships. The minimum funding amount is set at \$15,500 CDN per year plus tuition, and may increase depending on awards the student may receive. For students who receive scholarships and awards, the composition of the funding package is adjusted to include the award amount. Table 3.9 details the composition of the MASC funding packages currently offered by the Department. The scholarships listed indicate only the most common awards that students may receive, and the amounts shown are used as reference comparators when determining funding packages that include funding from other scholarship sources.

**Table 3.9 Department of Civil and Mineral Engineering Domestic and International Graduate Student Funding – Master of Applied Science (MASC)**

*MASC students receive 24 months of funding for their MASC program, at the yearly rates below*

	Major Award	Total Funding	Scholarship	Fellowship	TAship	RAship
<b>DOMESTIC MASC STUDENT FUNDING</b>	<b>NSERC CGSM</b>	\$29,550	\$17,500	\$2,100	\$4,700	\$5,250
	<b>Transportation Information Steering Committee Scholarship</b>	\$27,050	\$17,400	\$2,100	\$4,700	\$2,850
	<b>OGS*</b>	\$27,050	\$10,000	\$4,100	\$4,700	\$8,250
	<b>QEII-GSST</b>	\$27,050	\$15,000	\$2,100	\$4,700	\$5,250
	<b>Civil MASC Funding Package</b>	\$24,050	\$0	\$4,350	\$4,700	\$15,000
<b>INTERNATIONAL MASC STUDENT FUNDING</b>	<b>OGS Visa Competition*</b>	\$39,195	\$10,000	\$7,725*	\$4,700	\$16,770*
	<b>Minimum Civil MASC Funding Package</b>	\$39,195	\$0	\$8,005	\$4,700	\$26,490

Note: OGS scholarships are valued at \$15,000. \$10,000 is provided by the Ontario Government as a scholarship, and the remaining \$5,000 is paid by a fellowship top-up of \$2,000 and an RA top-up of \$3,000.

Students undertaking the MASC program must normally complete a minimum of 2.5 full-course equivalents as part of their core program. Course selections are determined in consultation with the student’s academic supervisor, with a view to concentrating on courses that will provide the most relevant background to the student’s chosen research area. Development of the research thesis usually commences in the second term of the student’s first year, and research projects will often involve industrial partnerships, project management experience, and collaboration with leading experts, thus preparing graduates for rewarding careers within industry. The student’s program outline is approved by the Department’s Graduate Studies Committee.

The culmination of the MASC program is a public, oral presentation of the student’s research thesis, coupled with a formal assessment of the thesis by the supervisor and a second academic reviewer. Student’s wishing to continue to pursue their research more in-depth may choose to fast track to the PhD program, provided the transfer is sanctioned by the student’s academic supervisor.

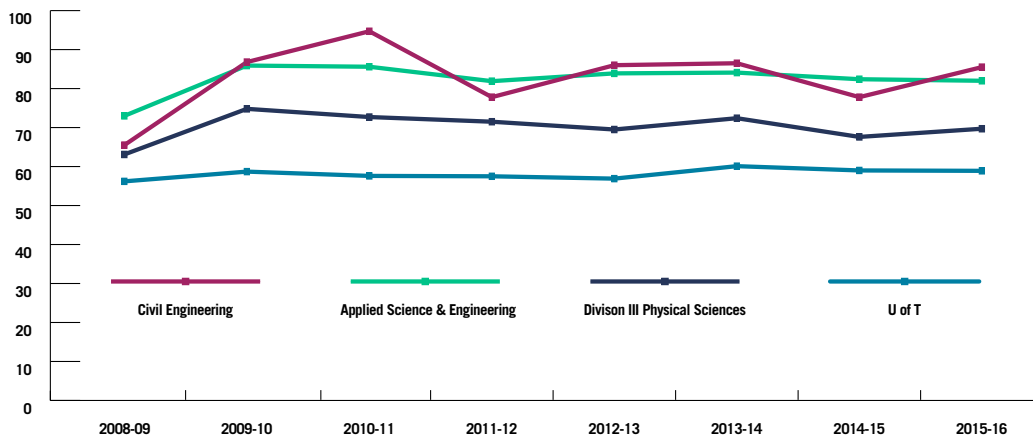
Notwithstanding the more recent application data examined earlier, application to the MASC program has remained steady and strong, with the number of applications received more than doubling over the period 2009-2016. On average, the Department issues offers on a ratio of 1 to 4, or approximately 20-25%, with acceptances on offers coming in at around 85%, on par with the Faculty and well above the divisional and institutional averages. Table 3.10 and Figure 3.8 clearly demonstrate these trends.

**Table 3.10 Applications, Offers, Registrations – Master of Applied Science in Civil Engineering**

	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16
<b>Applications</b>	98	122	173	160	226	225	209	231
<b>Offers</b>	29	38	38	36	50	52	36	55
<b>New Registrants</b>	19	33	36	28	43	45	28	47

Source: ROSI using screen 4BEG (Admissions Statistics).

**Figure 3.8 Offer Acceptance Rates – Master of Applied Science in Civil Engineering in Comparison to the Faculty of Applied Science and Engineering, U of T Physical Sciences Division III, and U of T**



Notes:

1. Academic Year runs from Fall to Summer. For example, 2015-16 runs from September 2015 to August 2016.

2. Division III Physical Sciences includes the following graduate programs:

Aerospace Science and Engineering, Applied Computing, Astronomy and Astrophysics, Biomedical Engineering, Chemical Engineering and Applied Chemistry, Chemistry, Cities Engineering and Management, Civil Engineering, Clinical Engineering, Computer Science, Earth Sciences, Electrical and Computer Engineering, Environmental Science, Materials Science and Engineering, Mathematical Finance, Mathematics, Mechanical and Industrial Engineering, Physics, Statistics.

### 3.4.3 Doctor of Philosophy (PhD) in Civil Engineering

The Doctor of Philosophy (PhD) program is a full-time, four-year program designed for outstanding individuals who are keenly interested in a career in fundamental or applied research. The PhD program is also fully funded, with students receiving a minimum of \$17,000 CDN plus tuition per year. The composition of the funding package is structured similarly to the funding packages provided to MSc students (see Table 3.11)

Generally, the tuition amount of the funding package is provided through the research assistantship component. This arm of funding is contributed by the student’s academic supervisor, via the supervisor’s research funds. One of the challenges that had faces was the cost of tuition for international students. However, the University of Toronto has recently reduced international tuition for PhD students to domestic levels. This will greatly assist the Department and academic supervisors in our effort to attract top international candidates.

Table 3.12 details the composition of the Department’s 2017-2018 PhD funding package. Similar to the MSc funding mechanism, the composition of the package is adjusted according to scholarships and awards a student may receive.

**Table 3.11 Department of Civil and Mineral Engineering Domestic and International Graduate Student Funding 2017-2018– Doctor of Philosophy (PhD)**

PhD students receive 4 years of funding for their PhD program, at the yearly rates below

	Major Award	Total Funding	Scholarship	Fellowship	TAship	RAship
DOMESTIC PHD STUDENT FUNDING	NSERC VCGS	\$54,700	\$50,000	\$0	\$4,700	\$0
	NSERC CGSD	\$46,550	\$35,000	\$1,900	\$4,700	\$4,950
	NSERC PGSD	\$32,550	\$21,000	\$1,900	\$4,700	\$4,950
	OGS*	\$27,550	\$10,000	\$4,300	\$4,700	\$8,550
	QEII-GSST	\$27,550	\$15,000	\$2,300	\$4,700	\$5,550
	Minimum Civil PHD Funding Package	\$25,550	\$0	\$4,850	\$4,700	\$16,000
INTERNATIONAL PHD STUDENT FUNDING	Chinese Scholarship Council	\$24,605 in addition to the value of CSC scholarship	external	\$7,835	\$4,700	\$12,070
	NSEC IPS	\$40,693	\$21,000	\$5,753	\$2,350	\$11,590
	OGS*	\$40,693	\$10,000	\$8,223	\$4,700	\$17,770
	Minimum Civil PHD Funding Package	\$40,693	\$0	\$8,503	\$4,700	\$27,490

Notes:

OGS scholarships are valued at \$15,000. \$10,000 is provided by the Ontario Government as a scholarship, and the remaining \$5,000 is paid by a fellowship top-up of \$2,000 and an RA top-up of \$3,000.

MASc students who transfer to the PhD program receive five years of funding

Overall, departmental funding for both the MASc and PhD programs is consistent with funding levels set in graduate units across the Faculty, although the composition of the our departmental funding packages may differ slightly from other units. For example, some graduate units do not include Teaching assistantships as part of their funding packages, while others may not factor some external scholarships in their funding allocations. The choice to include teaching assistantships or external scholarships is solely at the discretion of the individual department, and in the case of the Department of Civil and Mineral Engineering the decision to include these sources in its funding guidelines was expressly made to correspond to our budgetary capacity.

Nevertheless the total amount of student funding from department and research fund sources has steadily increased each year. The following chart demonstrates the growth in this area over the period 2007-08 to 2016-17 from \$3.3-million to \$6.4-million.

**Table 3.12 Department of Civil and Mineral Engineering Graduate Student Funding and Academic Area, Academic Years 2007-08 to 2016-17**

	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17
Scholarships	829,602	1,110,526	1,146,207	1,179,090	984,465	1,178,499	1,211,859	1,458,163	1,511,483	1,268,233
Faculty & Department Funds	1,311,735	1,394,152	1,334,513	1,504,670	1,729,246	1,869,771	1,966,020	1,799,901	2,009,187	2,455,516
Research Funds	1,115,578	978,588	1,374,029	1,606,334	1,784,261	2,081,586	2,512,127	2,186,898	2,462,601	2,677,388
Total	3,256,915	3,483,266	3,854,749	4,290,094	4,497,972	5,129,856	5,690,006	5,444,962	5,983,271	6,401,137

As with the MASc program, the PhD program involves advanced courses and an intensive research program culminating in a thesis. The number of courses required is contingent upon the student's previous academic credentials, depending on whether they are entering the program directly after

completion of a bachelor's degree, or following completion of a Master's degree. Regardless, the course requirement must add up to at least nine graduate level half-courses beyond the Bachelor's degree.

Similar to the MSc, the PhD student course selections are determined in consultation with their academic supervisor, generally based in subject material most pertinent to the student's chosen field of research. To ensure that the student's program is well balanced and provides sufficient breadth their academic program must also be approved by the Department's Graduate Studies Committee.

The steps to completion of the PhD program are somewhat more stringent in that the student must pass through three distinct phases of examination before completion of their program: the Comprehensive Oral Examination (COMP), the Departmental Oral Examination (DEX), and the Final Oral Examination (FOE). A supervisory committee, usually comprised of three faculty members with expertise in the research area, including the student's academic supervisor, is assigned to oversee development of the thesis throughout the entire process.

The Comprehensive Oral Examination serves as the initial stage in evaluating a PhD candidate's suitability for proceeding through to the intensive research-based aspect of their program. This is usually conducted after the candidate has completed most of their coursework, and ideally within one year after their first enrolment in the program. According to standard, the student is first required to submit a research proposal defining their hypothesis and formally respond in writing to a written set of questions concerning the research proposed. The questions are generated by the members of an enlisted comprehensive examination committee, comprised of at least four voting members from the graduate faculty, including the student's academic supervisor, and must be answered within a specified timeframe (normally within four working days). The candidate is then required to provide an oral presentation of their research proposal to the examination committee, and respond to questions arising from the presentation and the written portion of the exam. The examination committee then submits a recommendation to the departmental Graduate Programs office, advising:

- that the candidate proceed in the program with full emphasis placed on the research,
- that the candidate undertake additional preparatory work to improve their knowledge in the chosen research area before proceeding further,
- that the candidate be asked to withdraw from the program.

Where improvement in knowledge is recommended, the candidate may be required to undertake another comprehensive examination after the additional preparatory work has been completed.

The Departmental Oral Examination is conducted once the candidate's thesis is completely written and reviewed by the supervisor. As with the COMP exam, a Departmental Examination Committee consisting of at least four graduate faculty members, and including the candidate's academic supervisor, is convened. The student is required to give a 20-minute presentation in defense of their thesis, followed by a question period. There is no time limit to the question period. The oral presentation component of the examination is often open to allow fellow students and other faculty members to attend should they wish, but the question period is most often held in camera. Following the question period, the committee will deliberate on the candidate's preparedness to proceed through the final examination processes via the School of Graduate Studies, and/or will make recommendations with respect to areas within the thesis that may require further attention before proceeding to the final defense stage.

The Final Oral Examination is the last stage of assessment for completion of the PhD program. This examination is regulated by the School of Graduate Studies to ensure that the candidate's research is original and meets all criteria for the granting of a PhD degree. This includes a formal review of the thesis by an approved external examiner in advance of the oral examination, and the external reviewer's report is included in the examination package for the purview of the examination

committee. The examination committee consists of four to six voting members and usually includes the external examiner and the candidate's academic supervisor. To ensure impartiality, academic integrity and fair representation, the examination chair is appointed from among the SGS graduate faculty who are at arm's length from the Department.

While the number of applications to the PhD program are not as great as the MASc program, the Department strives to maintain a similar offer to acceptance ratio of 1:4, garnering an acceptance rate of approximately 80%, as shown below.

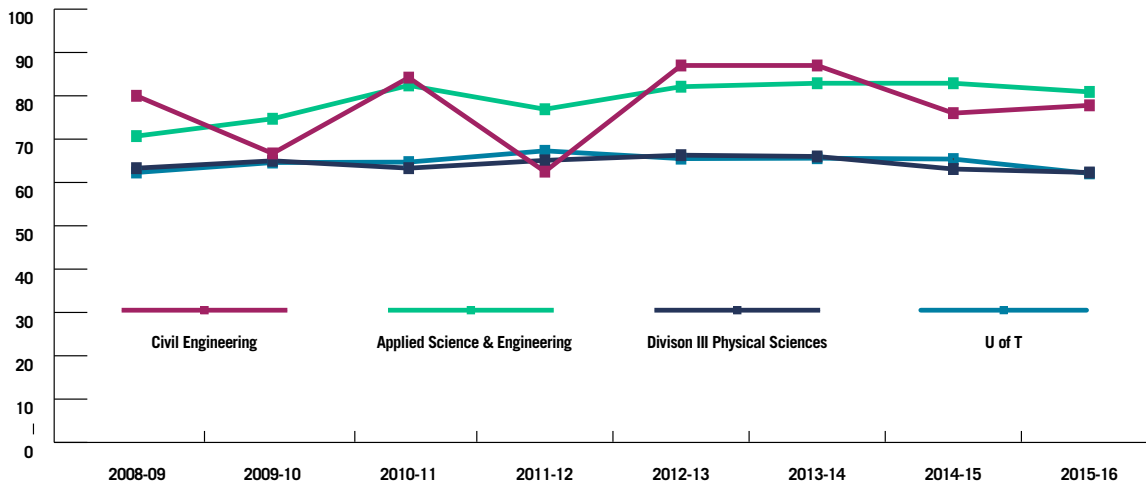
**Table 3.13 Applications, Offers, Registrations – Doctor of Philosophy (PhD), Civil Engineering**

	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16
<b>Applications</b>	83	83	127	140	139	107	108	100
<b>Offers</b>	15	21	19	32	23	23	25	27
<b>New Registrants</b>	12	14	16	20	20	20	19	21

Source: ROSI using screen 4BEG (Admissions Statistics).

The rate of acceptance of offers to the Civil Engineering PhD program is also on par with the Faculty, and above the divisional and institutional averages.

**Figure 3.9 Offer Acceptance Rates – Doctor of Philosophy (PhD), Civil Engineering in Comparison to the Faculty of Applied Science and Engineering, U of T Physical Sciences Division III, and U of T**



Notes:

1. Academic Year runs from Fall to Summer. For example, 2015-16 runs from Fall 2015 to Summer 2016.
2. Division III Physical Sciences includes the following graduate programs: Aerospace Science and Engineering, Applied Computing, Astronomy and Astrophysics, Biomedical Engineering, Chemical Engineering and Applied Chemistry, Chemistry, Cities Engineering and Management, Civil Engineering, Clinical Engineering, Computer Science, Earth Sciences, Electrical and Computer Engineering, Environmental Science, Materials Science and Engineering, Mathematical Finance, Mathematics, Mechanical and Industrial Engineering, Physics, Statistics.

### 3.4.4 Time to Graduation

The median time taken for completion of our MASc and MEng graduate programs has remained constant over the past five years, with MASc students completing within an average of two years, and full-time MEng students completing within one year. This is well within established guidelines.

However, the University target for completion of a PhD program is 48 months, or 4 years, and as

the following chart demonstrates, the median average for completion of the Civil Engineering PhD program has steadily moved beyond this over the past five years. In 2016-17, the average program length grew to 5.67 years. While we recognize that it is inherent in the nature of in-depth investigation to experience some setbacks pursuant to establishing qualitative research results, it is nevertheless incumbent upon the Department to bring the time to completion of the PhD program more in line with established parameters.

To address this we are exploring several potential internal mechanisms that may help to facilitate program progression. For example, we could consider eliminating the requirement of the Departmental Oral Examination. This program element has served the Department very well over the years in terms of aiding our assessment of a candidate's preparedness to proceed to thesis development. However, this is not a formal program requirement as defined by the School of Graduate Studies, but rather is an internal departmental requirement. This additional criterion can add a full semester onto a candidate's progress, so is worth reviewing through analytical discussion with our faculty and doctoral-stream students.

Another mechanism could be to establish a set of timelines mapped to program milestones, and develop a process to ensure adherence to these milestones, for example defining an express purpose in association with specific supervisory committee meetings. Other potential mechanisms will be explored as we continue this discussion within our community.

**Table 3.14 Median Time to Graduation (in Years) for Civil Engineering PhD, MASC and MEng Graduate Students 2007-2008 to 2016**

		2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17
PhD	Median	4.67	5	5	5.33	5.33	5.33	5	5.33	5.33	5.67
	Count	12	11	13	15	9	14	15	19	13	18
MASC	Median	2	2	2	2	2	2	2	2	2	2
	Count	26	24	23	18	25	32	36	38	40	33
MEng (FT)	Median	1	1	1	1.33	1	1	1	1	1	1
	Count	18	29	31	25	33	29	40	37	38	32
MEng (EXT FT)	Median								1.33	1.67	1.33
	Count								1	19	19
MEng (PT)	Median	1.67	1.67	2	2.33	1.84	2	2	1.67	2	2.17
	Count	12	16	18	20	25	30	26	19	11	16
MEngCEM (FT)	Median								1.33	1.33	1.33
	Count								6	9	8

### 3.4.5 Master of Engineering (MEng) in Civil Engineering

The Master of Engineering Program (MEng) is course-based and intended to provide continuing and advanced education for recent graduates and civil engineers in professional practice. MEng students are responsible for funding their own programs, although many are sponsored by their employers or by government agencies.

Completion of the program requires undertaking 10 one-semester courses, thus achieving a total of 5.0 full course equivalents. Six of the 10 courses selected must be offered through the Department. The remaining four courses can be from outside of the Department, and a further two of these can be from outside of the Faculty, or the University. In lieu of one or two individual courses, students may also opt to complete a one or two-term design project to achieve 0.5 or 1.0 credits respectively. All MEng student program plans must be submitted to the Graduate Programs office for review and approval by the Associate Chair – Graduate Studies.

The program can be taken on a full-time, extended full-time, or part-time basis. The usual time to completion of the MEng program on a full-time basis is 18 months, but it is possible to complete the program within one academic cycle (i.e., consecutive Fall, Winter and Summer sessions.)

The extended full-time option is a relatively new registration approach in which full-time students may complete their programs by spreading their studies over a slightly longer period of time. The advantage is that students may take up to six courses per year over four to six terms, thus allowing them to take more courses than the requisite 10 courses required for completion of the program, without having to pay any additional tuition over and above the full MEng program fee. This may also allow students to take course(s) that may have been temporarily unavailable for a given year.

MEng students also have the opportunity to participate in two certificate programs offered through the Faculty: Entrepreneurship, Leadership, Innovation and Technology in Engineering (the ELITE Certificate) and Engineering and Globalization (the Global Certificate). The ELITE Certificate is available through four distinct pathways: Leadership, Entrepreneurship & Innovation, Finance & Management, and Engineering & Society. Both the ELITE Certificate and the Global Certificate programs can be seamlessly achieved through integration of the student's core program by applying their four non-departmental course slots towards ELITE or Global course offerings.

Information regarding the ELITE Certificate programs can be found at: <http://gradstudies.engineering.utoronto.ca/professional-degrees/elite-certificate/>. Details regarding the Global Certificate program can be found at: <http://gradstudies.engineering.utoronto.ca/professional-degrees/global-certificate/>.

Civil Engineering was the first department in the Faculty to offer a Master of Engineering program, commencing in 1998. Since that time, the MEng program has grown at a steady pace, such that the total number of students enrolled in our MEng program is now equal to that of our MASc and PhD students combined.

Table 3.15 shows the growth in our MEng program over the past five years. The greatest challenge to keeping pace with this growth, while maintaining the quality of our program, is the ability to provide sufficient support to our MEng students, in terms of both human and physical resources.

**Table 3.15 Growth in Registrations in the Master of Engineering Program 2012-2017**

Academic Year	MEng FT	MEng PT	MEng EFT	MEngCEM (Cities)	Total: All MEng
September, 2012	33	10			
January, 2013	13	7			<b>63</b>
September, 2013	34	14	17	8	
January, 2014	5	2	4		<b>84</b>
September, 2014	28	7	14	16	
January, 2015	2	2	5		<b>74</b>
September, 2015	29	13	16	8	
January, 2016	6	5	5		<b>82</b>
September, 2016	21	12	22	10	
January, 2017	6	5	11		<b>87</b>
September, 2017	15	17	37	8	<b>77</b>

Notes:

Graduate students may commence their program in September or January. The numbers shown in the Total:MEng column reflect the total number of registrations in the given academic year.

2017 numbers were extracted prior to the November 1 count, and do not include registrations that will commence in January 2018.

The Extended Full-Time (EFT) program option commenced in September 2013.

The MEngCEM program commenced in September 2013. Students may only begin their program in September.

Our current financial position does not provide opportunity to dedicate full-time support staff exclusively to the MEng program, and our current space allocation prohibits our ability to provide dedicated physical resources, such as student computing facilities or study space, to these students. However, MEng students do have open access to common computing and study facilities shared with other students.

To respond to the need for increased student support, we recently separated responsibility for administration of the MEng program from the doctoral-stream programs administration, and appointed one of our existing Student Services staff to oversee MEng student records, to serve as first point of contact for program issues, and to provide routine counseling services. For matters of a more complex nature, we refer the MEng students to the Graduate Programs Administrator and/or the Associate Chair- Graduate Studies.

### *3.4.6 Master of Engineering in Cities Engineering and Management (MEngCEM)*

Instituted in 2013, the Master of Engineering in Cities Engineering and Management (MEngCEM) program is the most recent addition to our graduate program offerings. This specialized program is designed to develop a corps of highly skilled professional civic managers who are expertly equipped to address the growing and increasingly diverse needs facing today's urban centres. Through the MEngCEM program students gain a comprehensive understanding of the interaction between the systems and services of the city, improve their analytic skills in assessing the environmental, economic, political and social risks impacting civic policy making, and develop the skills and techniques required to solve unique urban challenges.

The program is only available on a full-time basis, and requires two-years to complete. Students must achieve a total of 10 one-session graduate courses, five of which are core to the program, with another four selected from the infrastructure engineering elective courses offered through the Department. To provide breadth, the tenth course must be selected from a list of technology management courses. All student study plans must be submitted for review and approval by the program's Academic Coordinator.

The structure of the program is defined within three primary elements: infrastructure engineering, cities as complex systems, and an integrative practicum. The program delivery method requires students to focus on their academic courses over the first four semesters of the program, followed by a culminating semester at a paid practicum. The practicum usually takes place over the summer months (May-August). Through the practicum students gain opportunity to establish a professional network within the field, and to apply what they have learned in the classroom within a "real-world" setting. Practicum placements must be pre-approved by the program Academic Coordinator before commencement, and assistance in identifying appropriate practicum placements is provided through the Department's Graduate Programs office.

Although the program fee for the MEngCEM degree is on par with the cost of other professional program fees at the University, the administration of the tuition for the program is structured so that students pay fees for one-full year, plus one semester of study. The Department is in the process of changing this so that the program length will officially be 12-months. Students can then opt to register in the extended full-time option should they wish. The paid practicum is independent of tuition and monies earned in practicum placements help students to offset the cost of their academic program.

MEngCEM students graduate with a comprehensive understanding of the interaction between the systems and services of a city, the analytical skills necessary to assess the risks and impacts of policy change related to critical infrastructure within a city, and the management skills and evidenced-based techniques required to address the unique challenges inherent to cities effectively. To date, students

in the MEngCEM program have secured practicum placements and/or full-time employment post-graduation in the following agencies and engineering consulting firms:

AECOM, Ag Methane Advisors, Allstream Inc.; BA Consulting Group, King Abdullah Economic City, McElhanney Consulting Services, the Ministry of Transportation, Navigant Consulting, the Ontario Ministry of Environment and Climate Change, Paradigm Transportation Solutions, the Region of Waterloo, the Regional Municipality of York, St. Michael’s Hospital, Terraprobe, Tetra Tech EBA, UTTRI at U of T, WSP Canada, York Region, and Yukon Highways and Public Works.

In its inaugural year, an explicit decision was made to limit enrollment in the program to allow opportunity for review and refinement prior to opening registrations up more broadly. The first year cohort was established at eight students, and registration has remained steady since. There are currently 17 students in the program, with 50% registered under the extended full time option. Interest in the program is strong and the Department is now targeting to expand registrations to 25 new admissions per year. A steady and gradual increase in new admissions will ensure the quality and integrity of the program.

**Table 3.16 Applications, Offers, Admissions – Professional Master’s Degree in Cities Engineering and Management (MEngCEM)**

	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17
<b>Applications</b>	///	///	///	///	19	62	46	51
<b>Offers</b>	///	///	///	///	11	31	17	22
<b>New Registrants</b>	///	///	///	///	8	17	9	10

Source: ROSI using screen 4BEG (Admissions Statistics).

A recent development aimed at furthering the objectives of the MEngCEM program is a potential collaboration with KPMG’s Centre of Excellence in Cities. KPMG is one of the nation’s leading auditing, tax and advisory services companies. Within its “Cities” advisory services portfolio they provide knowledge and expertise in leading practices to municipal governments, helping to advise and support the sustainable development of cities and influence the effective provision of city services. They are keenly interested in the evidence-based and data-driven nature of decision-making, combined with the public policy and urban planning lens that the MEngCEM program engenders.

In the fall of 2017, a meeting with senior representatives from KPMG’s Centre of Excellence in Cities took place in which opportunities for potential partnerships in various program aspects, such as guest lectures, provision of case studies and data sets for student analysis, practicum and employment opportunities, and possible contributions to course content was explored. The meeting was extremely fruitful, and we look forward to continuing this discussion throughout the coming year.

### 3.4.7 Graduate Programs Curriculum and Program Delivery

In addressing the graduate programs offered by the Department of Civil and Mineral Engineering it is important to present the doctoral-stream programs (MAsc, PhD) as distinct from the professional engineering programs (MEng, MEngCEM), due to the distinguishable nature of these two program streams. Doctoral-stream programs place emphasis on research and development, while the emphasis of the professional programs is on practical application. Nevertheless, the majority of Civil Engineering graduate courses are open to students from all programs with course selection based on the student’s chosen area of specialization. Additionally, all students undertaking a Civil Engineering graduate program must participate in and receive a non-graded credit for the JDE1000Y – “Ethics in

Graduate Research” seminar, offered through the Faculty, and generally taken at the commencement of the student’s given program. All students working within laboratory environments are also required to undertake the appropriate Environmental Health & Safety (EHNS) training relative to their area of specialization. The EH&S courses are offered through the University’s Environmental Health & Safety Office.

While many of the courses offered through our graduate programs can be of equal value to both doctoral-stream and professional practice students, there are areas where these programs branch off to provide courses pertinent to the respective degree type, or research specialization area. For example, all of the CEM core courses (CEM1000, CEM1001, CEM1002, CEM1004, CEM1005) are designed specifically for students enrolled in the Cities and Engineering Management MEng program. The CIV Special Studies courses ending in numbers 98 or 99 (i.e., CIV1198, CIV1299) are often utilized to pilot new courses within the confines of a limited or targeted enrollment, or as one-time-only offerings to enable doctoral-stream students to engage in in-depth literature reviews within their area of specialization. The Entrepreneurship Leadership, Innovation and Technology in Engineering (ELITE) suite of courses listed under course code APS are only available to MEng students undertaking this program emphasis.

A copy of the School of Graduate Studies 2017-18 Calendar entry, outlining Civil Engineering graduate programs is attached in Appendix L, or can be viewed on-line at: <https://sgs.calendar.utoronto.ca/degree-print/Civil-Engineering>.

The Department has a number of state-of-the-art lab facilities available to aid student research, such as the Drinking Water Research Laboratory, the Groundwater Research Laboratory, the Rock Fracture Dynamics Lab, the Structures Facility, the Intelligent Transportation Systems Lab, the Concrete Materials Laboratory, and the Mining and Environment Laboratory. The U of T “Lab Innovation for Toronto” (LIFT) project, with funding from the Federal Government Post-Secondary Strategic Investment Fund, will accelerate infrastructure improvements across the Faculty, with significant improvements to our other lab facilities located in the Galbraith Building, such as the Advanced Simulation and Structural Dynamics Laboratory, and the Structural Testing Facility.

We also collaborate with other departments to secure access to courses that will build upon our students’ core knowledge base and provide breadth. For example, graduate students working in the area of water research take a core course offered through the Department of Chemistry (CHM1410: Analytical Environmental Chemistry). Graduate students may also individually request permission to take courses pertinent to their field of research that are available through other departments at U of T, or through partner institutions approved by the School of Graduate Studies.

### *3.4.8 Assessment of Learning*

Similar to the provincially tabled UDLE’s that serve as the formal measures for determining the competencies, knowledge and skills of students graduating from our undergraduate programs, the FASE developed a similar set of degree level expectations (GDLEs) to guide assessment of our MEng, MASc and PhD programs. These GDLEs were adopted by all departments in the Faculty in March 2011, and have been employed in our assessment of graduate learning since.

Each of the GDLEs consists of six sets of expectations, five of which are shared among the three

programs. The sixth expectation is different for MEng (“Knowledge of Methodologies”) and MAsC and PhD students (“Research and Scholarship”). Detailed descriptions of the Faculty GDLE’s prescribed for each of our graduate programs is attached in Appendices M.1, M.2 and M.3. The following briefly explains how our programs and curricula enable graduate students to achieve these expectations.

### **GDLE 1: Depth and Breadth of Knowledge**

Assessment of the depth and breadth of knowledge achieved through our Master of Engineering programs is generally ascertained from student success in courses and overall academic standing. To summarize, the MEng program consists of 10 one-semester courses, six of which have to be from the Department of Civil and Mineral Engineering. The remaining four can be from outside of the Department, and two of these can be from outside of the Faculty of Applied Science of Engineering, or outside of the University of Toronto. MEng students also have the option of completing a one or two course-equivalent project, which counts toward the six Civil courses, and are encouraged to concentrate their course selections in one of the nine areas of specialization to gain depth of knowledge in a particular area. MEng students can also broaden their knowledge with courses offered through the Faculty’s ELITE program, which provides opportunity to gain exposure to concepts in entrepreneurship, leadership, and innovation.

Students in the Cities Engineering and Management MEng Program (MEngCEM) must complete four mandatory courses and complete a four-month internship. In addition, MEngCEM students are required to complete five elective courses; four of these are infrastructure engineering electives, chosen from one of the program specialization areas. The final elective is selected from a list of technology management courses, and is meant to provide breadth.

Doctoral-stream program students achieve depth of knowledge primarily through thesis work, so are expected to devote the greater portion of their time toward research. In preparation for the research component of their program, MAsC students are required to take five courses, while PhD students must take a minimum of four. To ensure depth within their area of research specialization, students choose their course selections in consultation with their academic supervisor.

Students are encouraged to take courses from other departments and outside the FASE for breadth.

### **GDLE 2: Level of Application of Knowledge**

Level of knowledge application is maintained by exposing students to technical courses and scientific research. Civil engineering is by nature an applied discipline and our technical courses typically include applications of scientific principles and design concepts. Many of our courses include projects that offer additional opportunities for students to apply knowledge to solving problems.

MEng students in the project option, and MAsC and PhD students further build competence in the application of knowledge to develop solutions for targeted and often complex problems.

### **GDLE 3: Professional Capacity / Autonomy**

Our students are encouraged to practice personal responsibility, accountability, intellectual independence, and academic integrity throughout their degree program. We encourage them to participate in the professional skill development series offered by the U of T School of Graduate Studies (SGS). Students can also develop professional capacity and autonomy by taking courses such as those offered by the Faculty’s ELITE program.

MAsC and PhD students are provided additional opportunities to develop these skills and autonomy

via their research work. PhD students may also participate in the Prospective Professors in Training Program.

There are also numerous student chapters of professional organizations available to engage students more fully in their chosen field, and expand their networking opportunities.

#### **GDLE 4: Level of Communication Skills**

Our graduate students have a range of opportunities in which to learn and practice their written and oral communication skills. Graduate course work is imbued with opportunity to develop communication skills in the form of written assignments and oral presentations. Additionally, many of our courses involve team projects, which also serves to enhance interpersonal communication skills among team members.

Doctoral-stream students also contribute to peer-review published papers, often listed as first author, and their supervisors ensure that opportunities to present their work in public forums such as conferences are available to the greatest extent possible. The School of Graduate Studies provides a mechanism for securing funding to attend a conference in instances where a lack of funding to participate in a conference program is a hindrance.

A further element for measuring the effectiveness of our doctoral-stream PdD program is the external review of the student thesis. Although the student's academic supervisor nominates the external examiner, the appointment is approved by the School of Graduate Studies. This ensures an unbiased assessment of the work, free of conflict of interest, and therefore challenges the student to articulate their work professionally and to the best of their ability.

#### **GDLE 5: Awareness of the Limits of Knowledge**

Students develop an awareness of the limits of knowledge while taking technical courses. MEng students choosing a project option are exposed to additional opportunities through the process of defining the project's scope and objective.

For MAsc and PhD students, ongoing literature review is an essential part of the research process, thus providing opportunity to develop an awareness of the limits of established and/or shared knowledge, and guides their decision-making when planning future directions in their work.

#### **GDLE 6: Knowledge of Methodologies (MEng students) / Research and Scholarship (MAsc and PhD students)**

MEng students are required to take various technical courses and are expected to gain knowledge of discipline-specific methodologies. Students who choose to do a project are also exposed to research methodologies.

The MAsc and PhD programs in Civil and Mineral Engineering are research-intensive. Therefore, students are guided by their academic supervisor and (for PhD students) their Supervisory Committee, in developing their abilities to identify and formulate research questions, design and implement a research plan to generate new knowledge or understanding, and analyze experimental data and/or computational results to develop and formulate new concepts. Students learn to articulate their

findings in the form of a written thesis, and through submission of research papers to scholarly peer-reviewed publications. Additionally, PhD students are expected to become specialists in their fields and lead independent research programs.

MASc students work towards these same goals, but with contributions scaled to the shorter duration of the MASc program.

### 3.4.9 Student Satisfaction

Student satisfaction at program completion is a meaningful measure of success for our graduate programs. Tables 3.17 and 3.18 demonstrate that U of T Civil Engineering graduate students are largely very satisfied with their educational experience. Ratings for our doctoral-stream programs indicate that our students view the quality of our teaching, research training, and supervision slightly above those of the U15 Engineering schools.

**Table 3.17 Student Satisfaction Benchmark - Doctoral-Stream Students 2010-2016**

Means are out of 5 (1=Poor, 2=Fair, 3=Good, 4= Very Good, 5=Excellent)

Benchmarks	CGPSS	U of T Civil Engineering	U15 (Civil Engineering <sup>1</sup> )	U of T (All disciplines)	U15 (All disciplines)	Ontario (All disciplines)
Number of Respondents	2010	33	184	2,086	8,047	4,685
	2013	61	351	2,681	10,015	5,585
	2016	41	312	2,253	10,181	6,423
1. Quality of Teaching	2010	3.98	3.41	3.86	3.73	3.74
	2013	3.68	3.54	3.80	3.74	3.77
	2016	3.80	3.58	3.84	3.77	3.80
2. Research Training and Career Orientation	2010	3.06	2.69	2.88	2.74	2.70
	2013	3.03	2.78	2.81	2.70	2.70
	2016	3.26	2.97	2.83	2.82	2.78
3. Supportive Dissertation Advisor	2010	3.30	3.25	3.30	3.29	3.33
	2013	3.28	3.25	3.30	3.31	3.36
	2016	3.44	3.28	3.33	3.34	3.38

<sup>1</sup>Civil Engineering comparison group is based on the Classification of Instructional Programs (CIP) code 140801 (Civil Engineering, General) and 140899 (Civil Engineering, Other) .  
<http://stds.statcan.gc.ca/cip-cpe/2digit-2chiffres-eng.asp>

Note:

1. U of T, U15, and Ontario values only include responses from doctoral-stream students.
2. U15 and Ontario values exclude University of Toronto
3. U15 includes Alberta, British Columbia, Calgary, Dalhousie, Laval, Manitoba, McGill, McMaster, Montreal, Ottawa, Queen's, Saskatchewan, Waterloo, Western.

Although the professional Master's students rank the quality of our teaching well above the U15 Engineering schools, their view of the research training and career orientation provided is slightly below that of the U15 schools. While not a required aspect of their academic program, professional stream graduate students are encouraged to attend doctoral-stream student presentations as well as our special speaker series, thus providing insight into our research and furthering the student's awareness of emerging discovery directions within the profession. Additionally, they have the option to select a research-based project as part of their academic program.

With respect to career orientation, we are striving to improve upon our efforts in this area through the creation of a series of graduate career panel discussions, targeted career fairs, and encouraging participation in professional association activities. Our Master of Engineering in Cities Engineering and Management program requires students to complete an approved internship within a relative work setting, which significantly contributes to their career orientation.

**Table 3.18 Student Satisfaction Benchmark Professional Master's Students 2010-2016**

Means are out of 5 (1=Poor, 2=Fair, 3=Good, 4= Very Good, 5=Excellent)

Benchmarks	CGPSS	U of T Civil Engineering	U15 (Civil Engineering1)	U of T (All disciplines)	U15 (All disciplines)	Ontario (All disciplines)
Number of Respondents	2010	32	74	1,861	5,110	4,012
	2013	36	116	2,411	6,782	5,038
	2016	30	87	2,121	6,308	5,454
1. Quality of Teaching	2010	3.83	3.65	3.89	3.77	3.76
	2013	4.00	3.72	3.88	3.79	3.74
	2016	4.06	3.80	3.84	3.82	3.78
2. Research Training and Career Orientation	2010	2.78	3.06	3.19	3.15	3.17
	2013	2.98	3.03	3.23	3.17	3.08
	2016	2.97	2.84	3.29	3.21	3.19

1Civil Engineering comparison group is based on the Classification of Instructional Programs (CIP) code 140801 (Civil Engineering, General) and 140899 (Civil Engineering, Other) .  
<http://stds.statcan.gc.ca/cip-cpe/2digit-2chiffres-eng.asp>

Notes:

1. U of T, U15, and Ontario values only include responses from professional master's students.

2. U15 and Ontario values exclude University of Toronto

3. U15 includes Alberta, British Columbia, Calgary, Dalhousie, Laval, Manitoba, McGill, McMaster, Montreal, Ottawa, Queen's, Saskatchewan, Waterloo, Western.

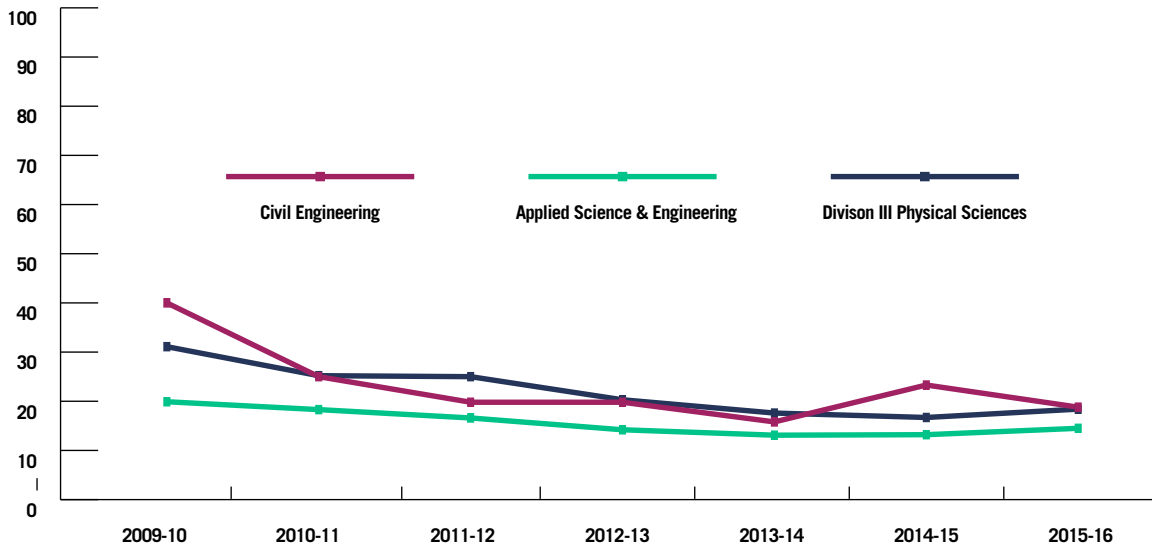
## 3.5 Student Awards and Professional Development

### 3.5.1 Graduate Scholarships

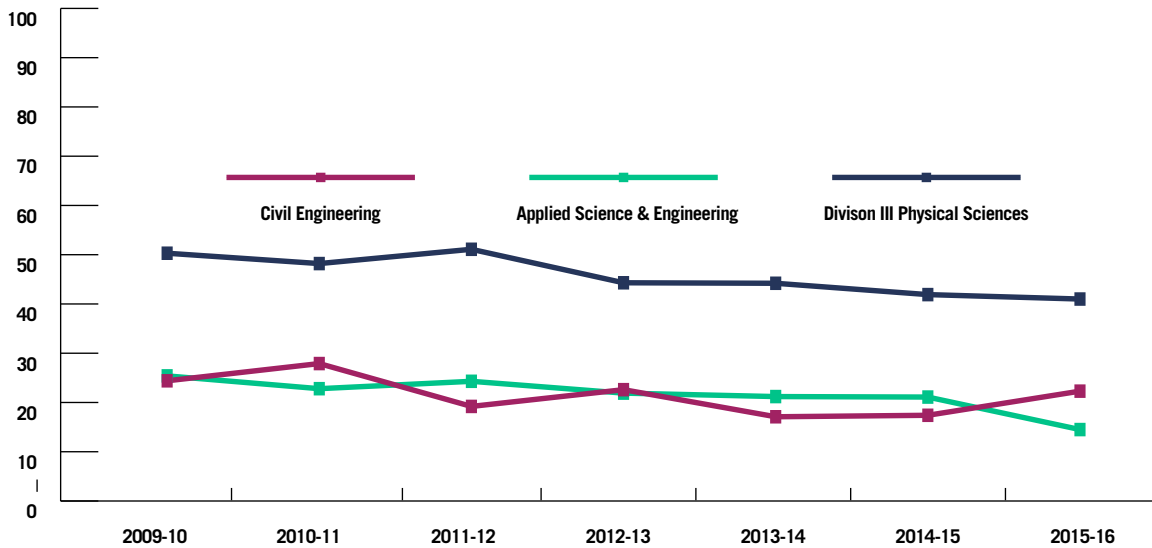
The percentage of full-time Civil Engineering MAsc students receiving external fellowships and scholarships may not be exceptional in and of itself, but the standing of Civil Engineering master's students is undeniably competitive with the percentages attained at both the Faculty and the University's Division III: Physical Sciences levels.

Civil Engineering doctoral-stream students show a comparable level of success in securing external fellowships and scholarships, and are competitive in comparison to the percentage attained at the Faculty level, but well below the success rates established across the division. To a certain extent this can be attributable to targets set by the institution or the funding bodies, such as NSERC, which are often driven by political mandates. However, the Faculty has recently determined to place priority emphasis in the areas of water, sustainability and AI advanced learning, all areas of research that are closely tied to work currently underway within the Department, and we fully expect to see substantial increases in external support over the next few competition rounds. Figure 3.10 and Figure 3.11 depict these trends.

**Figure 3.10 Comparison of Full-Time Master’s Students with External Fellowships/Scholarships Civil Engineering, Faculty of Applied Science and Engineering, and Division III: Physical Sciences**



**Figure 3.11 Comparison of Doctoral-Stream Students with External Fellowships/Scholarships, Civil Engineering, Faculty of Applied Science and Engineering, and Division III: Physical Sciences**



## 3.6 Quality Enhancement

The University provides a wealth of student services designed to enrich and enhance the collective student experience and to assist our students in meeting their academic goals. For example, the University of Toronto Library (UTL) system is the largest academic library in Canada and is currently ranked 4th among academic research libraries in North America. Its research and special collections comprise over 12 million print volumes, 5.6 million microforms, over 17,000 journal subscriptions and rich collections of manuscripts, films and cartographic materials, with access to more than 1.9 million electronic books, journals and primary source materials.<sup>2</sup>

Further, all University of Toronto undergraduate and graduate students have access to student services on all three campuses, Mississauga, St. George (downtown Toronto), and Scarborough, regardless of their “home campus”. These services and co-curricular educational opportunities complement the formal curriculum by engaging and challenging students to reach their full potential as learners, leaders and citizens, and combine to support the success of our students from the time they are admitted through degree completion and beyond. Additionally, the Faculty provides our undergraduate students with a variety of services through the FASE Registrar’s office, and graduate students have access to a wide range of services and co-curricular programs through the School of Graduate Studies (SGS).

A full outline of the support services universally available to University of Toronto undergraduate and graduate students is included in the supplemental documentation section of this report, as is a report detailing the full range of library services available to Civil and Mineral engineering students. An outline of the broadly based (undergraduate) support services provided through the Faculty Registrar’s Office is also appended.

For our part, the process of enhancing the quality of our programs and the associated learning and teaching environment is an ongoing priority for the Department. At the time of the last review the Department structure had a Departmental Academic Planning Committee responsible for all undergraduate and graduate programs in the Department and a Mineral Academic Planning Committee, which dealt with the Lassonde Mineral Engineering undergraduate curriculum. These committees passed resolutions to the Department Academic Planning Committee for approval and forwarding to Departmental Council. In 2017 the Departmental and Mineral Academic Planning Committees were merged to create a new Undergraduate Studies Committee. A new Graduate Studies Committee was also formed to deal exclusively with graduate curriculum and graduate programs. This restructuring accomplished two objectives: increasing cohesion between the Civil and Lassonde Mineral programs that share a number of common courses, and separating undergraduate and graduate curriculum responsibilities to allow greater oversight of the graduate programs.

In preparation for the Fall 2018 CEAB review of our undergraduate programs, the Department is undergoing a thorough curriculum review and mapping of CEAB Graduate Attributes to the Civil and Mineral curricula. This process has involved significant student input.

### 3.6.1 Ancillary Student Support

Each year the Department participates in the Student Levy Fund program to purchase new lab and computer equipment for undergraduate student use. In recent years the Department has spent \$330,000, matched 2:1 by the Engineering Society. Recent purchases include:

<sup>2</sup> Figures as of 2015 taken from UTL’s 2016 Annual Report. <http://www.library.utoronto.ca/library/aboutlibraries/annualreport/2016/AnnualReportUTL2016.pdf>

- weather station for the Gull Lake camp
- new computers for the Undergraduate Computer Labs
- new equipment for the concrete materials and geotechnical engineering labs
- new teaching aids for teaching mechanics and structural engineering
- new software for transportation courses
- new furniture for the CIV and MIN student Common Rooms

The Department created a suite of new faculty offices in the Lassonde Mining Building bringing faculty teaching in the Lassonde Mineral Engineering program together in the same location and closer to the Lassonde Mineral Engineering students. In addition, a new MIN Student Common Room (the Rock Lounge), new graduate student space, and new meeting space were created adjacent to the new faculty offices.

Through a strategic reassignment of space located in the Galbraith Building we were able to add approximately 60 new, and much needed, graduate student office spaces.

### *3.6.2 Challenges and Opportunities*

We have identified the following challenges to our undergraduate programs:

- promoting both of our undergraduate programs more effectively in order to attract a greater share of TrackOne transfers
- developing strategies to better cope with the impact of fluctuations in the mineral industry on enrolment in the Lassonde Mineral Engineering program
- closing the Infrastructure Option in Engineering Science, which will impact our base budget financing revenue relative to teaching
- improving student participation in the Faculty “Multidisciplinary Capstone Program” through developing and leading a greater number of projects that incorporate a strong Civil Engineering component
- reviewing our Civil and Lassonde Mineral Engineering undergraduate curricula to better align lab experiences with course content, and identifying areas where efficiencies may be achieved through amalgamation of course content

Challenges identified with respect to our graduate programs include:

- promoting our doctoral-stream programs more aggressively in order to expand our applicant pool and attract top candidates
- securing more endowed scholarships to help offset the cost of student tuition
- accommodating the growth in our professional programs within a reality of static space and stretched human resources
- growing enrolment in the MEng in Cities Engineering and Management, especially to keep pace with and secure qualitative practicum placements

Opportunities for the undergraduate programs include:

- engaging the Lassonde Advisory Board and the Civil Industry Advisory Board to provide mentoring, networking, and experiential learning opportunities for students
- working with the newly identified Graduate Attribute maps to improve curricula
- developing new labs to correspond with the newly renovated space in the Department
- providing new opportunities for students to learn about issues facing Indigenous peoples
- developing a new Civil-related option in Engineering Science
- adding new elements of sustainability to the curriculum to align with the expertise of recent hires
- developing new teaching approaches to take best advantage of the new TEAL rooms currently under development in the CEIE building

- improving facilities for student counselling by relocating the Student Services Office to new quarters in the Galbraith Building (currently occupied by Advancement).

Opportunities for the graduate programs include:

- introducing new research directions and increasing capacity to capitalize on recent faculty hires
- developing new research opportunities enabled by the Civil Industry Advisory Board, the Lassonde Advisory Board, and the new Director of Corporate Relationships of the Lassonde Institute of Mining
- providing access to new lab facilities currently under development (mining and environment, concrete materials, building science)
- utilizing Department communications personnel to improve branding of graduate programs and highlight the diverse range of research in the Department
- developing an MEng program specialization in mineral engineering
- pursuing acquisition of additional space from Academic Campus Events, made possible as a result of the space opening up in the CEIE Building. ■

# 4. RESEARCH

## 4.1 Overview

The Department of Civil and Mineral Engineering encompasses a highly diversified, interdisciplinary research portfolio. Civil engineering is concerned with all aspects of the urban habitat and the interactions that exist between the built, natural and human environments. Our research in civil engineering creates the knowledge that drives the construction sector, an industry that accounts for 11% of Canada's gross domestic product. The profession is responsible for a built infrastructure that is worth more than \$5-trillion a year in Canada alone. An industry of this size and importance has immense potential to fund research and to benefit from its results. The research foci of faculty within the Mineral Engineering specialization of the Department is ingrained in developing innovative solutions to the challenges facing the mining industry today, not only with a view to improving the operational efficiency of the mine cycle, but to also improve sustainability within the industry through minimizing environmental risks and decreasing financial liabilities.

The span of research activities undertaken within the Department is broadly encapsulated under five overarching thematic areas: Structural Engineering; Transportation Engineering and Planning; Environmental Engineering; Building Engineering; and, Mining and Geomechanics. However, employing these five primary thematic areas does not intend to suggest that the breadth of our research is mutually exclusive of any other areas of investigation. Rather, the overall range of research undertaken within the Department is categorized under these five themes for ease of cohesion. Within each of these primary themes there are several tertiary specializations that research groups branch out to, for example:

### BUILDING ENGINEERING

Building Science  
Concrete Materials  
Construction Management  
Indoor Air Quality  
Information Systems

### TRANSPORTATION ENGINEERING AND PLANNING

Freight Transportation  
Integrated Land Use and Transport Modelling  
Intelligent Transportation Systems  
Public Transportation Operations and Planning

### ENVIRONMENTAL ENGINEERING

Drinking Water Research Group  
Groundwater Research Group  
Low Impact Development  
Sustainable Infrastructure  
Water and Energy Resources

### STRUCTURAL ENGINEERING

Assessment and Rehabilitation  
Bridge Design  
Concrete Structures  
Resilience of Critical Infrastructure  
Seismic Resilience  
Steel Structures  
Structural Dynamics and Earthquake Engineering

### MINING AND GEOMECHANICS

Dynamic Fracture  
Liquefaction and Cemented Paste Backfill  
Mining Engineering  
Numerical Modelling  
Rock Fracture  
Rock Mechanics

The Department supports several affiliated centres and institutes that have evolved out of these diverse areas of investigation, including the Institute for Sustainable Energy, the Centre for Resilience of Critical Infrastructure, the Lassonde Institute of Mining, the University of Toronto Transportation Research Institute (UTTRI), the Institute for Water Innovation, and most recently, the Building Tall Research Centre.

Facilities developed by the Department to directly support our research includes the following:

- Advanced Simulation and Structural Dynamics Laboratory
- Centre for Building Excellence Laboratory
- Structural Testing Facility
- Drinking Water Research Laboratory
- Groundwater Research Laboratory
- Rock Fracture Dynamics and Structures Facility
- Intelligent Transportation Systems Lab
- Concrete Materials Laboratory

## 4.2 Research Highlights

The majority of faculty members associated with the Department of Civil and Mineral Engineering lend their expertise to more than one area of specialization. A listing of our faculty members, grouped within their primary thematic research area and, where applicable, showing the sub-specialization areas their research branches into is attached in Appendix N. The following is a brief synopsis of the research currently underway in the Department within each of the primary thematic research areas.

### 4.2.1 Building Engineering

Building engineering is concerned with the planning, design, construction, operation, renovation, and maintenance of buildings. This encompasses the exploration of all phases of the life cycle of a building as an advanced technological system, and brings into consideration the impacts of buildings on their surrounding environment, as well as the impacts of the surrounding environment on buildings. There are currently eight researchers grouped under this umbrella of the Civil Engineering research portfolio: Tamer El-Diraby, R. Doug Hooton, Brenda McCabe, Daman Panesar, Karl Peterson, Kim Pressnail, Jeffrey Siegel and Marianne Touchie.

Professor **Doug Hooton** is the NSERC/CAC Industrial Research Chair in Concrete Durability and Sustainability. His research involves finding ways to reduce the greenhouse gas emissions associated with concrete infrastructure. He investigates the use of materials such as supplementary cementitious materials and ground limestone to produce a stronger and more durable concrete product. His research has informed the specification codes associated with the American Concrete Institute, the Canadian Standards Association and ASTM standards.

Professor **Daman Panesar** is one of the inaugural recipients of the Erwin Edward Hart Professorship in Civil Engineering, accorded in recognition of high-level research excellence and exemplary graduate student mentorship. A broad objective of Professor Panesar's research is to advance concrete technologies by investigating new types of concrete to reduce environmental impact, improve economic feasibility, achieve desired plastic and mechanical properties, and improve long-term durability performance. Examples of examinations undertaken to date include the study of low carbon footprint materials, nano-cellulose fibers, industrial by-products, supplementary cementing material, and fillers on the durability performance of concrete resulting from coupled degradation mechanisms.

Professor **Karl Peterson**'s research centers on advancing the use of various microscopy techniques and x-ray tomography for analysis of concrete air void systems and microstructure. He is currently working with a number of agencies on methods for analysis of concrete microstructure, and a number of these agencies are now using his automated concrete air-void analysis system.

Professor **Tamer El-Diraby** works in civil informatics, with a focus on using Building Information Modelling (BIM), semantic systems, and social network analysis to promote collaborative management of project knowledge. The software tools he develops serve to improve decision-making associated with construction projects.

Professor **Brenda McCabe** conducts her research in the field, collecting data to develop analysis tools to make the construction site and construction process safer for workers and site visitors. Her work has involved providing consultation to the Toronto Airport Authority on the major renovations recently made to Pearson International Airport and collaborating with the Ministry of Transportation of Ontario to assess the impact of highway construction on traffic. A variety of construction firms apply her research findings to improve the safety and efficiency of their construction processes.

Professor McCabe is also the director of the Building Tall Research Centre (BTRC), a newly developed partnership between academia, industry and government that will act in an advisory capacity to the profession. The express mission of BTRC is to cluster, highlight, and promote research related to tall buildings from multidisciplinary technical perspectives. These areas include, but are not limited to, building science, construction, environment, geomechanics, materials, resilience, structures, sustainability, and water resources.

Professors **Kim Pressnail** and **Jeffrey Siegel** tackle the most fundamental issues in sustainable buildings so that people can make informed decisions about energy use and health.

Professor Siegel's research aims to understand the transport, fate and control of indoor contaminants. His work includes developing a nuanced understanding of how buildings affect the indoor microbiome: the community of microorganisms that are indoors. His research team examines factors that lead to the proliferation of dangerous or pathogenic microorganisms, as well as those that lead to a healthy and diverse microbial community.

Professor Pressnail dedicates his research to improving environmental issues that occur within existing buildings. The scope of his work ranges from developing energy-saving retrofit plans for post-war multi-unit residential towers within urban environments, to improving airflow conditions in rural homes of children with asthma, to remediation of buildings built on contaminated soil, and assessment of buildings with mould and moisture problems.

Professor **Marianne Touchie**'s (cross-appointed to MIE) broad work in building engineering encompasses several aspects of environmental performance: building energy use; indoor environmental quality; thermal comfort; energy modeling; building environmental monitoring; building retrofits; occupant behavior; heat pump technology; low-energy buildings. Currently she is studying the interaction between energy performance and indoor environmental quality in Toronto's aging multi-unit residential buildings, including a number of buildings used for social housing.

Professor Touchie is also the Vice Chair of ASHRAE's Technical Committee 2.1 on Physiology and Human Environment and the Academic Director and Chair of the Building Science Specialist of Ontario (BSSO) Committee for the Ontario Building Envelope Council (OBEC).

### 4.2.2 Structural Engineering

Structural engineers are responsible for engineering design and structural analysis, with practitioners most often specializing in a particular area of structures such as bridge or building engineering, or mega-urban and/or industrial structures. In the Department of Civil and Mineral Engineering, research investigation in structural engineering is broadly encompassed under seven key sub-categories: assessment and rehabilitation, bridge design, concrete structures, infrastructure and critical infrastructure resilience, seismic resilience, steel structures, and structural dynamics and earthquake engineering. The following summaries profile the research undertaken by the ten principal investigators in the Department who are currently working within this field: Fae Azhari, Evan Bentz, Constantin Christopoulos, Michael Collins, D. Paul Gauvreau, Oh-Sung Kwon, Oya Mercan, Jeffrey Packer, Shamim Sheikh and Frank Vecchio.

The focus of Professor **Fae Azhari's** (cross-appointed to MIE) research is in Structural Health Monitoring (SHM), which is a methodology employed to accurately monitor the behaviour of structures by constantly assessing their performance, and providing continuous data on their current conditions. She is working to adapt existing technologies and methods to create novel solutions for SHM and prognosis, with the goal of addressing some of the gaps in the succession of tasks from sensor development to implementation and decision analytics.

Professor **Evan Bentz** is an expert in the development of structural software, Professor **Frank Vecchio**, a Bahen/Tanenbaum Professor in Civil Engineering specializes in structural modelling, and University Professor **Michael Collins** is a world- renowned expert in research involving reinforced concrete. Collectively they are addressing the problem of how engineers can use new approaches in design to better assess and repair structures before catastrophe strikes.

Hypotheses on the mechanisms of building collapse are validated using the U of T-designed Shell Element Tester located in the Civil Engineering Structural Testing Facility. This is the only facility of its kind in Canada capable of testing full-scale shell elements subjected to all eight possible force components. Combined with the U of T-designed structural analysis software, "Response", these researchers can predict the behaviour of structures in extreme circumstances. The "Response" software has helped revolutionize building codes across Canada, the United States and Europe. The advances in testing scope and precision that these collaborators have made will help to make building assessment and maintenance faster and more efficient, enabling engineers to more accurately predict which structures are safe following seismic events, thereby saving lives and reducing costs.

Professor **Constantin Christopoulos** holds the Canada Research Chair in Seismic Resilience. Professor **Jeffrey Packer** is a Bahen/Tanenbaum Professor of Civil Engineering. Together they work with the interdisciplinary Centre for Resilience of Critical Infrastructure to perform large-scale tests under real-time loading conditions. Their objective is to assess and develop cost effective designs that will mitigate the vibrations caused by seismic events and severe winds, thus enhancing the comfort and safety of occupants in tall buildings.

Other ongoing research includes investigations of welds in steel hollow structural connections, shock load tests on steel and glass, and blast testing using a simulator that is unique in Canada.

A former NSERC Chair in Design Engineering, Professor **Paul Gauvreau** specializes in bridge design. He is working on developing new bridge systems that make efficient use of new materials such as high-strength concrete, emerging reinforcement materials, and innovative wood products. His work also examines sustainable bridge design, bridge aesthetics and the development of simple, rational models for visualizing the flow of forces in reinforced and pre-stressed concrete structures. His research findings help to validate new bridge designs and building materials that use fewer, more highly developed technological substances, thus minimizing environmental and economic tolls.

Professors **Oh-Sung Kwon** and **Oya Mercan** are advancing hybrid simulation techniques that combine numerical models and experimental specimens using computer technology to determine how buildings will respond to seismic activity. The programming of the computational/control platform used to conduct experiments, which allows engineers to manipulate code, was developed in-house. Experimenting with a myriad of algorithms rather than being limited to predetermined programs, the research group has developed an integrated simulation framework that can seamlessly integrate numerical models in several analysis platforms and experimental specimens in geographically distributed laboratories.

Multiple tests conducted across several laboratories worldwide is helping to develop technology that more accurately and efficiently predicts structural behaviour during extreme seismic events. Through this integrated simulation framework, a regional scale simulation will be possible which will help evaluate the resilience of urban infrastructure.

Professor **Shamim Sheikh's** current research is in the areas of seismic resistance of concrete structures and the use of fiber reinforced polymers as a replacement for steel to develop corrosion-free concrete structures. Steel corrosion is one of the biggest drains on the economy and our infrastructure resources. Professor Sheikh's work is focused on seismic upgrade and rehabilitation of existing structures as well as building new structures for longer service life. This ongoing work has led to the development of better design procedures, more efficient structures, and a quicker turnaround time for the rehabilitation of structures needed by all associated stakeholders.

### *4.2.3 Transportation Engineering and Planning*

Transportation Engineering and Planning at U of T combines scientific analysis and the use of technology to inform the planning, functional design, operation and management of transportation infrastructure and monitoring systems. There are six lead researchers within the Department dedicated to this area of investigation: Baher Abdulhai, Khandker Nurul Habib, Marianne Hatzopoulou, Eric Miller, Matthew Roorda and Amer Shalaby.

Professor **Baher Abdulhai** is investigating new ways to alleviate gridlock and manage congestion using Intelligent Transportation Systems (ITS) technologies and software. His research team has developed a multiple-agent system reinforcement learning integrated network (MARLIN), which they are applying to traffic control systems in urban intersections. Although the idea of intelligent traffic infrastructure is not a new one, MARLIN is unique in that it allows decentralized placement of intelligence within each traffic light. This avoids the need for expensive communications infrastructure, or for a centralized staffed control room, which translates into municipal cost savings and enhanced reliability over other systems currently in use.

Professor **Matt Roorda** holds the Canada Research Chair in Freight Transportation and Logistics and heads up the Centre for Urban Freight Analysis. The mandate of the Centre is to examine new methods for improving the efficiency and sustainability of urban freight operations, achieved through using optimization methods to reduce travel distances, assessing the use of alternative fuel vehicles, encouraging the delivery of goods outside of the times when congestion is worst, and considering population exposure to truck emissions.

Data resources are vital to this research, so a combination of survey data, truck GPS data, roadside sensors, and other “big data” sources are culled to inform the investigation. The development of new approaches to collecting, combining and analyzing freight data sources is another major challenge that is being addressed by this research team. Their work will lead to a more deliberate approach to urban freight policies, such as curbside parking for trucks in downtown areas, sustainable logistics concepts for industry partners, and the determination of long-term infrastructure decisions within municipalities.

Professor **Amer Shalaby** focuses his research on crowds and congestion, both at the local and global levels, with particular emphasis on disruption management. This work intends to help transportation authorities to respond more effectively to unexpected impediments or crises within a network, and permit the rerouting of passengers without seriously affecting migration patterns. As this work continues to evolve it will have ramifications for predicting crowd behaviours on micro levels, such as subways and other public transit applications, where large crowd congestions occur.

Professor **Marianne Hatzopoulou** is the Canada Research Chair in Transportation and Air Quality (TRAQ). Her research specializes in the simulation of road transport emissions and urban air quality to evaluate population exposure to air pollution. This involves investigating how transport emissions are generated, how they disperse into urban environments, and the targets of exposure. Traffic patterns, road design, and characteristics of the built environment are examined to identify ways they can be modified to improve air quality in urban areas.

Professor Hatzopoulou’s work has shown that improving traffic operations in large cities can achieve significant reductions in air pollution and greenhouse gas emissions, irrespective of the need to rely on alternative fuels. Her efforts in developing new technologies such as micro and mobile sensors is changing the way air pollution is being monitored and mapped in urban areas.

Professors **Khandker Nurul Habib** and **Eric Miller** focus their research investigations within the area of transportation modelling and simulation.

Professor Khandker Nurul Habib develops mathematical, behavioural models to ascertain how human beings currently move from one location to another, and the multiple ways in which people respond to changes in the urban infrastructure. Using activity-based travel modelling, his research group assesses the choices people make and why they make them. Municipal planners frequently reference the models generated when making evidence-based planning decisions.

Professor Eric Miller is a well-known and highly regarded pioneer in the development and application of agent-based microsimulation model systems in high-performance computing environments. As director of the University of Toronto Transportation Research Institute (UTTRI), his research is centered in the implementation of activity-based travel models for use in operational practice.

This includes the development of integrated transportation-land use models that permit the analysis of the two-way interaction between transportation systems and urban form. His work serves to improve urban transportation best practices and policy decision-making and, thereby improves the quality of life in urban settings.

Professor Miller has also played a key role in establishing the Data Management Group (DMG), which provides data to government agencies, private sector partners working for government, and university researchers in support of a wide variety of travel behaviour analyses and modelling activities. He was also instrumental in the creation of the Travel Modelling Group (TMG), a research consortium that seeks to provide a forum and mechanism for inter-agency collaboration that will lead to improved travel modelling practice for all. Current GTHA transportation agency partners in TMG include Metrolinx, the Ontario Ministry of Transportation, the Cities of Toronto, Hamilton, Mississauga and the Regions of Durham, York, Peel and Halton. Professor Miller currently serves as TMG’s Research Director.

#### 4.2.4 Environmental Engineering

Environmental Engineering is a wide-ranging sub-discipline of engineering concerned with the application of scientific and engineering principles to protect, improve and/or remediate our natural environment from the adverse effects resulting from both natural phenomena and human activities. It also encompasses issues of public health as pertains to wastewater management and waterborne diseases, waste disposal and sanitation in urban and rural settings, air pollution control and energy conservation, and environmental sustainability.

The Environmental Engineering group of researchers in the Department comprises one its largest areas of specialization, with ten principal investigators leading this arm of our mission. Their research is generally categorized under six key areas: drinking water, groundwater, water and energy resources, surface water, low impact development, and sustainable infrastructure.

Environmental Engineering researchers include professors Robert Andrews, Susan Andrews, Jennifer Drake, Ron Hofmann, Bryan Karney, Heather MacLean, Elodie Passeport, Daniel Posen, Shoshanna Saxe and Brent Sleep.

Professors **Robert Andrews**, NSERC Industrial Research Chair in Source Water Quality Monitoring and Advanced/Emerging Technologies for Drinking Water Treatment, **Ron Hofmann**, NSERC Associate Industrial Chair in Technologies for Drinking Water Treatment, and **Susan Andrews**, Associate Chair – Graduate Studies, comprise the Drinking Water Research Group (DWRG). Their research hub is home to one of the most comprehensive water research laboratories in Canada, providing access to more than \$3-million worth of analytical equipment that facilitates detection and monitoring of emerging contaminants.

Collectively they conduct full-scale pilot research with industry partners, governments, and agencies around the world on water-related issues ranging from microbial risk assessment, to photolysis-based advanced oxidation, effectiveness of granular activated carbon and ferrate treatments, and the development of computer applications for improved water quality that generate lower environmental impacts and reduced economic costs. Research completed in the Drinking Water Research Group has had a profound and direct impact on government policies related to the treatment and protection of drinking water. This includes the water treatment methods currently used in water facilities in the Greater Toronto Area, and expert recommendations made to the Ontario Ministry of the Environment and Climate Change. The DWRG is currently working on a variety of advanced water treatment technologies for use in resource-limited and drought-ridden regions.

Professors **Jennifer Drake** and **Bryan Karney** are working to solve the problem of how to sustain our limited water and energy resources while simultaneously continuing to accommodate the growing worldwide demand on these resources. Both researchers collaborate with industry and government partners to identify ways to increase efficiency in regional water, storm water and sewage distribution systems, and hydro dams. Utilizing emergent methodologies such as low impact development, and newer sensor technologies for advanced performance monitoring, they seek to move engineering knowledge beyond the static models conventionally used for evaluating the sustainability of systems. Their work will help equip engineers with the ability to monitor and predict issues before they arise, to gauge risk before failures occur, to generate less waste, and to develop better policies that will lead to a more sustainable future.

Professor **Heather MacLean** conducts research in infrastructure systems design, green building design, greenhouse gas emissions, energy conservation and life-cycle cost/benefit analyses. Her aim is to advance scientific and engineering knowledge in the developing field of systems analysis for sustainable engineering, and the approach taken is widely interdisciplinary, incorporating environmental, civil, chemical and mechanical engineering, economics and public policy components. Some of the topical areas she has recently explored include life cycle assessment and techno-

economic methods incorporating uncertainty, bioenergy systems including bio-based electricity and liquid fuels (ethanol, hydrogen, and aviation fuels), conventional and alternative light-duty and medium-duty vehicles, conventional and unconventional fossil fuels, sustainable and resilient cities, and sustainable infrastructure.

Professor **Daniel Posen**'s research is rooted in system-scale environmental sustainability analysis. His work draws on a range of tools from engineering, science, economics, and public policy to provide quantitative analysis that will guide environmental policy and decision-making. Current projects involve prioritizing greenhouse gas mitigation strategies (with a focus on urban environments), and on selecting among competing uses for biomass.

Professor **Shoshanna Saxe**'s primary expertise is in life cycle greenhouse gas evaluation of rail infrastructure, including the impacts of construction, operation, influence on travel behaviour and interactions with land use. Her current research focuses on the intersection of mega infrastructure development and long-term sustainability goals. She carries out ex-post studies of working infrastructure to better-understand the complex ways large-scale civil infrastructure interacts with society.

Professors **Brent Sleep** and **Elodie Passeport** conduct hybrid research with laboratory experimentation, field studies and computer modelling to determine the fate and transport of organic chemicals in the subsurface and surface aquatic environments.

More specifically, Professor Brent Sleep's research is dedicated to developing innovative methods for remediation of soil and groundwater contamination, with a focus on organic contaminants. His research group is working on a variety of in-situ subsurface remediation methods, conducting laboratory and computer modelling studies of bioremediation, thermal remediation, and the applications of chemical oxidants and nanoscale zero valent iron for subsurface remediation. His group is also investigating the transport of pathogens in fractured rock aquifers.

Professor Elodie Passeport is the Canada Research Chair in Environmental Engineering and Stable Isotopes. Her research involves developing analytical tools based on stable isotope to study the behavior of organic chemicals in surface water environments such as rivers and lakes. Her research context spans from contaminated groundwater, wastewaters, industrial and agricultural effluents, to radiological pollution.

Results gained through this research is used by industrial partners to assess risk factors when contaminants enter a site, and to develop comprehensive remediation schemes that can more fully address environmental and health requirements.

#### 4.2.5 *Mining and Geomechanics*

Geomechanics is concerned with the behaviour of soil from a small scale to a landslide scale, and with rock mass characterization and rock mass mechanics, usually as applied to the petroleum industry, high depths, tunnel design, rock breakage, and rock drilling.

The breadth of research undertaken by the eight researchers associated with the Mining and Geomechanics group in the Civil and Mineral Engineering department is both impressive and comprehensive. Their collective research foci spans mechanics and geometry of fractured rock masses, engineering design of rock masses, laboratory study of dynamic earthquake ruptures, dynamic friction, mode I and mixed mode spontaneous fractures, dynamic response of materials under elevated temperature, failure analysis of composites, mechanical properties of multi-

phase granular materials, nano-adhesion of bio-inspired materials, and smart materials for sensor technology.

The Mining and Geomechanics researchers consist of professors Kamran Esmaili, Mason Ghafghazi, Murray Grabinsky, Giovanni Grasselli, John Hadjigeorgiou, John Harrison, Lesley Warren and Kaiwen Xia.

Professor **Murray Grabinsky** holds the Robert M. Smith Chair in Geotechnical Mine Design and Analysis. His research focuses on the conversion of mine tailings to Cemented Paste Backfill (CPB) for more efficient and safe handling of the waste material generated during the mining process. The CPB is produced through liquidation of the mine tailings that are mixed with a binder. However, his investigation goes beyond the traditional areas of liquefaction research and explores innovative new areas including the effects of binder hydration, sustained high frequency loading, heterogeneous in-situ conditions, and the use of rheology. Fieldwork is complemented by the development and application of numerical models and laboratory testing with the unique facilities developed in-house for CPB research.

Professor Grabinsky's research is conducted in partnership with mining companies that produce large quantities of tailings, which has led his fieldwork to mines located in Canada, South America and Africa.

Professor **Kamran Esmaili** leads the work undertaken in the Mine Modeling and Analytics lab. His research strives to explore development of predictive analytics and smart modeling solutions for the mining industry that allows better mine design and continuous mining process control and optimization. The ongoing research projects fall into the following three key interrelated areas:

- development of innovative methods for real-time acquisition of high-resolution mining data, digital transformation of mining data, data integration, analytics and visualization;
- development of predictive 3D spatial models of rock mass properties (i.e. Geomechanical, Structural and Geometallurgical models) based on advanced statistical and geostatistical techniques; and,
- investigation of the influence of rock mass heterogeneity and anisotropy on its responses when subjected to different static and dynamic loading conditions (i.e. influence of heterogeneity and anisotropy on rock mass strength, fragmentation and stability).

The Mine Modelling and Analytics lab is equipped with a variety of computing tools to facilitate design of enhanced mining sites, and to run numerical simulations for analysis. The lab also has access to excellent field measurement tools including: a multi-sensor core logging facility (high-resolution 360-degree core scanner, Leeb Equotip hardness tester, Acoustic emission test, Schmidt hammer), a DJI-Matrices 600 Pro Drone, LiDAR, and Photogrammetry camera.

Professor **Mason Ghafghazi** works in the area of geotechnical engineering to create models that compute the response of geomaterials found in nature, such as gravel-sand-clay mixtures, or produced by human activity, for example mine tailings, to assess how structures will perform in the long term and under extreme events such as storms, floods and earthquakes.

The research process involves establishing an understanding of the fundamental behaviour of different materials through laboratory testing, and then developing mathematical models to replicate and predict variables such as stress-strain response, volumetric strains, and excess pore water pressure. The models generated are used to analyze field characterization tools to demonstrate how the interpretation of these tests would be affected by various soil properties. Large scale laboratory testing is performed to validate the predictions.

Professor **Giovanni Grasselli** is the NSERC-Foundation CMG Industrial Research Chair in Fundamental Petroleum Rock Physics and Rock Mechanics. His work is concentrated in examining the development of rock fractures under a range of thermohydro-mechanical conditions. This involves fundamental lab studies using x-ray tomography, and advanced numerical modelling using hybrid finite element discrete element methods (fem-dem). Professor Grasselli's lab is equipped with state of the art field measurement tools including the aforementioned point load tester, Schmidt hammer, and 3D laser scanner for rock fracture mapping.

By combining fundamental principles of rock physics and rock mechanics with seismic imaging, his research will help in the development of technology for smarter, unconventional petroleum production, while reducing environmental impacts and contributing towards safer field operations.

Professor **Kaiwen Xia** is seeking to advance the understanding of the fracturing of rocks through dynamic testing using a variety of innovative approaches. This includes extensive development and application of the split-Hopkinson bar apparatus. Improved understanding of fractures, cracks and micro cracks is providing new insights into the formation of earthquakes, and leading to better methods for predicting stability of rock masses for application in mining, tunnelling, hydrocarbon reservoir production, and rock slope stability.

Professor **John Hadjigeorgiou** holds the Pierre Lassonde Chair in Mining Engineering. He works in the areas of rock characterization, slope stability, tunnelling, reinforcement and support, and mine design. Specifically, he is investigating the behavior of mesh as a surface support in underground mines through detailed field observations and numerical modeling. He serves as a consultant to major mining companies, advising on the management of mining risk and its impact on operations. He has worked on mining projects in North and South America, Australia, Europe and Africa.

Professor **John Harrison** holds the W.M. Keck Chair in Engineering Rock Mechanics. His research is placed in the development of probabilistic and non-probabilistic methods for rock engineering design within the context of reliability-based design codes. The introduction and refinement of codes based on reliability-based design influences rock engineering and rock mechanics practices on a global level, and serves to reduce the level of risk and improve the economic efficiency of construction and mining sites.

Professor **Lesley Warren** holds the Claudette MacKay-Lassonde Chair in Mineral Engineering, and serves as the director of the Lassonde Institute of Mining. She is an applied scientist who combines geochemistry with molecular and experimental microbiology to identify the processes that affect water quality and reclamation efficacy. Her research intends to offer innovative new solutions for the minerals and energy sectors through integrating emerging molecular biological techniques initially developed for public health, and applying them to mining contexts to explore the roles of uncharacterized bacteria in affecting water quality. The information produced through her research will help to create new biologically informed practical tools to enhance environmental practice in the mining industry.

### 4.3 Research Impact and Assessment

The success of our research can be measured via a number of sources. Our consistent competitive standing in international rankings is certainly one benchmark that provides a quick assessment. Success can also be measured through the recognition of the strength of our research as reflected in our ability to compete for, and secure external funding. The recognition of our faculty in securing named awards, and support of our work through the creation of endowed funds, also provides meaningful insight. Additionally, our faculty's collective involvement and contribution to professional codes and standards are further indicators of recognition for our standard of excellence and leadership among our professional discipline. Table 4.1 and Table 4.2 indicate our success within each of these measures.

Civil and Mineral Engineering researchers are extremely proactive participants in Tri-Council awards competitions, with an average of 90% of eligible faculty competing on an annual basis.

**Table 4.1 Comparison of Participation Rates for Tri-Council Funding: Department of Civil and Mineral Engineering, Faculty of Applied Science and Engineering, Division III, and All U of T 2009-2013**

Eligible					
Department	2009	2010	2011	2012	2013
Department of Civil Engineering	32	34	36	33	35
Faculty of Applied Science and Engineering	198	200	205	206	218
Division III Physical Sciences	456	450	459	460	462
All UT Departments	1,951	1,961	1,982	1,936	1,973
Participating					
Department	2010-11	2011-12	2012-13	2013-14	2014-15
Department of Civil Engineering	29	31	30	31	34
Faculty of Applied Science and Engineering	187	189	187	196	206
Division III Physical Sciences	417	414	415	430	430
All UT Departments	1,286	1,286	1,293	1,307	1,270
Percent Participating					
Department	2010-11	2011-12	2012-13	2013-14	2014-15
Department of Civil Engineering	91%	91%	83%	94%	97%
Faculty of Applied Science and Engineering	94%	95%	91%	95%	94%
Division III Physical Sciences	91%	92%	90%	93%	93%
All UT Departments	66%	66%	65%	68%	64%

Data Sources: Fall 2006 to 2013 academic databases (VP-FAL) for eligible faculty (and their SGS division, faculty and department of primary appointment)

Notes:

1. Faculty members included in the "Eligible" columns were selected using the following criteria: tenure/tenure-stream professorial ranks paid by U of T.
2. Faculty members included in "Participating" columns were selected from Research Services' internal records if they fulfilled one of the following criteria:
  - a) Holds a grant from a Tri-Council CRC-eligible program with an instalment between April and March in each year, or b) Applied for a grant from a Tri-Council CRC-eligible program between June of the preceding year and December of the stated period.

Our success in securing Tri-Council funding can be measured by the number of grants awarded, and in this our faculty researchers have succeeded at a steady rate above 80% in the most recent competition cycles, on par with the averages achieved within the Faculty, and well above the institutional and national levels.

**Table 4.2 Comparison of Success in Tri-Council Grant Applications, Department of Civil and Mineral Engineering, Faculty of Applied Science and Engineering, U of T, and National Average: NSERC Discovery Grant**

Grant Start Year		2009	2010	2011	2012	2013	2014	2015	2016*
Department of Civil Engineering	Applications	6	5	9	9	9	10	6	9
	Successful	4	4	6	8	6	10	5	8
	Success rate	66.67%	80.00%	66.67%	88.89%	66.67%	100.00%	83.33%	88.89%
FASE	Applications	57	43	49	51	64	70	53	45
	Awarded	52	36	39	44	51	61	45	36
	Success rate	91.2%	83.7%	79.6%	86.3%	79.7%	87.1%	84.9%	80.0%
U of T	Applications	228	209	219	230	244	237	257	236
	Awarded	177	149	158	176	163	175	195	180
	Success rate	77.6%	71.3%	72.1%	76.5%	66.8%	73.8%	75.9%	76.3%
National	Applications	3,257	3,379	3,499	3,501	3,488	3,208	3,239	3,167
	Awarded	2,091	1,963	2,018	2,183	2,058	2,045	2,110	2,094
	Success rate	64.2%	58.1%	57.7%	62.4%	59.0%	63.7%	65.1%	66.1%

Notes:

Preliminary data is based on U of T internal records

Data of Faculty and U of T derived from Research Information Systems data, 2009 to 2016; National data from NSERC reports, 2009 to 2015

A breakdown of the amount of research funding awarded by agency is expressed in Table 4.3. In 2016, Tri-Council funding (via NSERC) represented 36.67% of the Department's total research funding, institutional initiatives comprised a total of 18.5%, and 17.8% was derived from other government sources. Funding acquired from corporate sources accounted for 9.43%, and not-for-profit was on par with institutional initiatives at 17.52%. The funding base available through government sources has been steadily decreasing over the past several years, while competition for these awards has steadily increased, and as such a concerted effort to expand our outreach for research support through the corporate and non-for-profit sectors will be a focal point for the Department over the coming years. With the Faculty's stated commitment to further innovative research in the areas of water, sustainability and AI advanced learning, all key areas of active research within the Department, we are confident that we are well positioned to continue our work on solid funding ground.

The tables below show the primary categories of research funding sources, and depicts the Department's performance within each of these categories.

**Table 4.3 Funding Amount Awarded Pro-rated to Grant Year (April-March) – Civil Engineering**

Funding Source	2009	2010	2011	2012	2013	2014	2015	2016
	\$ millions	\$ millions	\$ millions	\$ millions	\$ millions	\$ millions	\$ millions	\$ millions
Tri-Council	\$1.681	\$1.759	\$1.951	\$1.900	\$1.906	\$2.278	\$2.285	\$3.128
Institutional Initiatives	\$2.234	\$1.003	\$0.861	\$0.530	\$0.936	\$2.300	\$1.005	\$1.578
Government, Other	\$1.018	\$0.556	\$0.642	\$1.210	\$1.397	\$1.290	\$1.531	\$1.524
Corporate	\$0.921	\$0.733	\$0.672	\$0.582	\$0.584	\$0.549	\$0.482	\$0.804
Not-for-profit	\$1.535	\$1.971	\$2.021	\$1.668	\$1.912	\$2.372	\$1.759	\$1.494
<b>Total</b>	<b>\$7.389</b>	<b>\$6.023</b>	<b>\$6.148</b>	<b>\$5.889</b>	<b>\$6.735</b>	<b>\$8.788</b>	<b>\$7.061</b>	<b>\$8.527</b>

**Table 4.4 Active Award Count Pro-rated to Grant Year (April-March) – Civil Engineering**

Funding Source	2009	2010	2011	2012	2013	2014	2015	2016
Tri-Council	52	51	55	61	66	75	72	86
Institutional Initiatives	16	21	20	15	14	17	21	27
Government, Other	47	34	38	42	34	27	40	37
Corporate	21	19	23	21	22	21	21	28
Not-for-profit	39	40	37	44	48	55	44	43
<b>Total</b>	<b>175</b>	<b>165</b>	<b>173</b>	<b>183</b>	<b>184</b>	<b>195</b>	<b>198</b>	<b>221</b>

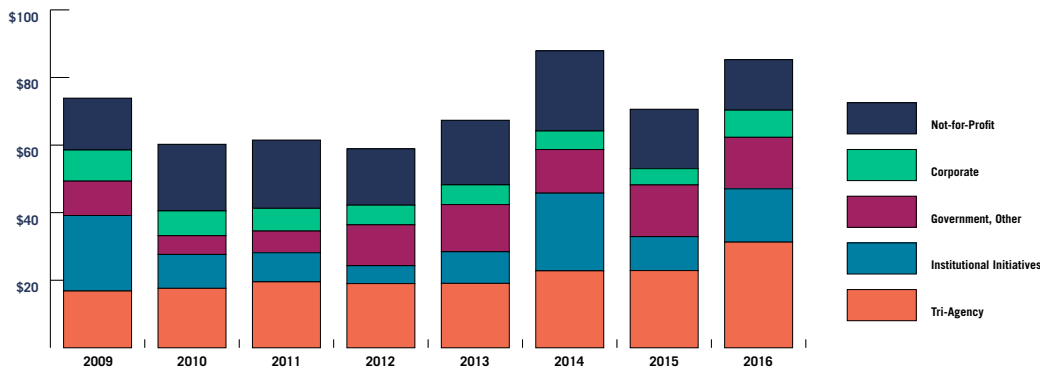
Data Source: UTBI Research Datacube (February 2017)

**Table 4.5 Composition of Funding Awarded as a Percentage of Total – Civil Engineering (Pro-rated to Grant Year (April-March))**

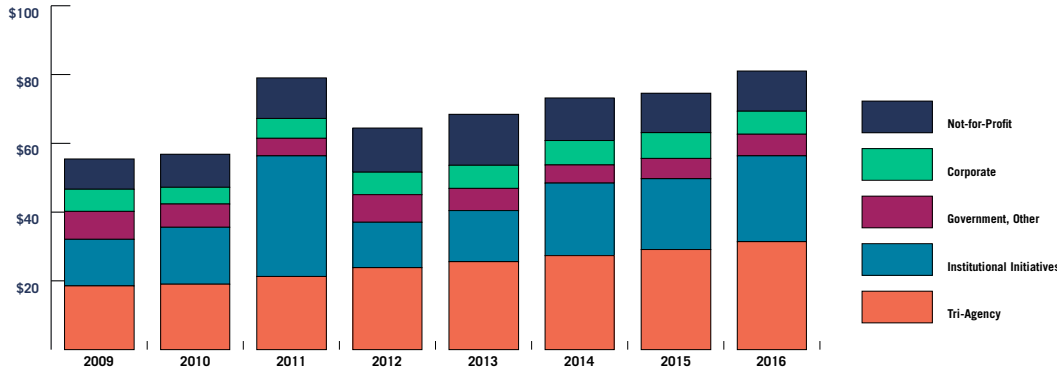
Funding Source	2009	2010	2011	2012	2013	2014	2015	2016
	% of Total	% of Total	% of Total	% of Total	% of Total	% of Total	% of Total	% of Total
Tri-Council	22.75%	29.21%	31.74%	32.27%	28.31%	25.92%	32.36%	36.68%
Institutional Initiatives	30.23%	16.66%	14.01%	8.99%	13.90%	26.17%	14.23%	18.50%
Government, Other	13.78%	9.23%	10.45%	20.54%	20.74%	14.68%	21.68%	17.87%
Corporate	12.47%	12.17%	10.94%	9.88%	8.67%	6.25%	6.82%	9.43%
Not-for-profit	20.77%	32.73%	32.87%	28.32%	28.38%	26.99%	24.91%	17.52%
<b>Total \$-millions</b>	<b>\$7.389</b>	<b>\$6.023</b>	<b>\$6.148</b>	<b>\$5.889</b>	<b>\$6.735</b>	<b>\$8.788</b>	<b>\$7.061</b>	<b>\$8.527</b>

The composition of the Department’s research portfolio is consistent with the funding matrix of the Faculty as a whole, as shown in Figure 4.1 and Figure 4.2.

**Figure 4.1 Composition of Research Funding Department of Civil and Mineral Engineering 2009 to 2016 by Grant Year (April-March)**



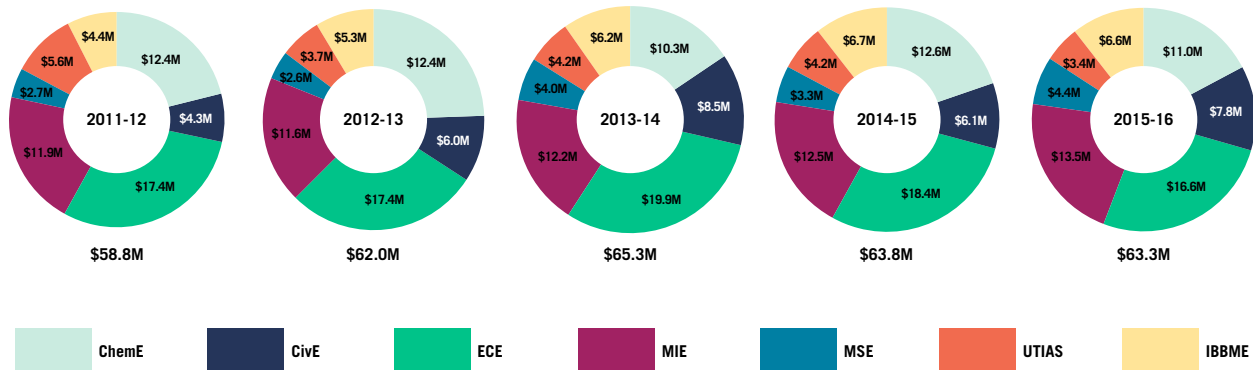
**Figure 4.2 Composition of Research Funding Faculty of Applied Science and Engineering 2009 to 2016 by Grant Year (April-March)**



Data Source: UTBI Research Datacube.(February 2017)

The Department's contribution to research operating funding approximates 8-10% of the total amount of research funding secured across the Faculty per year, which is also consistent with other FASE departments of comparable size. Figure 4.3 shows a comparison of the distribution of research operating funding across the Faculty by academic unit. Table 4.6 summarizes the percentage of the Department's contribution in comparison to the Faculty.

**Figure 4.3 Distribution of Research Operating Funding by Academic Area 2011/2012 to 2015/2016**



**Table 4.6 Percentage of Contribution of Civil and Mineral Engineering Research Operating Funding in Comparison to Total Funding Faculty of Applied Science and Engineering 2011-12 to 2015-16 by Fiscal Year (May-April)**

	2011-12	2012-13	2013-14	2014-15	2015-16
Total Research Funding FASE (in \$ millions)	58.8	62	65.3	63.8	63.3
Total Research Funding CivE (in \$ millions)	4.3	6	8.5	6.1	7.8
CIV Contribution by Percentage of Total	7.32%	9.68%	13%	9.59%	12.33%

### 4.3.1 Research Awards

Many of the faculty members of the Civil and Mineral Engineering department hold a major designation or named affiliation respective to their primary research portfolio. Specifically 19 of 42, or roughly 42% of faculty members appointed to the Department hold a named designation. Table 4.7 summarizes these designations.

**Table 4.7 Department of Civil and Mineral Engineering Faculty Research Designations**

Faculty	Primary Research Theme	Named Appointment
<b>Baher Abdulhai</b>	Transportation Engineering and Planning	Director, Centre for Automated and Transformative Transportation Systems (iCITY)
<b>Robert Andrews</b>	Environmental Engineering	NSERC Industrial Research Chair in Source Water Quality Monitoring and Advanced/Emerging Technologies for Drinking Water Treatment
<b>Constantin Christopoulos</b>	Structural Engineering	Canada Research Chair in Seismic Resilience
<b>Michael Collins</b>	Structural Engineering	University Professor
<b>Murray Grabinsky</b>	Mining and Geomechanics	Robert M Smith Chair in Geotechnical Mine Design
<b>Giovanni Grasselli</b>	Mining and Geomechanics	NSERC-Foundation CMG Industrial Research Chair in Fundamental Rock Physics and Rock Mechanics
<b>John Hadjigeorgiou</b>	Mining and Geomechanics	Pierre Lassonde Chair in Mining Engineering
<b>John Harrison</b>	Mining and Geomechanics	W.M. Keck Chair in Engineering Mechanics
<b>Marianne Hatzopoulou</b>	Transportation Engineering and Planning	Canada Research Chair in Transportation and Air Quality (TRAQ)
<b>Ronald Hofmann</b>	Environmental Engineering	NSERC Associate Industrial Research Chair in Technologies for Drinking Water Treatment
<b>R. Douglas Hooton</b>	Building Engineering	NSERC/CAC Industrial Research Chair in Concrete Durability and Sustainability
<b>Brenda McCabe</b>	Building Engineering	Director, Building Tall Research Centre
<b>Eric Miller</b>	Transportation Engineering and Planning	Director, University of Toronto Transportation Research Institute (UTTRI) Director, Data Management Group Director, Travel Modelling Group
<b>Jeffrey Packer</b>	Structural Engineering	Bahen/Tanenbaum Professor of Civil Engineering
<b>Daman Panesar</b>	Building Engineering	Erwin Edward Hart Professor in Civil Engineering
<b>Elodie Passeport</b>	Environmental Engineering	Canada Research Chair in Environmental Engineering and Stable Isotopes
<b>Matthew Roorda</b>	Transportation Engineering and Planning	Canada Research Chair in Freight Transportation and Logistics
<b>Frank Vecchio</b>	Structural Engineering	Bahen/Tanenbaum Professor of Civil Engineering
<b>Lesley Warren</b>	Mining and Geomechanics	Claudette Mackay-Lassonde Chair in Mineral Engineering Director, Lassonde Institute of Mining

The expertise of our faculty is recognized and affirmed through the numerous, substantive research awards accorded to them. For example, Professor Brent Sleep received an Ontario Research Fund (ORF) grant from the Ministry of Research, Innovation and Science to explore technologies for remediating contaminated groundwater. He also holds an NSERC CREATE grant which supports the development of the Remediation Education Network (RENEW). A primary objective of this initiative is to provide training to the next generation of engineers and scientists in the interdisciplinary professional and technical skills they need to work at cleaning up the most challenging contaminated sites in Canada.

Likewise, Professor Eric Miller and colleagues secured an ORF for the iCity project, focused in examining urban informatics for sustainable metropolitan growth. The CMG Reservoir Simulation Foundation/Foundation CMG (Computer Modelling Group) is sponsoring Professor Giovanni Grasselli's research in fundamental petroleum rock physics and rock mechanics, and the Canadian Nuclear Safety Commission is providing financial support to Professor Daman Panesar for her investigation into the consequences of concrete alkali aggregate reaction on existing nuclear structures. In 2014, Professor Leslie Warren was awarded a significant NSERC Collaborative Research and Development grant to support field investigation of BML water cap oxygen concentrations in partnership with Syncrude Canada. In 2016, she secured a substantial Genome Canada grant to explore mine wastewater solutions in association with a number of leading mining companies, mining associations and mining consulting groups, and the Barrick Gold Corporation is sponsoring Professor Murray Grabinsky's investigation into high performance cemented past backfill.

All of the above noted initiatives have received funding in excess of \$500,000. This represents only a sampling of the diverse research underway across the Department. Most of our faculty members have secured funding for multiple projects, with funds provided through a range of sources, and the majority of our investigators are supervising a minimum of eight funded projects at any given time. A full listing of funded projects by funding source can be found in Appendix O.

Our faculty researchers are also well recognized by virtue of the number of prestigious professional awards conferred to them. For example, at the international level in 2016-17 Professor Jeffrey Packer was named a fellow of the American Association for the Advancement of Science, Professor Frank Vecchio received the American Concrete Institute (ACI) Joe. W. Kelly Award, accorded for outstanding contributions to education in the broad field of concrete, and Professor Douglas Hooton received the ACI George C. Hoff Award for Concrete Technology as well as being named a Honourary Member of the Institute of Concrete Technology (UK). Professor Jeffrey Siegel was inducted as a fellow of the International Society of Indoor Air Quality & Climate, and Professors Evan Bentz and Michael Collins and their students Giorgio Proestos and Phillip Quach received the ACI Design Award.

Nationally, Professor Robert Andrews and Professor Heather MacLean received the Canadian Society for Civil Engineering (CSCE) Dr. Albert E. Berry Medal for outstanding contributions to environmental engineering. Professor Brent Sleep was inducted as a Fellow of the Canadian Society for Civil Engineering and Professor Bryan Karney received the CSCE Camille A. Dagenais Award for outstanding contributions by a civil engineer to the development and practice of hydrotechnical engineering in Canada. On the local scale, Professor Karney was also awarded one of six inaugural U of T/Faculty of Applied Science and Engineering's Hart Teaching Innovation Professorships.

Table 4.8 depicts the major awards conferred upon faculty of the Department for the period 2011-2016.

**Table 4.8 List of Awards Won by Faculty Members, Department of Civil and Mineral Engineering, 2011-2016**

Surname	Given Name	Award	Organization	Award Start Date
Abdulhai	Baher	Inventor of the Year Award	University of Toronto	2014-01-01
Abdulhai	Baher	Fellow	Engineering Institute of Canada	2016-01-01
*Adams	Barry	Camille A. Dagenais Award	Canadian Society for Civil Engineering	2011-06-18
Andrews	Robert	Julian C. Smith Medal	Engineering Institute of Canada	2011-03-05
Andrews	Robert	Albert E. Berry Medal	Canadian Society for Civil Engineering	2016-06-01
Andrews	Robert	Fellow	Canadian Academy of Engineering	2017-01-01
Andrews	Susan	George Warren Fuller Award	Ontario Water Works Association	2013-01-01
*Birkemoe	Peter	Lifetime Achievement Award	American Institute of Steel Construction	2014-09-01
Christopoulos	Constantin	Inventor of the Year Award	University of Toronto	2011-03-30
Collins	Michael	Fellow	Royal Society of Canada	2011-09-15
*Hauer	Ezra	Outstanding Career Centennial Road Safety Award	Transportation Association of Canada	2014-09-01
Hooton	R Douglas	Fellow	Engineering Institute of Canada	2011-03-05
Hooton	R Douglas	Arthur R. Anderson Medal	American Concrete Institute	2011-04-03
Hooton	R Douglas	V.M. Malhotra Award	International Congress on Concrete Durability	2012-05-01
Hooton	R Douglas	Fellow	Canadian Academy of Engineering	2013-01-01
Hooton	R Douglas	Research and Development Medal	Professional Engineers Ontario (PEO) / Ontario Society of Professional Engineers	2013-01-01
Hooton	R Douglas	Frank E. Richart Award	ASTM International	2013-09-18
Hooton	R Douglas	Fellow	Réunion Internationale des Laboratoires et Experts des Matériaux	2014-09-01
Hooton	R Douglas	Wason Medal for Meritorious Paper	American Concrete Institute	2015-01-01
Hooton	R Douglas	Julian C. Smith Medal	Engineering Institute of Canada	2016-01-12
Karney	Bryan	Camille A. Dagenais Award	Canadian Society for Civil Engineering	2016-06-01
MacLean	Heather	Fellow	Engineering Institute of Canada	2016-01-12
MacLean	Heather	Albert E. Berry Medal	Canadian Society for Civil Engineering	2017-06-01
MacLean	Heather	Fellow	Canadian Academy of Engineering	2017-01-01
McCabe	Brenda	Clean50	Corporate Knights	2012-05-01
Miller	Eric	Margolese National Design for Living Prize	University of British Columbia	2012-11-05
Packer	Jeffrey	Shortridge Hardesty Award	American Society of Civil Engineers	2012-01-01
Packer	Jeffrey	Fellow	Canadian Academy of Engineering	2012-06-01
Packer	Jeffrey	Fellow	Canadian Society for Civil Engineering	2016-04-01
Packer	Jeffrey	Fellow	American Association for the Advancement of Science	2016-11-21
Pressnail	Kim	Clean50	Corporate Knights	2012-05-01
Sheikh	Shamim	Fellow	Canadian Academy of Engineering	2012-06-01
Sleep	Brent	Fellow	Engineering Institute of Canada	2012-03-01
Sleep	Brent	Fellow	Canadian Society for Civil Engineering	2016-01-01
Vecchio	Frank	E. Whitman Wright Award	Canadian Society for Civil Engineering	2011-06-18
Vecchio	Frank	Fellow	Canadian Society for Civil Engineering	2015-01-01
Vecchio	Frank	Horst Leipholz Medal	Canadian Society for Civil Engineering	2015-01-01
Vecchio	Frank	Research and Development Medal	Professional Engineers Ontario (PEO) / Ontario Society of Professional Engineers	2015-01-01
Vecchio	Frank	Joe W. Kelly Award	American Concrete Institute	2016-04-01
*Young	R Paul	Fellow	American Association for the Advancement of Science	2011-12-13
*Young	R Paul	Queen Elizabeth II Diamond Jubilee Medal	Government of Canada	2013-02-19
*Young	R Paul	Fellow	Institute of Materials, Minerals, and Mining	2016-06-01

Data Source: Awards & Honours Database (Office of Vice-President, Research and Innovation)  
 Note that the Research Awards and Honours database tracks only research prizes, awards and honours received by faculty members during their time at University of Toronto. It does not include the following types of awards: salary awards (e.g. CRC, ERA); grants; teaching or education awards; fellowships at specific institutions; honorary or administrative positions in academic associations or societies or other universities; unselected fellowship or membership in academic associations or societies.  
 \* indicates Emeritus professors, retired post 2011.

### 4.3.2 Rankings

The Department was globally ranked 33rd in 2014 and 2015 and 31st in 2016 and 2017 in the QS Subject Rankings for Civil and Structural Engineering. For Civil and Structural Engineering we were first in Canada in 2014 and second in Canada from 2015 to 2017, one spot behind UBC in 2017 (overall score of 80.6 vs 81).

In contrast to our consistency in QS rankings, our NTU ranking has declined from a high of 8th globally in 2013 to 48th in 2017, as detailed in Table 4.15. The reasons behind this drastic change in the rankings are not clear. While decreases occurred across all categories, the most significant decreases occurred in the categories of 11 years citations, current citations, H-index, and Hi-impact journals. It is also not clear why categories such as current articles, current citations, and H-index have declined since 2013. From Figure 4.4, the number of articles published increased steadily from 2012 to 2014, then dipped slightly in 2015 and 2016 but remained above the 2012 level. One would expect that with a fairly stable faculty complement a metric such as H-index would also remain fairly stable. Nevertheless, the Scopus citations show that our collective impact has increased each year, growing from 4,320 tracked citations in 2013 to 6,607 in 2016, and to 6,161 as of October 2017 (please see citations data in section 4.3.3 “Publications and Citations”).

In the Mining and Mineral Engineering subject area the QS global ranking improved from 30th to 17th from 2016 to 2017 (third and fourth in Canada in 2016 and 2017, respectively). In the Shanghai Rankings for Mining and Mineral Engineering, we were ranked 9th globally, and first in Canada .

**Table 4.9 QS Ranking for Civil and Structural Engineering**

1	Massachusetts Institute of Technology (MIT)	26	The Hong Kong University of Science and Technology
2	University of California Berkeley	27	University of Michigan
2	University of Cambridge	28	Purdue University
4	Imperial College London	29	Monash University
5	National University of Singapore (NUS)	30	University of British Columbia
5	Tsinghua University	<b>31</b>	<b>University of Toronto</b>
7	Delft University of Technology	32	Shanghai Jiao Tong University
7	Stanford University	33	National Taiwan University (NTU)
9	The University of Hong Kong	34	Politécnica de Catalunya
10	ETH Zurich - Swiss Federal Institute of Technology	35	Politecnico di Torino
11	The Hong Kong Polytechnic University	36	The University of Manchester
12	The University of Tokyo	37	Tongji University
13	University of Oxford	38	Texas A&M University
14	Politecnico di Milano	39	The University of Auckland
15	KAIST - Korea Advanced Institute of Science & Technology	40	University of California
16	The University of New South Wales (UNSW Sydney)	41	KTH Royal Institute of Technology
17	Georgia Institute of Technology	42	National Technical University of Athens
18	Kyoto University	43	Hanyang University
19	University of Illinois at Urbana-Champaign	44	Tokyo Institute of Technology
20	University of Texas at Austin	45	Yonsei University
21	The University of Sydney	46	City University of Hong Kong
22	Nanyang Technological University	47	Technical University of Denmark
23	Ecole Polytechnique Fédérale de Lausanne (EPFL)	48	Technical University of Munich
24	Seoul National University	49	The University of Western Australia
25	The University of Melbourne	50	The University of Sheffield

**Table 4.10 QS Ranking Civil**

	2014	2015	2016	2017
World	33	33	31	31
Canada	1	2	2	2

**Table 4.11 QS Ranking Mineral**

	2016	2017
World	30	17
Canada	3	4

**Table 4.12 Shanghai Rankings Civil**

	2017
World	19
Canada	2

**Table 4.13 Shanghai Rankings Mineral**

	2017
World	9
Canada	1

**Table 4.14 NTU Ranking Civil**

	2011	2012	2013	2014	2015	2016	2017
World	24	13	8	10	23	35	48
Canada	1	1	1	1	1	1	2

**Table 4.15 NTU Detailed Ranking for Civil Subject**

	Rank	Total Score	11 Years Articles	Current Articles	11 Years Citations	Current Citations	Ave. Citations	H-Index	HiCi Papers	Hi-Impact Journal
2011	24	45.9	55.9	45.7	79.8	42.5	52.0	60.0	0.0	41.4
2012	13	50.4	53.9	42.9	72.1	52.6	51.3	72.7	15.4	52.3
2013	8	75.9	75.3	70.5	95.0	84.3	63.7	85.7	51.2	83.2
2014	10	73.0	75.3	72.9	92.6	68.7	62.4	64.5	51.5	88.8
2015	23	69.1	73.9	66.0	87.9	67.2	60.1	62.9	55.4	75.4
2016	35	64.8	72.9	66.2	81.4	60.5	56.3	57.9	55.7	63.5
2017	48	62.1	71.4	64.1	77.2	59.1	54.4	59.2	51.8	57.9

### 4.3.3 Publications and Citations

Publications, citations and rankings are further measures for assessing the productivity and quality of our research, although the publication sources most often referenced for the gathering of empirical data, such as those tracked by Thomson-Reuters and NTU, do not always coincide with the publication sources most pertinent to the diverse areas of specialization within the civil and mining engineering professions.

The majority of researchers working within a particular area of civil or mining engineering will publish in journals specific to their field. For example, researchers working in the area of transportation engineering and planning will publish in journals such as *Transportation Research*, the *ASCE Journal of Transportation Engineering*, or the *Journal of the Transportation Research Board*. Researchers specializing in structural engineering may seek to publish in the *ASCE Journal of Structural Engineering* or the *ACI Structural Journal*, and researchers working in environmental engineering may publish in any number of specialization periodicals, such as *Chemosphere*, the *Journal of American Waterworks*, the *Journal of Hazardous Materials*, or *Environmental Research*.

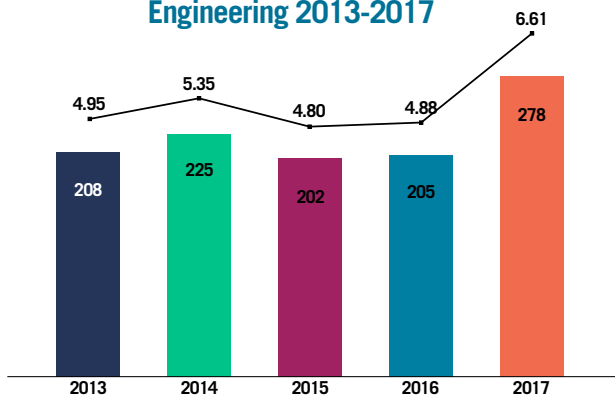
Nevertheless, the collective output of our researchers is prolific. During the period January 2016 to June 2017 our colleagues published a total of 278 peer-reviewed papers. This is exclusive of papers submitted for review, refereed conference papers or published abstracts. To demonstrate the breadth of outreach and output of our researchers, a list of papers published during this period is included in Appendix P, along with a listing of the key journals that have referenced our work in Appendix Q.

Figure 4.4 and Figure 4.5 below provide comparisons of the total number of peer-reviewed publications generated by our faculty over the five-year period 2012-2017, and the total number of citations during this same five-year period. The average per faculty member is indicated in the corresponding line graph.

It is evident that our colleagues continue to excel in their research output, with the number of publications growing from 173 in 2012 to 278 in 2017. This represents an increase in output of 43.3% over 2012, and it is important to note that the number of publications tabulated for 2017 is predicated only on articles that were published during the first half of the year. Over the five-year period a total of 1,229 articles, or on average five to six publications per faculty per year, were published.

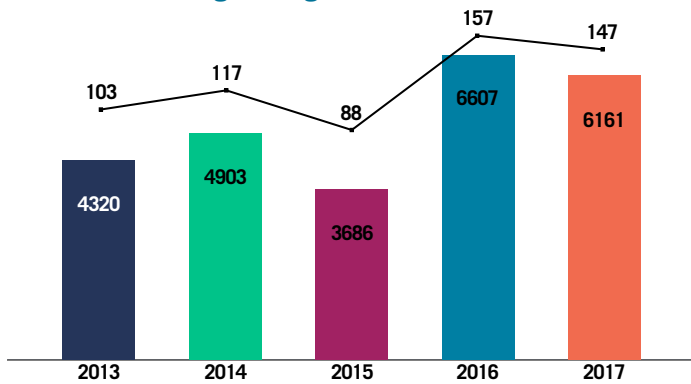
In terms of measuring the impact of our research, drawing on the number of citations tabulated over this same period, in 2012 there were 3,883 citations documented. In 2017 the number grew to 6,161, an increase of 59% over 2012. Again, the number of citations tabulated for 2017 is based on citations documented during the first half of the year only. The total of all citations over the five-year period was 25,677, or approximately 122 citations per faculty per year (See Table 4.16).

**Figure 4.4** Number of Articles Published by Faculty of the Department of Civil and Mineral Engineering 2013-2017



Data source: Elsevier Scopus <https://www.scopus.com/search>

**Figure 4.5** Number of Citations Attributed to Faculty of the Department of Civil and Mineral Engineering 2013-2017



Data source: Elsevier Scopus <https://www.scopus.com/search>

**Table 4.16 Research Citations, 5-Year Summary**

	<2013	2013	2014	2015	2016	2017	5-Year Total
Total	20,448	4,320	4,903	3,686	6,607	6,161	25,677

Data source: Elsevier Scopus <https://www.scopus.com/search>

## 4.4 Collaboration in Research

Every faculty member in the Civil and Mineral Engineering Department is integrally involved in collaborative research of some form, whether this be intra-disciplinary, interdisciplinary, or multidisciplinary in scope.

The NSERC CREATE Remediation Education Network (RENEW) program spearheaded by Professor Brent Sleep involves researchers and practitioners from four Canadian universities, (U of T, Western, Queen's and Waterloo), eleven international academic institutions and six leading environmental remediation firms. The private sector partners provide internships to graduate students from the four academic institutions involved. A key component of the program is soft skills and advanced technical skills training.

The iCITY ORF project headed up by Professor Eric Miller (noted earlier in this chapter) involves Professor Baher Abdulhai of our Department, as well as 15 other researchers from three universities (U of T, Waterloo and OCAD U).

Professor Robert Andrews is collaborating with researchers at the University of Texas (Austin) to develop a method to scale down biofiltration studies, with an aim to bringing these investigations down to the lab-scale rather than the more costly pilot-scale approach. Professor Andrews has also joined in numerous collaborative projects with researchers from the National University of Singapore, most recently they are exploring opportunities to collaborate on direct potable water reuse.

Professor Fae Azhari recently began a joint field-testing project in partnership with colleagues from the Chalmers University of Technology (Sweden) and the University of Perugia (Italy) to install cementitious monitoring sensors in a wind turbine foundation. Data collection will be ongoing.

Professor Kamran Esmaeili is leading an NSERC Collaborative Research and Development (CRD) funded initiative to develop unmanned aerial vehicle systems for real-time mining data acquisition and decision-making, along with colleagues from the U of T's Institute for Aerospace Studies (UTIAS), the University of Western Ontario, and Laval University.

Professor Marianne Hatzopoulou is working with scientists at Public Health Ontario to study the associations between various forms of cancer and exposure to ultrafine atmospheric particles in the Greater Toronto Area. She is also working with the Montreal Department of Public Health, the Quebec Ministry of Transportation, and researchers at the University of Montreal to assess the quantification of the health effects of transportation policies in Montreal.

Professor Ron Hoffman is collaborating with a colleague from the FASE Department of Chemical Engineering and Applied Chemistry on the application of computational fluid dynamics for water treatment optimization. To date they have published three papers on this topic.

Professor Heather MacLean is involved in numerous collaborative initiatives, spanning participation in an NSERC CREATE funded project to develop the Centre for Research in Sustainable Aviation in partnership with lead researchers at UTIAS, and numerous collaborations with departmental faculty

on projects ranging from transport, indoor air quality, building energy use, biofuels, and food drying in developing countries. She is also engaged in partnerships with colleagues from the University of Calgary, Natural Resources Canada, and CANMET Energy investigating oil sands related research. Additionally, she is a key member of the BiofuelNet NCE, led by researchers at McGill University, which also involves collaborators from Queen's, Waterloo, UBC, and faculty from the Department of Chemical Engineering and Applied Chemistry at U of T and the Faculty of Forestry at U of T.

Much of the collaborative research that is currently underway is within the realm of active investigation, and therefore not all projects are appropriate for disclosure within this report. However, the intention of the examples provided above is to provide a representation of the range of collaborative investigations involving our faculty. While not exhaustive, the lists below show the range of companies, agencies and partner institutions our faculty members have had research collaborations with over the past five years.

### **MUNICIPALITIES AND MUNICIPAL AGENCIES**

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The Atmospheric Fund (Toronto)  
 City of Brampton  
 City of Cornwall (Ontario)  
 Region of Durham  
 City of Hamilton  
 Region of Halton  
 City of London (Ontario)  
 City of Montreal Department of Public Health  
 Metrolinx  
 City of Mississauga  
 Region of Niagara  
 City of Ottawa  
 Region of Peel  
 City of Peterborough  
 City of Toronto Transportation Services  
 Toronto Transit Commission  
 Toronto Community Housing  
 Toronto Hydro  
 Metropolitan Water District of Southern California  
 Union Water Supply System  
 Waterfront Toronto  
 York Region

Canadian International Development Research  
 Centre  
 Canadian Nuclear Laboratories  
 Canadian Nuclear Safety Commission  
 Canadian Urban Environmental Health Research  
 Consortium (CANUE)  
 CMG Reservoir Simulation Foundation/Foundation  
 CMG  
 Environment Canada  
 Environment and Climate Change Canada  
 Health Canada  
 Manitoba Department of Transportation  
 Ministry of Innovation, Science and Economic  
 Development Canada  
 Mining Association of Canada  
 Natural Resources Canada - CanmetENERGY  
 Natural Resources Canada - CanmetMATERIALS  
 Natural Sciences and Engineering Research  
 Council (NSERC)  
 Natural Resources Canada Mine Environment  
 Neutral Drainage Program  
 Neptis Foundation  
 Ontario Genomics  
 Ontario Mining Association  
 Ontario Ministry of Agriculture, Food and Rural  
 Affairs  
 Ontario Ministry of Natural Resources  
 Ontario Ministry of Transportation  
 Ontario Power Generation  
 Public Health Ontario  
 Quebec Ministry of Transportation  
 U.S. Department of Energy - Argonne National  
 Laboratory

### **FOUNDATIONS, ASSOCIATIONS, GOVERNMENT AGENCIES**

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Alberta Ministry of Transportation  
 California Air Resources Board  
 Canada's Genomics Enterprise (CGEn)  
 Canada's Oil Sands Innovation Alliance (COSIA)  
 Canadian Institutes of Health Research (CIHR)

**ACADEMIC INSTITUTIONS****Canada**

École Polytechnique Montreal  
Laval University  
McMaster University  
OCAD University  
Ryerson University  
Queen's University  
University of Alberta  
University of British Columbia  
University of Calgary  
University of Montreal  
University of Waterloo  
University of Western Ontario

**U.S.A.**

Arizona State University  
Carnegie Mellon University  
Colorado School of Mines  
University of California  
University of California, Berkeley  
University of California, Davis  
University of Central Florida  
George Washington University  
Harvard University  
Stanford University  
University of Texas (Austin)

**International**

American University of Beirut  
American University of Dubai  
Ben-Gurion University (Israel)  
Brazilian Bioethanol Science and  
Technology Laboratory (CTBE)  
Brescia University (Italy)  
Cairo University  
Chalmers University of Technology  
(Sweden)  
ETH Zurich  
Flemish Institute for Technological  
Research  
Hacettepe University (Turkey)  
Hanyang University (South Korea)  
Indian Institute of Technology Roorkee  
(India)  
INRA/AgroParis Tech (France)

Istanbul Technical University (Turkey)  
Korea Institute of Civil Engineering and  
Building Technology  
Nanjing Technological University (China)  
National University of Singapore  
Polytechnique University of Valencia  
(Spain)  
Seoul National University  
Technion - Israel Institute of Technology  
Tel Aviv University  
Tongji University (Shanghai, China)  
Universidad Autónoma de Nuevo León  
(UANL) (Mexico)  
Universidade São Paulo (Brazil)  
University of Bath (UK)  
University of Bristol (UK)  
University of Canterbury (New Zealand)  
University of Chile Santiago  
University of Concepción (Chile)  
University of Hasselt (Belgium)  
University of New South Wales  
(Australia)  
University of Perugia (Italy)  
University of Queensland (Australia)  
University of Technology Sydney  
(Australia)

**CORPORATE COLLABORATORS**

Advisian Management Consulting/Worley  
Parsons  
Arcadia Canada  
ArconTEST Inc.  
Arup Canada  
AUG Signals Inc.  
BASF Canada  
Candu Energy  
CarbonCure  
CastConnex  
Cellint Traffic Solutions (Israel)  
Cement Association of Canada  
CH2M Hill  
Concrete Ontario  
COMDEV/Honeywell  
Dow Chemical  
DuPont Canada  
Environmental and Regulatory  
Solutions Inc.  
Environmental BioDetection

Products Inc.  
EllisDon  
Esri Canada  
Exxon Mobile  
Fiberline Composites Inc., Canada  
Ford Canada  
FORGE Hydrocarbons Corporation  
General Electric  
Geosyntec  
Glencore - Sudbury Integrated Nickel  
Operations  
GM Canada  
Golder Associates Inc.  
GVA Lighting  
Hatch Ltd.  
Hudbay Minerals Inc.  
IBI Group  
IBM Canada  
ICRH  
IntelliStruct  
Imperial Oil  
Jerol Engineering  
Kinross Gold  
Klohn-Crippen-Berger  
Lafarge-Holcim  
Latin America Development Bank  
McEwen Mining  
NCK Engineering Ltd.  
Nobelgen Inc.  
NRB Inc.  
Oldcastle Precast (Colorado, USA)  
PEEK Traffic (USA)  
Pinchin Environmental  
Pultron Composites Ltd.  
(New Zealand)  
RealTech  
RESCON  
SETS International (Saudi Arabia)  
Shell Canada  
St. Marys CBM  
Stantec  
Statprofs  
Stephenson Engineering  
Suncor Energy  
Syncrude Canada Ltd.  
Trapeze Software Inc.  
Ushta Infinity Construction Co. Pvt. Ltd.  
(India)  
WSP-Parsons Brinkerhoff

## 4.5 Technology Transfer and Industrial Relationships

The Department currently accounts for a five-year average of approximately 3% of the University's achievement in technology transfers via disclosures, 4% of patents issued, and 5% of enterprise start-ups.

**Table 4.17 Technology Transfer Indicators: Department of Civil and Mineral Engineering Share to University of Toronto 2012-2016**

	FY2012	FY2013	FY2014	FY2015	FY2016 Preliminary	5-YR SUM
<b>Disclosures</b>	3.3	1.8	5.0	5.0	6.0	21.2
	158	166	147	174	169	814
	2.1%	1.1%	3.4%	2.9%	3.6%	2.6%
<b>Licenses</b>	0	2	1	1	0	4
	29	36	40	39	32	176
		5.6%	2.5%	2.6%		2.3%
<b>Patent Applications</b>	1	1	4	0	1	7
	43	52	57	56	44	252
	2.3%	1.9%	7.0%		2.3%	2.8%
<b>Patents Issued</b>	1	0	1	1	1	4
	13	10	17	39	16	95
	7.7%		5.9%	2.6%	6.3%	4.2%
<b>Start-ups</b>	1	1	1	0	1	4
	17	12	20	17	13	79
	5.9%	8.3%	5.0%		7.7%	5.1%

Data Source: Technology transfer data records, Office of Vice-President, Research, 2012-2016.

### 4.5.1 Centres and Institutes

The Department supports several dedicated centres and institutes in support of its research mission. These include the Institute for Sustainable Energy, the Institute for Water Innovation, the Centre for Resilience of Critical Infrastructure, the Lassonde Institute of Mining, the University of Toronto Transportation Research Institute, and most recently, the Building Tall Research Centre.

The **Institute for Sustainable Energy (ISE)** is a collaborative initiative established by the Faculty of Applied Science and Engineering. The purpose of the ISE is to bring involved researchers together with partners from industry and government to explore methodologies for increasing energy efficiency and reducing the environmental impact of energy use and conversion. Membership is comprised of faculty from five of the seven primary departments in FASE, as well as from several departments from across the University. Professor Bryan Karney serves as representative for the Department of Civil and Mineral Engineering on the steering committee, and professors Heather McLean, Daniel Posen, and Tamer El-Diraby are all active members.

The Institute offers three distinct graduate programs and contributes teaching resources to the Sustainable Energy minor, which is available to Civil Engineering undergraduate students.

The ISE advisory board consists of 10 representatives from industry, and an emeritus professor from FASE.

The **Institute for Water Innovation (IWI)** is a collective of interdisciplinary researchers from four departments within the Faculty (Chemical, Civil and Mineral, Mechanical and Industrial, and Materials Science Engineering), who are engaged in various aspects of water research.

The aim of IWI is to develop innovations in water management, characterization, treatment, and remediation to address industrial, commercial, and domestic water challenges. Examples of the range of research topics involved include:

- watershed assessment and management
- mine hydrology and water balances
- drinking water distribution optimization
- sensor development
- chemical modelling of aqueous systems
- biochemical characterization
- membrane separation and distillation
- bioprocesses to treat effluent streams
- electrochemical methods for treatment and desalination
- bioremediation of groundwater
- engineering “green infrastructures” (for example in wetlands and bio-retention cells)
- removal of residual hydrocarbons from oil sand tailings

All doctoral-stream (PhD, MAsC) graduate students working in the area of water research may be involved in the projects undertaken by IWI researchers. However, another educational and training pathway available through the Institute is the Master of Engineering (MEng) emphasis in Advance Water Technologies and Process Design, in which MEng students from the participating departments follow the overarching requirements established by their home department, but select specific core and specialization courses as components of their program. These students also have the option to undertake an approved one or two term research-based project to enhance their program. Completion of the specialization signifies that the student has acquired in-depth knowledge of water treatment methods and design of treatment processes.

The Institute also seeks to actively partner with industry and public sector agencies to facilitate the translation of research into commercial practice.

The **Centre for Resilience of Critical Infrastructure (CRCI)** is largely a departmental initiative dedicated to advancing the field of infrastructure engineering and the understanding and practice of infrastructure resilience. Current membership consists of 10 faculty members representing all research areas currently active within the Department, along with several advisors from academia, industry and governmental institutions across Canada.

The CRCI offers graduate courses in structural and infrastructure resilience, and conducts intensive research in three main thrusts: Structural Resilience, Infrastructure Resilience and Control Systems.

Networking and professional development is an essential component of CRCI, achieved by direct engagement with the professional community through the Sandford Fleming Forum. The Forum serves to further understanding of the requirements and practices of resilience planning, and promotes discussion on current and emerging threats and concepts.

Industry partners include Arup, BRE Canada, Explora Foundation, and the Halcrow Group. Government associations include Defence Research and Development Canada, the Centre for Security Science, the Department of Homeland Security, the Combating Terrorism Technical Support Office, and the Centre for the Protection of National Infrastructure. Professional agency affiliates include the Institution of Civil Engineers (ICE), The Register of Security Engineers and Specialists (RSES) and the Critical Infrastructure Institute (CII).

The **Lassonde Institute of Mining (LIM)** is an interdisciplinary research consortium involved with conducting innovative investigations across the spectrum of mining activities, with a focus on sustainability. The development of new technology-driven solutions that will impact the operational efficiency of the mine cycle and improve sustainability through decreasing environmental risks and financial liabilities are driving factors in its research program.

Membership includes civil, materials, aerospace and chemical engineers, as well as geophysicists, geologists, geochemists, and environmental scientists. Key partnerships with industry include Syncrude Canada Ltd., the Canadian Oil Sands Innovation Alliance, McEwan Mining, Vale, Glen, Teck and Hatch, and Kinross Gold Corporation.

The Institute receives financial support through contributions from the Canadian minerals industry (in particular Dr. Pierre Lassonde), the Government of Canada and the Government of Ontario.

The **University of Toronto Transportation Research Institute (UTTRI)** is one of the longest standing research institutes in the Faculty. Comprised of 25 experts from engineering, economics policy, urban geography and planning, and computer science, the work of UTTRI involves examination and analysis in the areas of transportation monitoring, urban informatics, development of intelligent transportation systems, big data collection and dissemination, and consultation on strategic urban policy formulation related to transportation systems.

UTTRI's leadership and direction is guided by two governing bodies: an advisory board consisting of five industry and two institutional representatives, and an academic steering committee comprised of 13 faculty from across the University.

A recently established innovative offshoot of UTTRI is the iCity Centre for Automated and Transformative Transportation Systems (iCity-CATTS). The centre is the first at U of T mandated to specifically study how 'smart' transportation technologies, such as automated vehicles and e-sharing, will affect people's transportation choices, how businesses provide transportation as a service, and how cities should plan for those changes to achieve the best results for society.

Still in the early stages of formation, the iCity-CATTS will assemble a multidisciplinary team to create analysis tools, methods, models and decision support systems to quantify the impacts of transformative transportation technologies on transportation demand, system performance, health, the environment and society-at-large.

The **Building Tall Research Centre (BTRC)** is a new partnership venture between academia, industry and government. Through research, teaching and industrial collaboration the centre's focus is in bringing improvement to building productivity, performance of building-related systems, and energy performance. Professor Brenda McCabe serves as director of the centre, with leadership provided by industry advisory partners such as the Residential Construction Council of Ontario (RESCON), The Daniels Corporation, Menkes and Tridel. Initial funding for the initiative has been provided through the federal government via NSERC and the Scientific Research and Experimental Development (SR&ED) program.

#### 4.5.2 *Start-ups*

Spin-off companies are a common outcome of research within the discipline and numerous innovative enterprises have been initiated by members of our Department since the establishment of the School of Practical Science in 1873. The following are a few examples of the spin-off companies established by members of the Department in the last five years.

**Crowd2Know Inc.** was founded by Professor Tamer El-Diraby in 2016, with financial support provided through the University of Toronto's Connaught Fund, and under the auspices of the University's Early-Stage Technology (UTEST) initiative. The company operates in the area of stakeholder engagement to bring organizations operating in urban development closer to their clients, citizen groups and end users by providing a platform for listening, analyzing, and effectively communicating with each other. Using a suite of software products and in-house developed analysis algorithms, they provide a real-time mapping of stakeholders, discussion topics, and relative alignment of opinions that drive consistent recommendations for decision makers.

Professor Baher Abdulhai co-founded **Pragmatek Transport Innovation (PTI)** in 2013 in collaboration with PEEK Traffic Inc., a US technology-based company focused in the development and supply of intelligent traffic systems. Professor Abdulhai and his (then) doctoral student Samah El-Tantawy were named U of T Inventors of the Year in 2014 in recognition of their creation of the innovative MARLIN Smart Traffic Lights Control software. MARLIN seamlessly integrates with existing intersection traffic control system hardware to improve the flow of traffic through self-optimization of traffic lights. Based on extensive testing on a virtual model of downtown Toronto, MARLIN reduced motorist delays at intersections by an average of 40% and improved travel times on major corridors such as Toronto's Lake Shore Boulevard by 25%, while cutting down emissions by 30%. A pilot project deploying MARLIN at four intersections in the City of Burlington was undertaken in 2015. Through Pragmatek Transport Innovation, work to refine and further promote the technology is ongoing.

**Kinetica Dynamics Inc.** is a consulting and design firm specializing in seismic risk migration. Co-founded by Professor Constantin Christopoulos and Dr. Michael Montgomery in 2012 (while Dr. Montgomery was completing his PhD under Professor Christopoulos's supervision), Kinetica's mission is to enhance the dynamic performance and resilience of structures subject to wind and earthquake loading. They offer a number of services in support of tall building design, including preliminary conceptual high-performance seismic design of tall and complex buildings, peer review of high-rise building design, high-rise building damping and high-performance system design, and advanced modeling (including nonlinear models) of tall and complex buildings equipped with advanced vibration control technologies under simulated wind and earthquake loads.

Projects that Kinetica Dynamics has been involved in to date include the Bahai Temple project in Santiago, Chile and the 66-storey YC Condominiums in Toronto. Their research is widely presented at numerous international conferences, for example the World Conference on Earthquake Engineering, and the Council on Tall Buildings and Urban Habitat.

One of the key innovations developed by Kinetica Dynamics is the Viscoelastic Coupling Damper (VCD), a vibration damping technology that absorbs vibrational energy and transforms it into heat, reducing forces in adjacent building components. The technology has proven to be extremely effective in concrete structures where the stresses from vibrations are the highest. In 2015 Kinetica entered into a Memorandum of Understanding with Shanghai Led Dynamic Engineering to promote and expand VCD technology throughout Asia.

Dr. Sean Doherty received his doctorate in Civil Engineering at U of T in 2000. Initially his interests centered in urban planning and transportation, but over time his research focus transitioned to the area of health geography. He is especially interested in body-based sensors such as GPS and accelerometers, which are dramatically changing Geomatics and leading to breakthroughs in our understanding of exposure to risks and disease. In 2012 he established **MyTrak Health Systems Inc.**, a creative enterprise that provides health care and fitness technology solutions that engage people to get fit, stay fit and make better choices in their day-to-day lives. Innovations developed through MyTrak to date include:

- the MYTRAK Smart Coach, a device that tracks the intensity, frequency, and duration of users physical activity;

- the MYTRAK Success Coach, which determines ideal lifting weight and monitors member heart rate for determining appropriate rest time between sets; and,
- MY WAND, a core-training circuit for targeting core muscles with a cardio component to keep heart rate in the optimal zone.

As of July 2012, MYTRAK Health System Inc. began operating as a subsidiary of Medipattern Corporation. Dr. Doherty is a professor in the Department of Geography and Environmental Studies at Wilfrid Laurier University, and has served as chair of that department since 2016.

The most recent start-up enterprise borne through the Department is **Geomechanica**, a consulting firm established in 2016 that develops geomechanical simulation software and provides technical consulting and laboratory testing services for rock engineering applications. These applications include hydraulic fracturing (fracking), assessment of excavation damaged zones around underground openings, and rock slope and dam stability.

Geomechanica's engineering simulations are based on an advanced hybrid finite-discrete element software known as Irazu, a numerical code that combines principles of continuum mechanics with discrete element algorithms to simulate multiple interacting deformable and fracturing bodies. Four of the five principles of Geomechanica are graduates of the U of T Civil Engineering department. The Irazu software was developed in conjunction with their respective graduate research.

## 4.6 Student Engagement in Research

Throughout their undergraduate and graduate programs, our students enjoy access to a wealth of practical, applied, case studies from which to work with to develop their research capabilities, while working under the guidance of our faculty who are renowned within their field.

The foundation, second and third years of the undergraduate program provide students with full exposure to the knowledge base and engineering principles necessary to ensure that their education meets CEAB accreditation requirements. As such, our students gain the most concentrated exposure to research in their fourth year, when they have the opportunity to engage in a thesis-based project. This is in addition to the background research associated with their requisite capstone group design projects. Upper year undergraduate students also have opportunity to select from our 500-level technical elective courses which are shared with graduate students, thus bringing them more fully into the domain of research-based graduate work.

However, all of our undergraduate students have the opportunity to develop their research skills at any point within their program in conjunction with the various summer research opportunities offered through the Faculty and the University, such as the NSERC Undergraduate Student Research Awards (USRA) and the FASE Undergraduate Summer Research Fellowship programs. Additionally, many of our faculty researchers hire undergraduate students directly to work on projects within their labs exclusive of any competitive funded programs, and a good number of our undergraduate students, eager for exposure to the research environment, volunteer to work in a lab in order to gain and/or build on their applied research skills.

Our doctoral-stream graduate students are immersed in research from the onset of their programs, and have numerous opportunities to enhance their educational experiences through their contributions to published papers, making presentations at conferences and symposia, and through attending the many distinguished seminars and special lectures sponsored by the Department.

Also, as described earlier in this section, many of our graduates go on to establish their own companies, often to further work begun during their university program. ■

# 5. ORGANIZATION AND FINANCIAL STRUCTURE

## 5.1 Governance Structure

The Department is structured similarly to other departments within the Faculty. However, our governance structure is formalized with a constitution and with a departmental Council overseeing the institution and administration of the academic policies and procedures of the Department. Academic staff provide proactive representation in all key areas of governance concerning admissions, programs and curriculum, research, and development of physical resources, while the Department chair oversees the day-to-day aspects of academic and operational activities.

Governance processes are guided by our Constitution, which outlines the structure and function of the departmental Council and its standing committees. Figure 5.1 below denotes our governance organizational structure. A copy of our Constitution is attached in Appendix R.

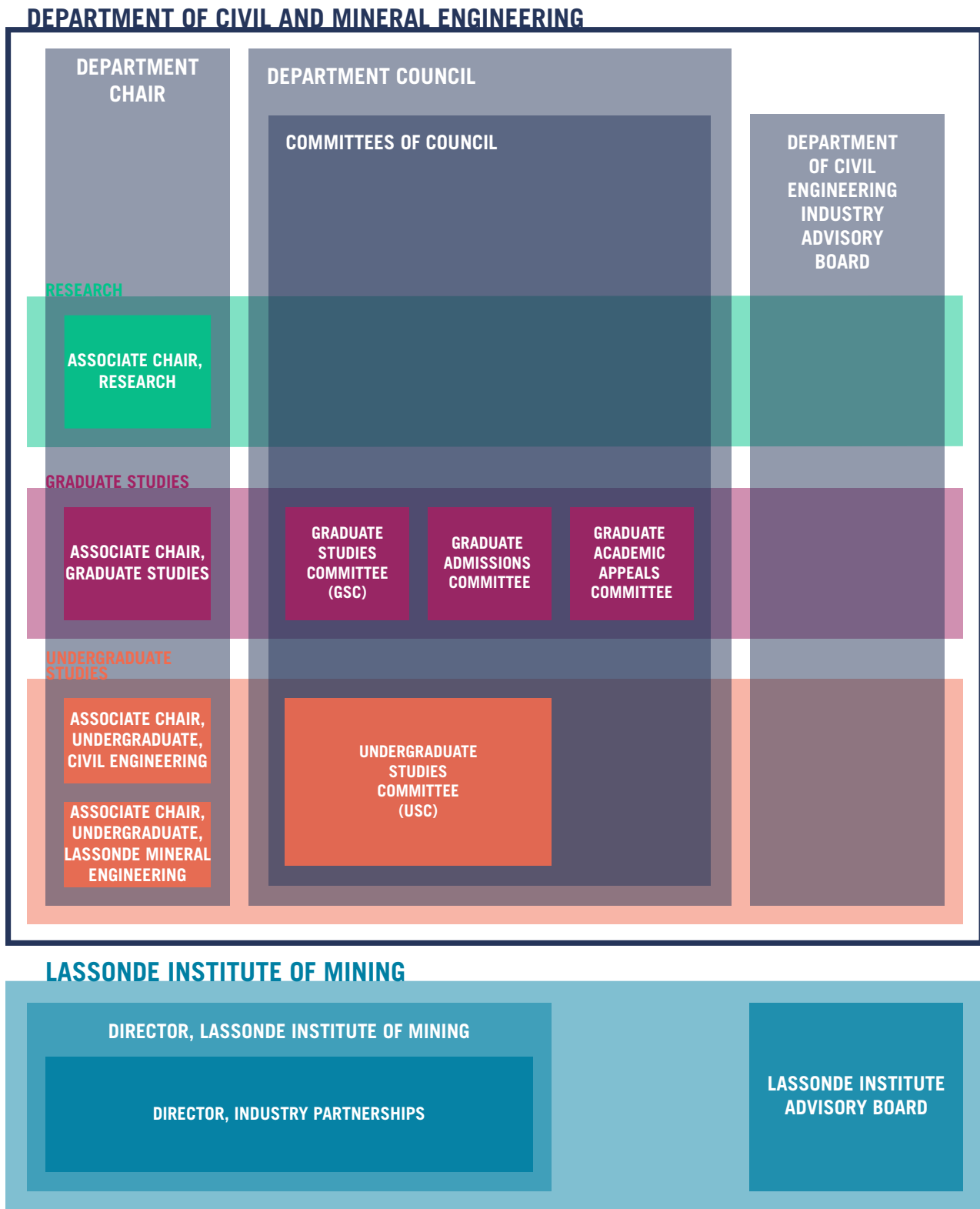
Matters pertaining to undergraduate recruitment, admissions and curriculum are generated from within the Department, but are ultimately approved through the standing committees of Faculty Council and administered through the Faculty Registrar's Office, while matters pertaining to graduate admissions and curriculum are administered and approved directly within the Department and sanctioned at the Faculty level.

Although not a committee of Council, the departmental Honours and Awards Committee is responsible for reviewing the curricula vitae of our faculty members for consideration for various national and international awards, such as the PEO awards and CSCE awards. This committee also reviews the nominations received for our Distinguished Lecture Series and determines the short list of candidates to invite. The committee has one representative from each research stream, and one person from this committee also serves on the Faculty's Awards Committee.

A similar committee is appointed to oversee departmental graduate student scholarships, while undergraduate scholarships are determined by the Faculty's Scholarships and Awards Committee, which has faculty representation from each department and division in the Faculty.

The departmental Graduate Academic Appeals Committee reviews graduate student petitions and oversees matters related to student academic status. Recommendations concerning appeals are submitted to the Department chair for action. Academic appeals associated with undergraduate studies is a centralized function, with departmental representation.

Figure 5.1 Governance Structure of the Department of Civil and Mineral Engineering



## 5.2 Administrative Structure

The administrative structure of the Department consists of the Chair, assisted by one executive assistant and a senior team of directors who oversee three key areas of departmental operations: administration and finance, technical services, and student services and external relations. Each director supervises a small team of support staff within their respective area of responsibility.

Previously there was an additional leadership role of director of strategic research systems, responsible for overseeing the area of research facilities development and infrastructure resources. When the incumbent retired, a decision was made to discontinue this role and the funding aligned to this position was redirected to the new role of Computer Network Manager. Otherwise, our management structure has not changed to any significant extent since 2012.

Figure 5.2 on the following page depicts the Department's current administrative structure.

The working environment within the administrative areas is collegial and supportive, and our staff are encouraged to seek out opportunities for professional development, through both internal University resources such as the Occupational Learning & Development Centre, and externally through participation in relevant webinars and attendance at conferences and professional development seminars.

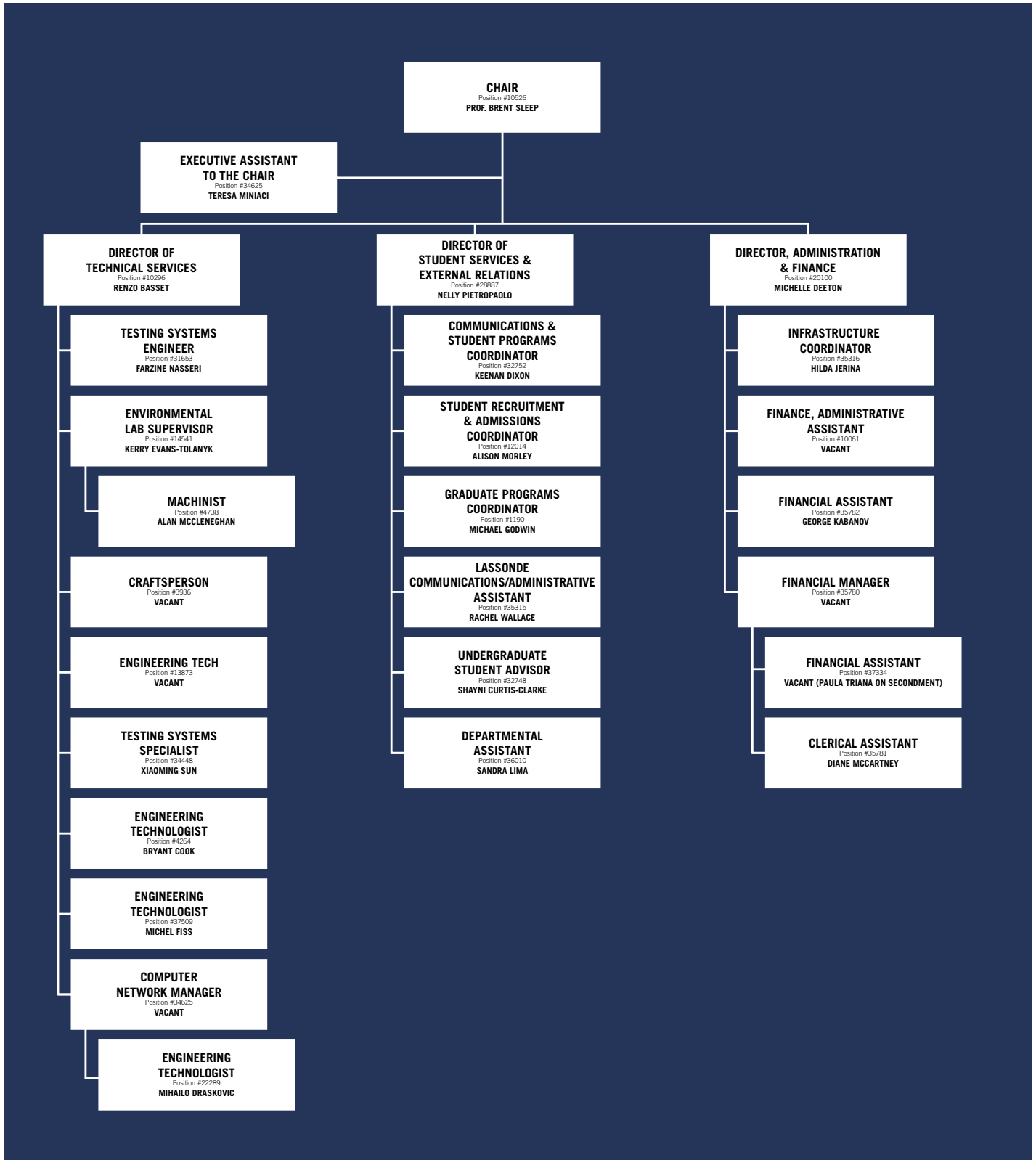
The introduction of new tools such as “My Research On-Line” (MROL), which enables grant holding researchers and financial staff to easily query information on the current status of research grants, and the “U of T Engineering CONNECT”, an on-line tool that empowers students, alumni, and student services staff to maximize on information sharing, have greatly helped to streamline some processes and decrease time required in performing repetitive functions, while improving access to information and analytical reports. Ongoing enhancements made to existing on-line tools such as ROSI/ACORN (student records and web services systems) for recording and tracking student records, and the Administrative Management System (AMS) suite which encapsulates the financial (FIS), human resources (HRIS), research (RIS) and advancement (DIS) processing and reporting functions also enable staff to optimize their efforts in processing work and generating reports.

Although the Department continues to keep pace and manage its administrative portfolio within the confines of our existing structure, and with minimal growth of our administrative complement over the years, the workloads respective to each administrative area have not remained static. This has placed additional pressure on the members of the administrative team. For example, the growing size of our MEng student population and the institution of the MEngCEM program and its internship component have added to the demands placed on program administration. Our faculty complement has grown from 36 to 42, thus increasing the demand for administrative support to faculty, especially as concerns financial management of research funds and physical resources distribution. Additionally, there are always operational changes from the institutional level, for example the continual downloading of administrative functions previously performed by central bodies, such as the School of Graduate Studies, have contributed to the pressure faced by our administrative staff.

The major changes made to our administrative structure since 2012 includes the creation of one new position to provide senior level support to oversee the Department's internal computing network, and one new administrative role was created to facilitate the activities of the Lassonde Institute of Mining. This position is a non-academic senior leadership role at the director level, with a focus on building and strengthening our partnership links within the mining industry.

We also formalized our departmental Communications portfolio with the appointment of one person to oversee the redesign of our website, and preparation of departmental reports and promotional materials, and one person to focus on communications related to the Lassonde Mineral Engineering Program and the Lassonde Institute of Mining.

Figure 5.2 Department of Civil and Mineral Engineering Administrative Structure



The computing technical staff are responsible for the ongoing maintenance of the networking services located within the central undergraduate student computing facilities, and our administrative offices. Computing facilities within research facilities are the sole responsibility of the respective research group.

Six technicians, who report directly to the director of technical services, provide support to the machining, woodworking and welding shops, and the research testing facilities. This team is also responsible for associated equipment maintenance.

Despite the cumulative increases to workload in some administrative areas, we do not envision a need for any major administrative restructuring, or for the creation of new administrative positions, within the foreseeable future.

### 5.3 Budget

In 2006 the University adopted a new approach to budgeting which allows for a more transparent and rational allocation of funds, while also placing the onus for fiduciary responsibility directly onto the academic unit. This approach is working extremely well and Civil and Mineral Engineering has welcomed and fully adapted to the mechanism.

Our net budget for the fiscal year 2017-18 was \$13,943,009, which is exclusive of the standard central recovery items associated with research overhead and facilities utilization. The Department's research overhead contribution was \$485,382 and our space tax amounted to \$2,800,764 (or approximately \$360 per net assignable square metre.) As a result of our success in securing one renewal and three new Canada Research Chair positions and two additional NSERC Industrial Chairs, in combination with growth in our research fund overhead and student BIU, we realized an increase of approximately \$1.6-million over the previous fiscal year.

As is the case with most enterprises, the costs associated with human resources represents the largest expense item, with academic salaries and benefits claiming 49.31% of our total net budget, administrative staff requiring 15.7%, teaching assistantships (which also comprises a portion of our graduate student funding package) received 9.06% and sessional instructors taking up a further 4.73%. This cost component represents a total of 78.8% of our annual budget and is, for the most part, intractable. The Department contributes a further 6.91% towards graduate fellowships and the remaining 14.28% of the budget, plus revenue and recoveries that are realized internally throughout the year, are dedicated to our ongoing operating expenses.

However, the current budgeting mechanism also allows for departments to maintain any surplus in their budget allocation and to carry these funds forward into future fiscal years, provided that a plan is in place for proactive utilization of these funds. In the 2016-17 fiscal cycle, the Department realized a carry-forward of \$2.4-million (exclusive of \$1-million held in a capital reserve fund). Some of these funds will be used to cover costs associated with several Strategic Infrastructure Fund (SIF) renovation projects currently underway, as well as provide funding for a number of new infrastructure projects scheduled to commence in late 2017 and early 2018. An outline of these initiatives will be addressed in the "Resources and Infrastructure" section of this report (Section 6.)

In the 2012 self-study report the Department indicated that there was an historic deficit of \$400,000, largely resulting from overspent research accounts and cost over-runs on renovations that needed to be cleared. This debt has now been retired.

With a view to our long-term planning over the next five years, we anticipate the following:

- with continued robust recruitment of graduate and undergraduate students, and continued growth in research funding, the Department should continue to be in a strong fiscal position with balanced budgets and funds available to support capital improvements and maintain or increase administrative support
- notwithstanding the University's recent adjustment to international PhD student tuition, an ongoing budgetary issue overall will be the escalating cost of graduate student funding packages, an issue for both the Department and academic supervisors
- increases in recoveries by the University for space and research administration will also impact the budget
- the University recently negotiated a new Strategic Mandate Agreement with the province, although the impact of this on the Weighted Graduate Units (formerly Basic Income Units) is not clear at present
- future increases in administrative staff and faculty, and further increases in graduate student numbers will necessitate the acquisition of space from other departments and/or renovation and repurposing of new space with the associated ongoing costs.

## 5.4 Communications

A dedicated communications position was incorporated into the administrative staffing complement in 2015, with primary responsibility for rebranding and maintaining the Department's website, develop social media campaigns to strengthen our outreach and ongoing communications with students and alumni, redesigning promotional materials, and serving as departmental liaison to both the Faculty Advancement and Communications offices. Through the creation of this position, the Department has enhanced its ability to respond to and generate content for the Department, Faculty and University news sites. The departmental website is being migrated to a more user-friendly platform allowing users to more easily access and edit information. Through our proactive participation in the rollout of the Faculty's "U of T Engineering CONNECT" initiative, our outreach and connection to alumni has significantly improved.

Communications projects currently underway include:

- the development of an archival repository for departmental reports, published papers, and news stories related to accomplishments of faculty, students and alumni,
- the development and implementation of a strategic communications plan which will directly link to departmental goals and objectives, and,
- further revamping of our program and recruitment promotional materials to ensure that we keep pace with contemporary conventions.

## 5.5 Reflections on Administration

Our staff are constantly working to improve our internal systems and refine their professional skills. They take pride in the work that they do, and feel that they are well positioned to continue their efforts to move the Department forward.

A recent change in leadership within our Administration and Finance office is providing us with an opportunity to redirect workflow, which will ultimately result in efficiency gains within the functioning of that office. With the growing level of research in the Department, a currently vacant position will be restructured to undertake responsibility for supporting faculty members in administration of large research grants.

As networked computing systems have become increasingly more complex, we acknowledge that IT support is a key human resources function requiring our attention at this time. An active search to fulfill a leadership position in this area is currently underway.■

# 6. RESOURCES AND INFRASTRUCTURE

The Department has a total of 7,760 NASMs (Net Assignable Square Metres) of teaching, research, student support, and administrative space assigned under its umbrella, which represents 12.04% of the total space currently allocated to the Faculty. The Department contributes approximately \$2.6-million, or 17.2% of its gross annual budget in flow through space tax for access to these resources. The Department is responsible for ensuring the ongoing maintenance of its infrastructure and any development costs associated with the renovation and/or upgrades made to these facilities.

Historically, the Department has occupied space dispersed throughout the Galbraith (GB), Sandford Fleming (SF), Haultain (HA) and Lassonde Mining (MB) buildings. The facilities primarily comprise a range of laboratories which support the various thematic areas of our teaching and research portfolio: structural, mining and geomechanics, building science, transportation engineering and planning, concrete materials, and environmental engineering. While some laboratory facilities may be identified as dedicated teaching or research spaces, the increasing demands of a growing curriculum combined with growing student populations has made it necessary for the Department to double-up on space utilization such that laboratory facilities are frequently used for both research and teaching activities. Where necessary, the Department also negotiates for access to additional laboratory facilities available through cognate departments, such as the Fluid Mechanics laboratory located in the Mechanical Engineering building and operated by the Department of Mechanical and Industrial Engineering (used for CME270), and the chemical laboratories located in the Lash Miller Chemical Laboratories building (used for CIV342, CIV1308 and CIV1319).

With respect to the fair assignment of space in a space-constrained system, and to ensure optimal utilization of space as the foci of our various constituents' changes over time, the Department adheres to the guidelines set out in its "Policy on Management of Department Space". This policy details the governing principles concerning space allocation and the process for determination of spatial assignments. A copy of the policy is attached in Appendix S.

In brief, existing laboratory resources include:

- the Haultain laboratory (HA53), a structural models laboratory that serves as both a structural mechanics and geomechanics laboratory;
- the Structural Testing Facility, located in the basement of the Galbraith and Sandford Fleming buildings, a unique structural engineering facility that enables researchers to perform experiments on large-scale structural and mechanical components, as well as conduct full-scale destructive tests under impact and high velocity loading conditions (this laboratory is networked to partner facilities located at École Polytechnique de Montreal, Sherbrooke, and McGill universities);
- the Intelligent Transportation Systems Laboratory (ITS lab) is a graduate research facility dedicated to generating simulations and for traffic monitoring based in real-time data (this lab is also made available to undergraduate students involved in transportation research);
- the Rock Fracture Dynamics lab, located in the Sandford Fleming building, is an integrated rock testing facility with geophysical monitoring and extensive numeric modeling capabilities. The adjacent Structural Remote Sensing and Data Visualization lab is utilized to monitor the performance of structures and bridges in service;

- the Building Science research facilities, also located in the Sandford Fleming building, provides access to climate simulators and data acquisition, as well as ample space to set up full size wall sections for testing;
- the Concrete Materials Laboratories on the third floor of the Galbraith building are equipped to perform a wide range of tests on concrete materials and to provide training at both the graduate and undergraduate levels. Specialized research equipment in the laboratories include numerous devices for characterization of the pore structure, permeability, and ion diffusion of concrete;
- the Geotechnical Laboratories, also on the third floor, are designed for combined teaching and research purposes. These laboratories are equipped to perform standard tests on soil, rock and concrete materials and to provide training at both the graduate and undergraduate levels; and,
- the Environmental research facility is a joined suite of labs located on the fourth floor of the Galbraith Building.

The labs are supported by three shop facilities for machining, woodworking and welding. Each shop is equipped with the appropriate tools and equipment to facilitate development of prototypes for course related student projects and research projects. The equipment inventories for each shop are continuously updated.

Although the Structural Testing Facility was fully renovated in 2008 with CFI funding, at the time of the 2012 review, the condition of the Department's other laboratory facilities was generally viewed to be in need of upgrading, especially in light of the Department's desire to be more responsive to advances in applied industry driven research. The Department embraced this recommendation and in 2013, the Environmental labs were significantly upgraded with funding from the Canadian Water Network, the Department, and the Faculty to unify and consolidate the facility, resulting in a greatly needed increase to the overall space allocation. Several new pieces of analytical equipment were acquired to properly outfit the new labs.

With the assistance of several infrastructure renewal funding partnerships, such as the Dean's Strategic Fund (DSF), the Canada Foundation for Innovation (CFI) and the Federal Government Post Secondary Strategic Innovation Fund (SIF), we have made significant capital investments to achieve the following additional improvements to our assigned facilities over the past five years:

1. The structures testing facilities that were located in GB12 and GB13 were closed in the fall of 2017 and renovations are now underway to repurpose these spaces. GB12 will become the new Geotechnical lab that will include installation of equipment for soils testing. This will support the research being undertaken by Professor Mason Ghafghazi.
2. GB13 will house a new climate controlled chamber that can accommodate a variety of research projects. The chamber will allow climate simulations of up to 60 degrees Celsius with 100% humidity. One of the intended purposes of this chamber is the study of concrete materials under extreme conditions, especially large-scale public works facilities such as nuclear reactors. This facility will support the research done by Professors Frank Vecchio and Daman Panesar.
3. Another major renovation underway in the basement of the Galbraith Building is the creation of a completely new Concrete Materials Laboratory. This will comprise all new infrastructure in an area of the basement previously composed of offices and storage, and part of an adjacent corridor (exterior to GB31). The facility will be equipped with a dedicated dust extraction system and new safety sub-systems (i.e., eyewash stations, deluge shower, etc.) as well as an overhead crane to assist in servicing the newly built sedimentation system.
4. In tandem with the project above, a new Geomechanics facility is being constructed to support the work of Professor Giovanni Grasselli and others within the Mining and

Geomechanics research group. This project is also being funded through the SIF program, and upon completion will house x-ray microCT (Computerized Tomography) and x-ray nano-CT machines, a 3D scanner, a 3D sand printer, and a Virtual Reality Modeling Language (VRML) projector.

5. Additional Strategic Innovations Fund renovation projects are occurring in the main Structural Testing Facility, as the former Concrete Materials lab (GB22, which was located within the Structures Facility) will be converted for use as a new Structures sample preparation room. Other areas within this Facility will also be upgraded as follows:
  - the 100% relative humidity chamber (used for curing concrete) will be rebuilt with new stainless steel shelving and a complete replacement of the water misting and heating system;
  - the rock crushing area will be expanded and outfitted with a new dust collection system, and,
  - the aggregate hoppers will be refurbished and partially rebuilt and will also be serviced by the same dust collection system mentioned above.
  
6. GB412 is currently under renovation to create the Mining Water and Environment Facility, to support environmental research, including the research of Professors Leslie Warren and Elodie Passeport. Adjacent to this Facility, a new lab for low impact development research (for example green roofs, permeable pavements) has been created to support the work of Professor Jennifer Drake.

Work is currently underway to develop the Building Energy and Indoor Environment (BEIE) testing facility, located in the basement of the Sandford Fleming building. The BEIE will support the work of Professors Marianne Touchie, Jeffrey Siegel and Kim Pressnail in building environmental monitoring and energy modelling. We anticipate this project will be completed by the spring of 2018.

In conjunction with this project, additional work is underway to create a Building Science Rooftop testing facility, located on the roof of the Sandford Fleming building. This facility will also support the work of Professors Touchie, Siegel and Pressnail. Funding for the project is provided through the Federal Government Post-Secondary Strategic Innovations Fund.

It is worth noting that much of the work undertaken in our research facilities is done to ensure that our labs remain compliant with constantly changing Environmental Health & Safety legislation.

Over and above the lab improvements, renovations were made to the Building Science research group office suite located in GB314. Funds were also allocated toward the renovation and purchase of contemporary furniture for the new graduate student office spaces located on the first floor of the Sandford Fleming Building (SF1102) and the fourth floor of the Galbraith Building (GB415 and GB422).

The first floor offices located in the Lassonde Mining Building were completely renovated to accommodate both faculty and graduate students, and to create a new drop-in computing facility and common room for the Lassonde Mineral Engineering undergraduate students. Funding for this \$1-million project was equally shared between the Department and the Faculty.

All classrooms are considered shared facilities and as such are under the jurisdiction of the University's Academic and Campus Event Office (ACE). All departments within the Faculty must submit booking requests to this office on an annual basis in order to secure classroom space for undergraduate course delivery. However, the Department does have ownership over two lecture spaces located in the Galbraith Building (GB117, GB217) which are primarily used for graduate courses. As such, the Department is responsible for any upgrades or renovations made to these spaces.

A facility unique to the Civil and Mineral Engineering Department is the Goldcorp Innovations Suite located in the former attic space of the Lassonde Mining Building (LMB500). This facility, created in 2011, provides design space for 10 studios equipped with a total of 100 computers, 24 graduate workspaces, a conference room, and a special event reception area. The design spaces are fully equipped with integrated presentation equipment, computer stations, and board style meeting tables to facilitate group discussion. These design spaces are regularly used as an undergraduate student computing lab, except for those times when classes are scheduled in the studios. Some of the computers are reserved for fourth year LME students to run the mine design software used in their capstone design course. When not being utilized for student or teaching purposes, the facility also serves as a conferencing centre for department-sponsored guest seminars, staging of the public component of our PhD departmental examinations and MASc thesis presentations, and for alumni events and advisory board meetings.

The remaining space directly assigned to the Department is allocated to individual faculty offices, student computing and common use support space, administrative offices, shared meeting rooms, and a modicum amount of space is allocated to storage.

The Department provides technical support for student and administrative computing resources, but responsibility for maintenance of computing resources relative to research activities are usually within the purview of the various research groups. Some research groups that deal in the collection and assimilation of large data, such as the University of Toronto Transportation Research Institute (UTTRI), fund dedicated staff, either as research associates or technical experts, to be responsible for ensuring the integrity of their respective computing systems.

The current breakout of assigned departmental space by category is shown in the table below.

**Table 6.1 Space Allocations – Civil and Mineral Engineering**

Category	Total Assigned	% of Total Space
Academic Offices	666.80	8.59%
Support Staff Offices	296.20	3.82%
Student Common Space	91.12	1.17%
Graduate Student Offices	1100.15	14.18%
Non-Tiered Classroom	249.37	3.21%
Office Support Space	730.91	9.42%
Research Lab Space	2379.87	30.67%
Research Lab Support	870.23	11.21%
Research Office/Project Space	201.25	2.59%
Teaching Lab Space	804.54	10.37%
Student Support Space	117.19	1.51%
Undergraduate Lab Support Space	94.14	1.21%
Undergraduate Computing Space	158.94	2.05%
<b>Total space assigned to Civil and Mineral Engineering</b>	<b>7,760</b>	<b>100.00%</b>

## 6.1 Engineering Society Student Levy Fund

The resources within the undergraduate student computing facilities are rotationally updated, although this is usually achieved in conjunction with proposals submitted for consideration via the FASE Temporary Student Levy Fund. This annual fund is amassed through voluntary undergraduate student incidental fee contributions. The annual allocation of Levy Funds is fairly and equitably determined by

the board of directors of the student-run Engineering Society, but the process for securing funding is quite competitive among the Engineering departments. As such, the desired level of financial support is not always achieved in a given year. Full funding for approved projects is provided on a 2:1 matching basis, with the Department contributing one-third of the total cost. The table below demonstrates the support and projects funded through the Student Levy Fund over the past five years.

**Table 6.2 Civil and Mineral Engineering Department Levy Fund Projects 2013-2017**

Year	Engineering Society	Department Contribution	Total	Key Projects
2013-14	51,000	15,300	66,300	Upgrades for CivEng student computer lab; data acquisition systems for Solid Mechanics experiment, reaction frames for Solid Mechanics, vacuum pumps (CIV342), mineral design plotter (capstone Mineral Design); USVP device; assorted hand tools
2014-15	19,475	9,738	29,213	Concrete test hammer; fishfinder, tricorder compass and clinometer, handheld thermometer, PA system and mixer, webcams (all equipment in support of CME courses)
2015-16	41,000	35,413	76,413	Filter assemblies, flow tracker and hip waders, upgrades to soil shear strength testing equipment, software licenses, Kit "C", laptop computers, FSP units, terabyte hybrid disk drives (all equipment in support of CME courses)
2016-17	51,100	17,850	68,850	Pressure meter kit, compressometer/extensometer, testing on clay specimens, weather station (all equipment in support of various courses); Update of undergraduate student common room
2017-18	62,400	29,200	91,600	Student common room - furniture; LMB fourth floor computer lab upgrades; portable laser particles, in-class demonstration units
<b>Total</b>	<b>224,975</b>	<b>107,501</b>	<b>332,376</b>	

## 6.2 Gull Lake Camp Facility

The Department continues to benefit from access to the Gull Lake Camp, located near Minden, Ontario. The facility is owned by the University, but is generously made available to the Department to host our annual CAMP (CME358H – Civil and Mineral Practicals). The CAMP course provides undergraduate students with the opportunity to acquire hands-on experience in the use of various field instruments used within their professions, and the processes involved with land surveying, water quality measurements, hydrologic measurements, and alternative energy system related measurements. Held in August of each year, each camp session is two-weeks in length, with two camp sessions normally run. We also access the camp for three days in early September each year to run CIV201; Introduction to Civil Engineering. In this course, students learn about the water and wastewater systems, hydrology, and biodiversity.

Originally built in 1920, the facility is in dire need of updating. A fundraising campaign, spearheaded by Professor Brenda McCabe, is currently underway and we are endeavouring to raise \$1.5-million to build new student accommodations. We are extremely grateful that the Faculty has generously contributed \$500,000 towards this initiative through the Dean's Infrastructure Innovations Fund to help kick-start the campaign.

At the start, there was one large bunkhouse that accommodated 50 students. Over time, the diversity of our undergraduate population shifted from predominantly male to now comprising of 43% female students. In 1992, an unused classroom building was renovated to create separate male and female dormitories, but with the ongoing growth in our female student population, the female side is becoming too small to adequately accommodate all of our students. Our goal is to replace the old bunkhouse with new accommodations that will accommodate up to 90 students at a time.

Over the years, the Department has continually contributed towards the maintenance and upgrading of the camp. We see this as one aspect of our contribution to the University community as a whole. For example, four years ago the Department upgraded the staff accommodations to respond to a need to increase the space available to house the teaching support staff. There is now accommodation to house four instructors and four TAs within one facility, and we doubled the number of shared washroom facilities.

The camp facility is also used by the Da Vinci Engineering Enrichment Program, (more commonly referred to as the DEEP Summer Academy), in June and July each year. This partnership works very well, as DEEP pays for its access thus contributing to our annual operating budget. In the past, the program has contributed towards the cost of several major upgrades to make the facility safer for younger student groups.

### **6.3 Future Space Planning**

Opportunity to bring further improvement to the Department's assigned space will be directed by our continued efforts in fund-raising, and responding to calls for infrastructure renewal proposals that may arise. However, our ability to address opportunities for infrastructure renewal continue to be hampered by the limited space available for expansion, and by the secondary challenge of deferred maintenance (such as asbestos abatement), which can drive the cost of any single project beyond the Department's funding capabilities. We therefore hope that the University may eventually arrive at a solution that will provide some funding relief to address this campus-wide issue.■

# 7. INTERNAL AND EXTERNAL RELATIONSHIPS

The Department of Civil and Mineral Engineering is fortunate for the strong ties established with industry over the years, and with our graduates who have moved on to professional careers. Some examples of key successes include:

- Professor Emeritus Gerald Steuart developed the Transportation Tomorrow Survey 2.0 (TTS) with the Transportation Information Steering Committee (TISC), the Ministry of Transportation of Ontario. The first survey was conducted in 1986. The TTS investigates and tests a broad range of alternative designs leading to a recommended new, comprehensive passenger travel survey program for the Greater Golden Horseshoe area that addresses the region's current and emerging data collection needs
- UTTRI has partnered with the City of Toronto to implement the 2017 King Street Streetcar Pilot Project, and with the Citymapper Ltd. app launch
- The Centre for Resilience of Critical Infrastructure (CRCI) has had many partners since its inception in 2011 including: Arup, PwC, Defence Research and Development Canada (DRDC), Department of Homeland Security, Combating Terrorism Technical Support Office (CTTSO) and Centre of the Protection of National Infrastructure (CPNI).

## 7.1 Industry and Government Relations

A unique offering of our Department includes the Civil and Mineral Engineering Career Fair hosted annually on the first Thursday in January. The event involves more than 20 companies from across the civil and mineral engineering sectors. The January 2018 fair was extremely well attended and we received many positive comments from company representatives with respect to the calibre of our students.

An initiative currently in the planning phase, with a launch date in 2018, will be the introduction of a Civil and Mineral Research Breakfast Series. The objective of this series will be to highlight ongoing priority research areas, increase engagement of alumni working in these priority areas, uncover potential prospect or research partners, and highlight PEY hiring opportunities. The proposed audience will include 12-15 alumni in senior and/or hiring positions in industry.

As our programs have grown over the years, the need to extend our outreach and strengthen our relationships with industry has increased. We fully recognize that more opportunities for placements and incentives through scholarships are needed. The Department will also look to formalize industry engagement strategies, capitalizing on growing research capabilities and areas within the Department.

### 7.1.1 *Advisory Boards*

The Department facilitates and engages two boards, each addressing the needs of the Civil and Mineral engineering portfolios, as outlined below.

#### 7.1.1.1 *Lassonde Advisory Board*

The Lassonde Advisory Board meets twice a year to discuss current mineral engineering issues, trends and opportunities with the Dean of the Faculty Applied Science and Engineering, the Department Chair, the Director of the Lassonde Institute of Mining, the Director of Industry Partnerships and the Lassonde Communications team member. The 2017-2018 Board members are:

- Pierre Lassonde, Chairman, Franco Nevada
- Teo Dechev, CEO & President, Mundoro Capital
- Louise Grondin, Senior VP, Environment & Sustainable Development, Agnico-Eagle
- Peter MacPhail, Chief Operating Officer, Alamos Gold Inc
- Sam Marcuson, Former Vice-President, Business Improvement, Vale Canada
- Michale McSorley, Former President, Falconbridge International
- Nathan Stubina, Managing Director, McEwen Mining
- Paul Tomory, Chief Technical Officer, Kinross Gold Corp
- Bert Wasmund Executive Director, Hatch

#### 7.1.1.2 *Civil Engineering Industry Advisory Board*

In past years, the Chair's Advisory Board informed philanthropic efforts and provided peripheral input into academic planning decisions. In Fall 2017, this body was dissolved and replaced by the Department of Civil Engineering Industry Advisory Board (IAB). This directorate's mandate is to provide assistance and guidance to the Department, support collaborative research activities with industry, and participate proactively towards our efforts in enhancing experiential learning opportunities. The IAB meets twice a year with the Department Chair, representatives from the FASE Advancement office, and a Civil Engineering communications team member, and we are continuing our efforts to solicit additional members. The current members of the IAB include:

- Christopher M. Harhay, President, Harhay Developments
- Jacinta O'Brien, Program Manager, Engineering and Construction Services, City of Toronto
- Joe Tiernay, Executive Director, Ontario Good Roads Association
- Mike Buckley, Director, Design Services, PCL Constructors Canada
- Chris Andrews, Senior Vice President, EllisDon
- Hugo Blasutta, Chief Executive Officer, WSP Canada

The Terms of Reference for the Civil Engineering Industry Advisory Board is included with this report (Appendix T). The terms of reference for the Lassonde Advisory Board are currently being developed.

### 7.1.2 *Alumni and Fundraising*

Growing and maintaining excellent relations with our alumni to invest their support of students and departmental initiatives is a high priority for the Department. The efforts to maintain strong connections with alumni span the spectrum from engaging students (future alumni), to inviting

specific alumni to targeted Department events. Communications with alumni through various means is critical to their engagement. Fundraising efforts are supported by the FASE Advancement team who works with the Department Chair and individual faculty members on identified fundraising priorities. A sampling of our activities related to alumni engagement and fundraising are provided below.

### 7.1.2.1 *Alumni Events*

Alumni events held each year include:

- Spring Reunion (late-May) is a lunch and facility tour held for around 25 alumni returning to campus
- CivMin Scholars Reception (October/November) brings together students with the alumni and donors who established and sponsored the various scholarships the students receive. The Department awards over 70 scholarships to both undergraduates and graduate students through endowments arising from the generosity of alumni or supported by industry and professional associations. A full listing of our current roster of scholarships is attached as Appendix U.
- The Department maintains a booth presence on the trade show floor at the Prospectors and Developers Association of Canada Convention, held in Toronto annually. We also host an alumni breakfast event (in association with the Women In Mining Toronto chapter) and co-host an alumni gathering (in partnership with the Department of Earth Sciences).

### 7.1.2.2 *Student-Alumni Engagement*

Students engage directly with alumni and industry through student academic clubs and industry association student chapters.

Industry associations that have a student presence on campus are:

- Canadian Society for Civil Engineering (CSCE)
- Canadian Institute of Mining (CIM)
- Canadian Electrical Contractors Association (CECA)
- Bridges to Prosperity
- Women in Mining

Student groups organize a number of Alumni Career Talks, Networking Events and Alumni Pub Nights. These events are normally attended by approximately 15-40 alumni and current students. The Student Services staff provides guidance and logistical support to students on an as needed basis.

### 7.1.2.3 *CONNECT*

CONNECT, a curated social media platform that provides engagement opportunities for engineering alumni around the world, is the Department's formal connection to our alumni. Over 730 Civil and Mineral alumni members are registered on CONNECT, and the communications team is working with other FASE members and advancement staff to explore and develop meaningful engagement strategies to better leverage the platform.

#### 7.1.2.4 *The Civilian*

The Department publishes an annual departmental magazine, *The Civilian*, every September. The publication is mailed to over 4,000 alumni and is met with positive feedback and enthusiasm. The magazine also serves as collateral for many advancement and development meetings.

#### 7.1.2.5 *Fundraising*

Regular meetings to strategize and review alumni lists identifying potential donors are held with the Department Chair, Director of Student Services and FASE Advancement senior leadership. Looking toward the future, securing an advancement representative to provide consistent support and learn the Department's needs and challenges will ensure greater development opportunities and success.

FASE has recently launched the Centennial Campaign for CAMP, which aims to raise \$1.5-million to undertake much-needed renovations, repairs and expansion to the site. The comprehensive upgrades will be in keeping with the rustic tradition that makes CAMP unique for students, preserving the site's rich 100-year history while also serving the needs of a changing student population and educational landscape.

In conjunction with the FASE Advancement office, the GRADitude campaign aims at engaging fourth year students to support experiential and collaborative opportunities for current and future students. The campaign has seen an increase in participating students over the past five years, although there has been a significant decline in the percentage of graduating class and dollars raised per capita. This has been identified by the Department as a priority area for outreach and analysis.

**Table 7.1 Civil Engineering GRADitude Contributions, 2001-2017**

	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017
<b>Total # students in class</b>	117	104	117	135	128	137
<b>Number of Donations</b>	31	53	47	59	71	35
<b>Total \$ Donated</b>	\$954.31	\$1,345.02	\$934.53	\$1,790.82	\$1,484.05	\$727.79
<b>Average Donation</b>	\$30.78	\$25.38	\$19.88	\$30.35	\$20.90	\$20.79
<b>\$ raised per capita</b>	\$8.16	\$12.93	\$7.99	\$13.27	\$11.59	\$6.74
<b>% class participation</b>	26.50%	50.96%	40.17%	43.70%	55.47%	32.41%

**Table 7.2 Lassonde Mineral Engineering GRADitude Contributions, 2001-2017**

	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017
<b>Total # students in class</b>	11	21	13	16	31	20
<b>Number of Donations</b>	6	21	13	16	31	19
<b>Total \$ Donated</b>	\$120.55	\$414.81	\$264.22	\$1,020	\$660	\$482
<b>Average Donation</b>	\$20.09	\$19.75	\$20.32	\$63.75	\$21.29	\$25.37
<b>\$ raised per capita</b>	\$10.96	\$19.75	\$20.32	\$63.75	\$21.29	\$24.10
<b>% class participation</b>	54.55%	100%	100%	100%	100%	95%

## 7.2 Relationships with Cognate Faculties, Academic Departments and Units

### 7.2.1 Partnerships within the University of Toronto

The Department of Civil and Mineral Engineering maintains excellent working relationships with many academic units across the University, and spearheads a number of multidisciplinary centres. For example, the Lassonde Institute of Mining includes members from six departments and two faculties, and the University of Toronto Transportation Research Institute (UTTRI) membership spans across 13 departments, two faculties and two schools. A complete outline of all multidisciplinary initiatives led by our Department is found in Section 4 of this report (Research).

Beyond the Department research facilities, many of our faculty are members of various cognate department and Faculty entities, including the Institute for Water Innovation, the Pulp & Paper Centre, the Institute for Sustainable Energy, and the Centre for Automated and Transformative Transportation Systems.

In addition to the faculty with cross appointments mentioned in Section 2 (Faculty), several of our faculty have status-only cross appointments (Table 7.3)

**Table 7.3 Faculty with Status-Only Appointments and Cognate Departments**

Faculty member	Cross appointment - status only
Jennifer Drake	Daniels Faculty of Architecture, Landscape and Design
Giovanni Grasselli	Earth Sciences
Heather MacLean	Chemical Engineering and Applied Chemistry
Jeff Siegel	Dalla Lana School of Public Health
Lesley Warren	McMaster University

### 7.2.2 Partnerships with Other Universities and Organizations

Our Department continues a history of partnerships with other universities and external organizations, important stakeholders in our research endeavours. Some successful examples include: The Drinking Water Research Group (DWRG) with the National University of Singapore; Professor Lesley Warren's partnerships with UC Berkley and Genome Canada; Professor Brent Sleep's partnership with ORF and NSERC Create partners at Western, Queen's, and Waterloo.

One example of a multi-stakeholder partnership is the Seismic Resilience Group (UT-SIM), led by Professors Constantin Christopoulos and Oh-Sung Kwon. This is an open framework for integrated multi-platform simulations for structural resilience with collaborators from around the world including: University of British Columbia (Canada); San Francisco State University (USA); University of Bristol (UK); University of Sannio, IUSS (Italy); Tongji University (China); University of Canterbury (New Zealand); and Pontificia Universidad Catolica de Chile (Chile). The open-source approach for integration of diverse numerical models and experimental specimens aims to improve partnerships among institutions in Canada and abroad. In April 2017, UT-SIM hosted an international workshop on multi-platform hybrid simulation using UT-SIM framework. The two-day workshop was attended by over 30 participants from around the globe, and provided hands-on training for researchers looking to develop simulation capabilities using the UT-SIM framework.

### 7.2.3 *Distinguished Lecture Series and Guest Speakers*

Since 2015, the Department has hosted a Distinguished Lecture Series with over 20 top researchers from around the world speaking on topics that include: building sciences, transportation, environmental engineering, geotechnical engineering, policy development and mineral engineering. The series aims to foster deeper connections with the entire research community, expose students to new research and ideas and expand Department conversations and dialogues.

Beyond the Distinguished Lectures Series, the Department typically hosts a significant roster of 15 or so guest speakers a year. Invited by faculty and supported by the Department Communications team as needed, these experts from industry, academia, government and other non-governmental agencies provide a real-world touchpoint to students.

### 7.2.4 *Reflections on Internal and External Relationships*

As one of the oldest Engineering departments at the University of Toronto, our Department's external reputation and profile are built on our successful history. However, at a recent town hall meeting, faculty discussed at length how to elevate and further position the Department's name. With our new mission statement and potential department name change, we will continue to better and more strategically reflect and inclusively represent the breadth of research and expertise of all our faculty members, and the two distinct degree experiences we provide to our undergraduate students. We hope to continue this forward momentum deepening, our academic foundations and strengthening our departmental morale to foster greater engagement from our students and alumni and to provide greater support to faculty endeavours.

The Department recognizes the need to increase alumni touchpoints through formalized events and meaningful electronic communications, both on and off the CONNECT platform. In 2018, the Department will prioritize increasing alumni participation and engagement on this platform and the communications team will implement various tactics and campaigns to leverage this powerful online tool.

There are many opportunities for the Department to continue its success in the area of external relations, from leveraging the industry expertise of our advisory boards for informed academic planning, to increasing research collaboration opportunities, the Department is developing a strategic plan for Industry and Advisory Board Relations that will be initiated in 2018. The Department will be engaging its Communications team to direct and lead the efforts while working in concert with FASE Advancement staff. In addition, the Department's Communications team will support and provide advice to our various research groups and faculty as needed to better present research offerings for increased partnership success.

The creation of the LIM Director, Industry Partnerships position will be an integral asset to furthering the Department's connections with industry. The role is still in the early stages of development but we are committed to building a broad industry-academia network and an operational structure to engage key industry thought leaders, and to ensure dissemination and translation of LIM research. ■

# 8. PREVIOUS REVIEW RECOMMENDATIONS

The Department engages in many forms of formal and informal quality review processes to ensure that our programs remain at the pinnacle of civil and mineral engineering education, that our research continues to foster innovation and bring improvement to society, and that our internal operations continue to run efficiently and meet the needs of all members of our community.

Our last formal review under the University of Toronto Quality Assurance Process (UTQAP) took place in 2011, and our undergraduate programs were thoroughly reviewed in 2012 in conjunction with the last cyclical accreditation review conducted by the Canadian Engineering Accreditation Board (CEAB). We also internally reviewed the Lassonde Mineral Engineering undergraduate program in 2012 immediately following our departmental review, and again in 2013-14 following the accreditation review.

The following is a summary of the central points raised during each of these consultations and our progress in addressing them.

## 8.1 University of Toronto Quality Assurance Process (UTQAP) 2011

A primary concern rising out of the 2011 UTQAP review was the integration of the Lassonde Mineral Engineering Program into the Department. In 1996, Pierre Lassonde provided funding to support the development of a mineral engineering program at University of Toronto to replace the Geological and Mineral Engineering program that existed at the time. This was first set up as a division, and professors teaching courses in the program came from different departments, primarily Civil Engineering. In 2005-2006 a decision was made to make the Department of Civil Engineering the administrative home of the LME program. At the time of our 2011 UTQAP review, the reviewers assessed that the two programs were not well integrated.

The Department undertook a two-step approach to respond to this. The first was to strike a taskforce to identify the source of the remaining integration issues and, where possible, recommend solutions for improvement. The second stage, which was a longer-term action, involved dedicating time and resources toward improving communication with the Lassonde Mineral Engineering students, and between the Civil and Lassonde Mineral Engineering students. Town halls were held to receive input from LME students and suggestions for improving communications and ensuring their inclusivity within our community.

With respect to the Civil Engineering undergraduate program, the reviewers cited recommendations to expand opportunities for interdisciplinary collaboration within the fourth year capstone group design course, to encourage greater use of innovative, experimental teaching approaches, and to incorporate more project-based, online or blended learning. The size of some classes, especially labs, were viewed as being too big for sufficient hands-on learning. The reviewers also recommended that a curriculum review be undertaken after completion of the (then upcoming) CEAB accreditation cycle.

The Department addressed the recommendation regarding the capstone group design course through a series of consultations between the capstone course coordinators and the NSERC Chair in Multidisciplinary Engineering Design, which generated new opportunities for multidisciplinary capstone experiences for students in both Civil Engineering and Lassonde Mineral Engineering. However, the Department acknowledges that there is still work to be done to encourage greater participation of Civil and LME students in the multidisciplinary capstone group design course.

The Department's curriculum committees were tasked with investigating additional innovative teaching opportunities to improve both undergraduate and graduate student learning. To initiate this task, the committees sought input from the Department's representative on the Faculty's Teaching Methods and Resources committee, the Vice-Deans for Undergraduate and Graduate Studies, and the University's Centre for Teaching Support & Innovation. Since then, several innovative teaching approaches have been introduced, such as inverted classes and utilization of technology enhanced active learning (TEAL) classrooms, and development of online course materials. We continue to share our suggestions for innovation and to seek out new approaches among our colleagues. The Department also separated the oversight of undergraduate and graduate curriculum from one committee into two: the Undergraduate Studies Committee, and the Graduate Studies Committee, respectively.

Large undergraduate class sizes are unfortunately intractable, as sectioning of larger classes for lectures is not an option. The teaching load per faculty is three courses per year, the standard load within the Faculty.

The Department is continuously reviewing our program curricula for refinement and development of new courses and specifics regarding curriculum review were thoroughly addressed through our 2012 CEAB accreditation review.

As concerns our graduate programs, the reviewers observed that graduate students would benefit from smaller class sizes, cross-specialization research seminars, and the introduction of a technical writing course.

To respond to this observation, the Department initiated a Distinguished Lecturer Series whereby renowned researchers from cross disciplines are invited to provide guest lectures. Our ability to respond to the observation regarding class sizes for graduate courses is controlled by the same constraints as our undergraduate courses, noted above. However, with a few exceptions, graduate course class sizes are reasonable and in some courses with a heavy project component the class size is capped. Teaching assistant support is also provided for any graduate course with more than 25 registered students.

The reviewers noted that there appeared to be a lack of faculty mentoring guidelines or processes, and that younger faculty felt that there was a lack of clear guidelines on the expectations for promotion and tenure. They also noted an apparent lack of collaboration between research specialization groups and that existing collaborations tended to be informal.

To address the suggestion regarding junior faculty on-boarding, the Department developed a *A Guideline for Mentoring Junior Faculty*. The document formalizes the responsibilities of a mentor, and established a mechanism for proactive tracking of the mentorship process. In addition, each pre-tenure faculty member has been appointed a senior faculty mentor. A teaching mentor is also hired to help guide each assistant professor when they join the Department.

A further key recommendation was to better integrate the Department's alumni relations and advancement efforts with that of the Faculty. The Department has responded to this through the hiring of two communications personnel who work in support of the director of student services and external relations, and provide departmental representation on Faculty-wide committees involved in these areas. The Department also works extensively with the Director, Foundation & Corporate Partnerships, the Executive Director of Advancement, and Senior Development Officers.

## 8.2 2014 Internal Reviews of the Lasonde Mineral Engineering Program

Following the UTQAP review of 2011 and the CEAB accreditation review in 2012, the Department underwent two successive internal reviews of the Lasonde Mineral Engineering Program. As these reviews were internal to the Faculty, we were not required to report on the reviewers observations to the Office of the Vice-Provost Academic Programs, although we did adhere to the UTQAP process in conducting these reviews.

The 2012 review primarily detailed recommendations on mechanisms for improving student relations. As noted in the 2014 internal review the following assessments were made, and the listed actions have since been taken to address and resolve the recommendations.

In response to recommendations to prioritize the need for an associate chair of the Lasonde Mineral Engineering program Professor John Harrison was appointed to the position in January 2015 for a 3-year term. In April 2017 Professor Lesley Warren was appointed as director of the Lasonde Institute of Mining (LIM). These hires have enabled us to move forward with our mandate to foster development of mining research across the University, enhance industry connections, and work collaboratively with the LME associate chair to enhance teaching and research.

The reviewers also noted that LME students would benefit from additional support from the PEY office. This is a priority for the Department, and we are working with the Faculty and the PEY office to hone processes and increase student success. We hope to see tangible benefits for students in 2018.

With the appointment of the new LIM Director and the recent creation of the position of LIM Director of Industry Partnerships, the Department is poised to address and enhance the respective LME and LIM profiles and strengths, both internally and externally. The new appointments were finalized in November 2017, and 2018 will be the first year of implementation. The Department has great hopes for future success.

Finally, the internal review report recommended the hiring of a teaching stream faculty member. This is identified as one of the specific initiatives associated with future directions of the Department.

## 8.3 2013 CEAB Reviews of Civil Engineering and Lasonde Mineral Engineering

The 2013 CEAB review provided general recommendations for all FASE programs regarding Graduate Attributes. The Department is currently preparing for the Fall 2018 CEAB visit with a focus on tracking and assessing graduate attributes and on continuous curriculum improvement.

### 8.3.1 Civil Engineering Program

Several measures have been taken to address a major comment about the lack of hands-on laboratory experience in the Department. The revision of the curriculum for the two-week Civil and Mineral Practicals (CME358) course, held at the Gull Lake Camp, has provided an enriched hands-on experience for students in a challenging environment. Since the review, research space (100 m<sup>2</sup>) in the Haultain Building basement was converted to undergraduate lab space for structures (CIV209) and geotechnical courses (CME321, CIV324). With more space and smaller sections, this has provided more opportunity for hands-on learning by students. The Department also moved the water and wastewater treatment labs (CIV342) from Civil space in the Galbraith Building to much larger and

better equipped laboratories in the Department of Chemistry, allowing for larger sections and more hands-on experience. The Department also purchased additional equipment (in some cases with support from the Student Levy Fund) for these labs. Current renovations in the Galbraith Building for concrete materials, mining and environment, and geotechnical engineering will further enrich the laboratory experience for Civil and Mineral students. However, given the space constraints, and class sizes, the Department must continue to find creative ways to add further opportunities for students to engage in hands-on lab experiences. There may be exciting opportunities for students to incorporate into courses use of the maker space that will be created in the new CEIE Building.

### 8.3.2 Lassonde Mineral Engineering Program

The number of full-time faculty directly associated with the LME program was highlighted as a concern in the 2013 CEAB report. In 2012, there were three Department of Civil Engineering faculty teaching LME courses and 15 cognate department faculty. We now have 22 full-time faculty members associated with LME – 17 from the Department of Civil and Mineral Engineering (some teaching multiple courses), and five from cognate departments. The following table breaks down all LME courses offered.

**Table 8.1 Number of Full-Time Faculty Teaching LME Courses Compared with Sessional Lecturers**

No. core courses	No. elective courses	Course code	Professors	PhD	Sessional	Delivered by Department:
13	1	MIN ###	5		8	Civil Engineering
8		CME ###	13			Civil Engineering
3	3	ESS ###	2	1	1	Earth Science
	1	CHE ###	1			Chemical Engineering
2		MSE ###	2			Materials Science & Engineering

Moreover, a limited scope of research experience was highlighted regarding faculty directly associated with LME, and it was noted that they had a strong focus on rock mechanics. The Department has responded to this concern by hiring Lesley Warren (MIN 400H1), who has a research focus on environmental aspects of mining; Kamran Esmaeili, who has a research focus on mine design, mine to mill optimization and mining robotics; and Mason Ghafghazi, who has a research focus on soils mechanics. Erin Bobicki, specializing in mineral processing, was hired as a ment between Chemical Engineering and Applied Chemistry, and Materials Science and Engineering, and now teaches the Mineral Processing course (MSE301) to Lassonde Mineral Engineering students.

The CEAB recommended that the sequence of specialized courses (based on the Faculty's 2011-2012 calendar), be examined to ensure students are adequately prepared for their capstone group design projects. Recognizing the need to strengthen the course sequence, the following actions were taken to resolve this issue:

- MIN450H1F Mineral Economics was made a compulsory course effective September 2012
- MIN401H1S Mineral Reserve and Mineral Resource Estimation and MIN470H1S Ventilation and Occupational Health were made compulsory courses in 2013
- two new compulsory courses, MIN 250 Surface Mining, and MIN351 Underground Mining, were introduced in 2012-2013, replacing a single course that covered both open pit and underground mining (MIN350)
- a new course in Acid Rock Drainage was introduced in 2017

Acknowledging that increased enrolment in Civil and Lassonde Mineral Engineering stretches laboratory resources, the Department responded by creating a new 100m<sup>2</sup> teaching laboratory (HA53), from what was previously a research lab.

To increase laboratory experience in MIN courses the following facilities were improved, were constructed since 2012, or are currently under development with new lab sessions introduced in the relevant courses:

- Rock Mechanics laboratory (for MIN429)
- Ground Support Laboratory (for MIN565)
- Undergraduate Mineral Processing Laboratories (in partnership with ChemE and MSE, for MSE301)
- Water and Environment Mining Facility (for new course in Acid Rock Drainage)

Noting the reviewers' concerns regarding curriculum, such as overlap in some of the Earth Science (ESS) courses, the need for more modern tools and techniques at field camp and in courses (for example, AutoCAD), and the lack of a comprehensive view of mining in the capstone design course, the Department has implemented the following since 2015:

- as a result of an extensive curriculum review process by the (then) MIN Academic Planning Committee, four courses were made compulsory;
- among the compulsory courses, MIN450 Mineral Economics and MIN430 Mining Environmental Management address the reviewers' concern about compulsory mineral content, as well as their concern with the number of complementary studies Academic Units (AUs);
- the CAMP (Civil and Mineral Practicals) course, CME358, was revised to incorporate additional elements related to hydrology and water quality. These topics relevant to mineral engineering are taught by Professor Warren;
- the LME capstone project as coordinated by Professor Kamran Esmaeili now reflects the entire mine life cycle. In addition, Professor Esmaeili is implementing multi-disciplinary aspects to expose students to all facets of the industry. This will come into effect in September 2018.

It was recommended a full-time faculty member was needed to teach the subject of mineral finance. Although this has not yet occurred, a sessional instructor has been secured from industry to provide consistency for the past two years (Mathangi Gopinathan). ■

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# 9. FUTURE DIRECTIONS

The Department has made excellent progress since the last external review in 2012. We have made several key faculty hires, increasing diversity and increasing strength in a number of areas, all with a significant focus on developing systems-based sustainable solutions. We continue to attract excellent undergraduate students and move towards gender parity in the undergraduate population. We have made significant investments in our research and teaching infrastructure and embarked on a number of innovations in teaching.

Through consultations with students, staff, and faculty, a range of opportunities have been identified to keep the civil and mineral engineering fields at the forefront of teaching and research in a time of rapid technical and social change, shifting government funding priorities, and evolution of the engineering profession.

In line with the opportunities identified, the core initiatives for the Department in the next five years will include:

- ongoing curriculum review and embrace of innovation in teaching and experiential learning to sustain and elevate our undergraduate and graduate programs
- initiatives to improve recruitment of excellent doctoral-stream students
- review and optimize administrative systems in the Department to provide improved support for the education and research mission of the Department
- strengthening our external relations to provide opportunities to enrich the student experience and raise our research impact through academic-industry partnerships
- pursuit of large interdisciplinary collaborations in research, within U of T, nationally, and internationally

We are proud of our undergraduate and graduate programs and the students who graduate from them. While we offer them a rigorous education, there are many areas where we can continue to improve our programs. Increasing design content in second year, addressing workload issues, increasing connections between courses, integrating mining-specific examples into CME courses, and increasing the number and quality of hands-on labs are just some of the areas that will be addressed in our ongoing curriculum review. Innovations in teaching enabled by new technologies and by facilities in the CEIE will be a priority in maintaining and enhancing a dynamic curriculum to continue to meet the needs of students and the profession.

Participation in Graduate Research Days has helped in recruitment of MASc students and the Department attracts a good number of MEng students. Increasing enrolment in the MEngCEM program remains as a challenge that will require continued promotion and increased outreach to relevant industry and government agencies. Recruitment of doctoral-stream students has been a long-term issue that the Department must address, particularly considering the importance of doctoral-stream students to world-leading research programs. Improved branding, effective use of social media, and outreach to students in peer institutions are needed. Decreasing time to completion for PhD students in the Department will improve the attractiveness of our PhD program.

The Department has a dedicated team of staff that support the Department's education and research missions. However, growth in the research enterprise, downloading of administrative tasks to the Department, and needs for increased support of students have put a strain on the administrative staff. Management of space, the Department IT infrastructure, and support of faculty for research administration are all areas that need to be addressed.

The Department has benefited greatly from the generous support of alumni, through their involvement in advisory boards, giving guest lectures, mentoring students, financially supporting scholarships and other initiatives (e.g. Gull Lake Camp), and hiring our students for PEY or full-time positions. Meaningful engagement of alumni requires a focused effort and personnel resources. The CONNECT platform has been a significant help in communicating with alumni and increased outreach through other social media has helped. Strengthening alumni relations to support teaching and research and the student experience will continue to be a major priority for the Department.

The Department has had success in a number of large collaborative projects (ORF, NSERC CREATE, Canadian Water Network, the Innovation Superclusters Initiative, etc.) in the last five years. The Department, in collaboration with the Faculty will continue to encourage participation in these types of projects, including providing enhanced support for research administration.

## 9.1 Specific Initiatives

The following specific initiatives in support of the core initiatives and other priorities of the Department are contemplated:

### 9.1.1 Curriculum and Student Support

- ongoing curriculum review aligned with CEAB requirements for tracking graduate attributes
- development of online curriculum, supported by government and U of T funding programs
- adaptation of teaching methods to use the new Teaching Enhanced Active Learning (TEAL) classrooms in the CEIE Building
- new option in Engineering Science, perhaps in transportation systems with an emphasis on automated vehicles, machine learning/big data and sustainability
- creation of an MEng in mineral engineering
- involvement of the Civil Engineering Industry Advisory Board and Lassonde Advisory Board members in student mentoring opportunities
- development of a new bunkhouse at Gull Lake Camp to support our changing student demographic population and to allow for extended season use of Camp for undergraduate and graduate teaching
- relocation of the Student Services team to new offices to facilitate an improved environment for student counselling.

### 9.1.2 Faculty Renewal

Initiatives identified include:

- complementary hire in geosciences associated with the Foundation Computer Modelling Group NSERC Industrial Research Chair
- conducting a search for a tenure stream appointment to replace an upcoming planned retirement within the Structures Section
- initiating a search for a teaching stream appointment to support the Lassonde Mineral Engineering program
- pursuing opportunities for potential hires arising from FASE interdisciplinary searches.

### 9.1.3 Teaching and Research Infrastructure

New teaching and research facilities currently under construction, renovation, or recently completed include:

- Mining and Environment Lab (January 2018)
- Low Impact Development Lab (November 2017)
- Concrete Materials Lab (March 2018)
- Geomechanics Imaging Lab (X-Ray MicroCT and NanoCT)
- Materials Environmental facility (February 2018)
- Geotechnical Engineering Lab (March 2018)
- Building Science Lab (April 2018)
- Building Science Test Suites (May 2018)
- Stu Blusson Earth Sciences Visualization Facility, to open in the CEIE Building in May 2018
- possible acquisition of additional space for offices for graduate students, postdocs, research associates, research managers

With these improvements to the teaching and research infrastructure, a thorough review of all space in the Department will be undertaken to ensure optimal use of space consistent with the Department's space policy.

### 9.1.4 Administrative Support

Ongoing and future organizational plans include:

- creation of one new position in the Department Business Office to focus on administration of research grants
- completion of search for new Network Manager position (February 2018)
- assessment of technical support needs across the Department, including management of departmental space

### 9.1.5 External Relations

Our plans for further development of external and industrial relations are:

- expand the Lassonde Advisory Board and the Civil Engineering Industry Advisory Board to 10 – 12 members each
- develop frameworks for meaningful engagement of board members
- creation of a new Strategic Development position for the Lassonde Institute of Mining
- completion of our research branding exercise and implementation of same on the departmental website and communications materials
- initiate alumni breakfast series (February 2018)

### 9.1.6 Doctoral-Stream Student Recruitment

Our goals for increasing awareness of our doctoral-stream programs include:

- completion of research branding exercise and implementation of same in Departmental website and communications materials
- enhanced profiling of accomplishments of current doctoral-stream students and alumni in social media and website
- increasing collaboration with other civil and mineral/mining engineering departments across Canada to raise the profile of graduate studies in engineering
- proactively working with FASE Advancement to increase endowments for new graduate scholarships.■

# GLOSSARY

*Acronyms or terms used throughout this document:*

<b>ACE</b>	(University of Toronto) Academic and Campus Events Office
<b>ACI</b>	American Concrete Institute
<b>AI</b>	Artificial intelligence
<b>ASCE</b>	American Society of Civil Engineers
<b>ASHRAE</b>	American Society of Heating, Refrigerating and Air-Conditioning Engineers
<b>BEIE</b>	Building Energy and Indoor Environment (testing facility)
<b>BIM</b>	Building Information Modelling
<b>BSSO</b>	Building Science Specialist of Ontario
<b>BTRG</b>	Building Tall Research Group
<b>CAMP</b>	Civil and Mineral Practicals (Survey CAMP)
<b>CEAB</b>	Canadian Engineering Accreditation Board
<b>CEIE</b>	Centre for Engineering Innovation and Entrepreneurship
<b>CEM</b>	Cities Engineering and Management (program/course)
<b>CFI</b>	Canada Foundation for Innovation
<b>CHM###</b>	Chemistry course
<b>CIV###</b>	Civil Engineering undergraduate course
<b>CIVE</b>	Civil Engineering
<b>CIV/MIN</b>	Civil and Mineral Engineering
<b>CME###</b>	Civil and Mineral Engineering undergraduate course
<b>COMP</b>	Comprehensive Oral Examination
<b>CONNECT</b>	UofT Engineering on-line alumni community platform
<b>CPB</b>	Cemented paste backfill
<b>CRC</b>	Canada Research Chair
<b>CRCI</b>	Centre for Resilience of Critical Infrastructure
<b>CS</b>	Complementary Studies (undergraduate course)
<b>CSCE</b>	Canadian Society for Civil Engineering
<b>DEEP</b>	(FASE) Da Vinci Engineering Enrichment Program
<b>DEX</b>	Departmental Oral Examination
<b>DMG</b>	Data Management Group
<b>DSF</b>	Dean's Strategic Fund
<b>DWRG</b>	Drinking Water Research Group
<b>ECE</b>	(Department of) Electrical and Computer Engineering
<b>EH&amp;S</b>	Environmental Health & Safety
<b>ELITE</b>	Entrepreneurship, Leadership, Innovation and Technology in Engineering (certificate program)
<b>ESS###</b>	Earth Sciences course
<b>FASE</b>	Faculty of Applied Science and Engineering
<b>FOE</b>	Final Oral Examination
<b>GA</b>	Graduate Attributes
<b>GB</b>	Galbraith Building
<b>GDLE</b>	Graduate Degree Level Expectations

GLOSSARY (CONT'D)

<b>GPA</b>	Grade Point Average
<b>GRADitude</b>	Graduating student fundraising campaign
<b>GTHA</b>	Greater Toronto and Hamilton Area (region)
<b>HA</b>	Haultain Building
<b>HIP</b>	High impact practices
<b>iCITY</b>	Centre for Automated and Transformative Transportation Systems
<b>ISE</b>	Institute for Sustainable Energy
<b>IT</b>	Information technology
<b>ITS</b>	Intelligent Transportation System
<b>IWI</b>	Institute for Water Innovation
<b>LIFT</b>	Lab Innovation for Toronto (project)
<b>LIM</b>	Lassonde Institute of Mining
<b>LME</b>	Lassonde Mineral Engineering (program)
<b>LMB/MB</b>	Lassonde Mining Building
<b>MIE</b>	(Department of) Mechanical and Industrial Engineering
<b>MIN###</b>	Mineral Engineering undergraduate course
<b>MSE</b>	(Department of) Materials Science and Engineering
<b>NCE</b>	Networks of Centres of Excellence
<b>NSERC</b>	Natural Science and Engineering Research Council
<b>NSERC CREATE</b>	NSERC Collaborative Research and Training Experience (program)
<b>NSERC CRD</b>	NSERC Collaborative Research and Development (grant)
<b>NSSE</b>	National Survey of Student Engagement
<b>NTU</b>	National Taiwan University (ranking)
<b>OBEC</b>	Ontario Building Envelope Council
<b>OGS</b>	Ontario Graduate Scholarship
<b>ORF</b>	Ontario Research Fund
<b>PEO</b>	Professional Engineers Ontario
<b>PEY</b>	Professional Experience Year
<b>PTR</b>	Progression through the ranks
<b>QS</b>	Quacquarelli Symonds (University World Rankings)
<b>RENEW</b>	Remediation Education Network
<b>SF</b>	Sandford Fleming Building
<b>SGS</b>	School of Graduate Studies
<b>SIF</b>	(Federal Government Post Secondary) Strategic Innovation Fund
<b>TA/TAship</b>	Teaching Assistant/Assistanceship
<b>TE</b>	Technical elective course
<b>TEAL</b>	Technology Enabled Active Learning (classroom)
<b>TMG</b>	Travel Modelling Group
<b>TrackOne</b>	General first-year undergraduate studies in FASE. Upon successful completion of TrackOne students choose from one of the Engineering undergraduate programs, excluding Engineering Science.
<b>Tri-Council</b>	references Government bodies overseeing administration of research funding programs, i.e., Canadian Institutes of Health Research (CIHR), Social Sciences and Humanities Research Council (SSHRC) and Natural Science and Engineering Research Council (NSERC)

## GLOSSARY (CONT'D)

<b>TTS</b>	Transportation Tomorrow Survey
<b>U15</b>	U15 Group of Canadian Research Universities
<b>UBC</b>	University of British Columbia
<b>UDLE</b>	Undergraduate Degree Level Expectations
<b>USC</b>	Undergraduate Studies Committee (USC)
<b>U of T</b>	University of Toronto
<b>UTIAS</b>	University of Toronto Institute for Aerospace Studies
<b>UTQAP</b>	University of Toronto Quality Assurance Process
<b>UTTRI</b>	University of Toronto Transportation Research Institute

## Degree Codes:

<b>AECIVBASC</b>	Bachelor of Applied Science - Civil Engineering
<b>AELMEBASC</b>	Bachelor of Applied Science - Lassonde Mineral Engineering
<b>MASc</b>	Master of Applied Science in Civil Engineering
<b>MEng</b>	Master of Engineering in Civil Engineering
<b>MEngCEM</b>	Master of Engineering in Cities Engineering and Management
<b>MEng EFT</b>	Master of Engineering - Extended Full-time Option
<b>PhD</b>	Doctor of Philosophy in Civil Engineering

