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MEMORANDUM

ATTENTION: Senate | TEL

FROM: Peter Keller, Vice-President, Academic and Provost, and Chair, SCUP

RE: External Review of the Department of Earth Sciences (SCUP 18-47)

DATE: December 11, 2018 | TIME

At its December 5, 2018 meeting, SCUP reviewed and approved the Action Plan for the Department of Earth Sciences that resulted from its External Review.

The Educational Goals Assessment Plan was reviewed and is attached for the information of Senate.

Motion:

That Senate approve the Action Plan for the Department of Earth Sciences that resulted from its External Review.

c: B. Ward
P. Kench

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MEMORANDUM

ATTENTION	Peter Keller, Chair, SCUP	**DATE**	November 22, 2018
FROM	Wade Parkhouse, Vice-Provost and Associate Vice-President, Academic	**PAGES**	1/1
RE:	Faculty of Science: External Review of the Department of Earth Sciences		

Attached are the External Review Report and the Action Plan for the Department of Earth Sciences (EASC). The Educational Goals Assessment Plan is included, for information only, with the Action Plan.

Excerpt from the External Review Report:
"EASC delivers a comprehensive educational program, recognized by undergraduate and graduate students alike for its high quality."

Following the site visit, the Report of the External Review Committee* for the Department of Earth Sciences was submitted in May 2018. The Reviewers made a number of recommendations based on the Terms of Reference that were provided to them. Subsequently, a meeting was held with the Dean of the Faculty of Science, the Chair of the Department of Earth Sciences and the Director of Academic Planning and Quality Assurance (VPA) to consider the recommendations. An Action Plan was prepared taking into consideration the discussion at the meeting and the External Review Report. The Action Plan has been endorsed by the Department and the Dean.

Motion:

That SCUP approve and recommend to Senate the Action Plan for the Department of Earth Sciences that resulted from its external review.

*External Review Committee:
Stephen Johnston, University of Alberta (Chair of External Review Committee)
Claudia Schröder-Adams, Carleton University
Brian Branfireun, Western University
Bernhard Mayer, University of Calgary
Jeremy Venditti (internal), Simon Fraser University

Attachments:
1. External Review Report (May 2018)
2. Department of Earth Sciences Action Plan
3. Department of Earth Sciences Educational Goals Assessment Plan

cc Paul Kench, Dean, Faculty of Science
Brent Ward, Chair, Department of Earth Sciences

EXTERNAL REVIEW REPORT:
DEPARTMENT OF EARTH SCIENCES, SIMON FRASER UNIVERSITY

External Review Committee
Stephen T. Johnston, University of Alberta (Chair)
Claudia Schröder-Adams, Carleton University
Brian Branfireun, Western University
Bernhard Mayer, University of Calgary
Jeremy Venditti, Simon Fraser University (Internal Member)

INTRODUCTION

The external review team visited the Department of Earth Sciences (EASC) from Wednesday, March 21st to Friday, March 23rd, 2018, having received access to the Self Study Report and accompanying documents on Tuesday, February 13th, 2018. A copy of the visit Agenda / Schedule is attached (Appendix 1). Our mandate was to "assess the Unit and comment on its strengths and weaknesses, and on opportunities for improvement" with respect to its 1) educational program, 2) research, 3) administration, and 4) work environment. In addition, we were asked to address the unit's future plans and to comment on a series of specific questions.

Here we first provide an executive summary of the unit's main strengths and the challenges that need to be addressed to ensure its continued success. We then provide a more detailed assessment of the four specific areas listed above, summarizing the strengths and the challenges for each. We end by commenting on the future plans of the department and attempt to provide answers to the specific questions listed in the Review Committees 'Terms of Reference'.

EXECUTIVE SUMMARY

Overall Strengths

- EASC delivers a comprehensive educational program, recognized by undergraduate and graduate students alike for its high quality.
- Underpinning the undergraduate program are three highly dedicated and talented instructors, who work together as a team, take care of many introductory courses, and allow research faculty members to focus on upper year specialized classes.
- The undergraduate program provided by EASC includes a strong field school component. This experiential learning remains a draw for students and adds to a solid hands-on learning experience.
- The accreditation of both the department's Geology and Environmental Geoscience undergraduate programs by Engineers & Geoscientists British Columbia (EGBC) results in near 100% job placement. The importance of the EGBC accreditation is recognized by employers, explaining the high job placement numbers within the Earth and

Environmental Science disciplines.

- Research conducted in EASC is diverse, in part of excellent quality, societally relevant, and provides numerous opportunities for significant student involvement.

Main Challenges

- The department is too content with the status quo, has limited aspirations when it comes to strategic planning for the future, and needs to be more proactive in seeking solutions to some long standing issues (such as space).
- An emphasis on preserving a very broad research diversity results in a diffuse research focus, a lack of critical mass in almost all research areas, reduced visibility and limited impact.
- Declining undergraduate student numbers present a dilemma particularly given that the department will see a significant number of retirements in the near future.
- Articulation of the EASC programming with the broader scope of partially overlapping thematic programming in the Faculty of Environment needs to be addressed by greater coordination and collaboration.

1a) TEACHING (UNDERGRADUATE PROGRAM):

Strengths

1a-1. EASC delivers a broad educational program with strengths in natural hazards, hydrogeology, resource geology and glaciology. Undergraduate students recognize and appreciate that they are receiving an excellent and broad education. The intensive field-based activities, field schools and the high experiential content were some of the main factors that contributed to student satisfaction with their programs.

1a-2. EASC has a very dedicated, experienced and enthusiastic set of 3 instructors all of whom are fully integrated into the department and who are highly valued by their colleagues. The introductory geology courses, which are delivered by the instructors, are engaging, high quality courses that attract students into the earth science program. Earth Science 101 is an influential course that has in some cases changed students' perspectives and trajectories as undergraduates.

1a-3. EASC is able to offer two streams that lead to professional accreditation by EGBC (Geology; Environmental Geology). Excellent programs + accreditation = JOBS, and the diversity of the programs leads to workplace resilience in a highly changeable sector of the economy. This incredible strength of EASC needs to be maintained and promoted, but should not be taken as an excuse to resist change!

1a-4. Significant local opportunities, such as the annual Exploration RoundUp meeting provide students with exposure to major conferences. This exposure, together with the high quality education being provided to EASC students in two EGBC accredited programs, results in excellent job opportunities that are not commonly available to students elsewhere. These include placements in academia, government, industry and consulting.

Challenges

1a-1. Declining enrolment is a real threat to the health and breadth of the department. It is our understanding that much of the decline is primarily attributable to the loss of students from the general interest first year course offerings and not from a significant decline in the number of students pursuing Earth Science degrees. The loss of students from the introductory courses is in part due to the proliferation of similar first-year science breadth courses across the university, designed to satisfy Writing, Quantitative and Breadth (WQB) skills. There appears to be no upper administrative oversight on what constitutes a breadth-science course. EASC is well positioned to offer courses to satisfy breadth-science courses that should be of high interest from the student body, but the university has allowed a situation to develop where both science and non-science departments have added breadth-science courses in order to chase a fixed number of students. This is problematic for a small unit like EASC where teaching resources have been dedicated to breadth-science courses, only to have their value undermined by the proliferation of similar courses elsewhere. This situation benefits no one and is especially detrimental to small departments like EASC. An additional long term concern is that enrolment in the Earth Sciences is presently declining right across the country.

1a-2. There is a lack of awareness of the cost to EASC of low and declining enrolment, and our committee was provided with little evidence of any departmental strategy to address the drop. Strong enrolment numbers will be a factor in determining retirement replacements, and therefore a proactive departmental and institutional response to counter declining enrolment is required. There was little evidence of effort to understand what the undergraduate population is interested in (at best), or identify aspects of the existing course offerings that are seen as not relevant by students (at worst). There seems to be significant opportunities for the MINOR program that is not being capitalized on, particularly with EVSC where the addition of a minor could allow for professional accreditation with EGBC. The idea of a proposed joint program with Biology does currently not seem well thought out. The joint Chemistry - ES program (see below) should be made more attractive before expanding the offerings of joint programs.

1a-3. The joint Earth Science/Chemistry program, which was praised by students for its content, has not been successful in attracting students (only 4 at present). The program is essentially two separate programs that have been simply stuck together resulting in significant scheduling challenges. At present it is almost impossible to complete the joint program in less than 6 years. Better integration and coordination, and some flexibility regarding course requirements, could make this program much more attractive. By not providing an organized joint program that can be completed in 4 years the two departments are missing out on a significant opportunity.

1a-4. A 1st year Earth Science course is not mandatory for Faculty of Science students; changing this may increase undergraduate enrolment in EASC but would require support from the Dean of Science and higher administration. This is not an 'Earth Science' issue (although the impacts on EASC are substantial). It is a Science Literacy issue. Climate change is the most significant issue facing society, and Vancouver, because of its location on a major delta, will face significant climate change related challenges (rapid change in sea level being just the most obvious). In addition, Vancouver is located along a convergent plate boundary that is responsible for periodic mega-earthquakes and related tsunamis (the last one having taken place at 9:00 PM, January 26th, 1700). Given SFU's location, requiring some basic scientific literacy in Earth Science would seem to be due diligence; requiring an Introductory Earth Science course of all Science students is the easiest way to meet this responsibility. Pressure to implement this change has to come from the Dean of Science.

1a-5. The introductory Dynamic Earth course (EASC 101) competes with an Earth Systems course delivered by the Department of Geography. Whereas rules appear to exist within the institution to prevent such redundancies (see for example Geography being the only unit permitted to provide a GIS course), a lack of coordination of these two courses is tolerated to the detriment of both units, but with the more damaging impact on the smaller unit (EASC). Why greater coordination between courses, or entertaining combining courses, is not happening is not clear. In general, it appears that competition of similar courses in various Programs and Faculties negatively impacts enrolment in EASC.

1a-6. While providing programs that lead to professional accreditation is a strength of the unit, there appears little appetite to explore options to streamline the large number of courses offered in the undergraduate program while maintaining EGBC accreditation. Flexibility does exist within the EGBC guidelines, and the current programs could be revised to provide less prescribed routes to professional accreditation. Doing so would provide the unit with the opportunity to broaden its Earth System and Environmental course offerings (which, for example, could pave the

way toward meeting student demand for additional water-related and mathematical modelling courses).

1a-7. Online teaching opportunities are not being exploited in part because of what appears to be arbitrary rules regarding the maximum numbers of registrants allowed per course. Online courses such as Dinosaurs or Earth History, those without laboratories, should be reaching a much larger audience. Significant outreach efforts to elementary and secondary schools is an excellent long-term strategy for increasing interest in the program, but needs to be one component of a multi-faceted plan.

1a-8. There is a real need, identified by the undergraduates, for EASC students to have access to a GIS course with earth science applications. The current offerings from the Department of Geography provide training in the theoretical aspects of GIS, which serves geographers well. The courses do not, however, appear to serve the group of undergraduates who need user-level training in GIS as a tool, EASC students among them. Providing EASC students with GIS training appears to require upper administration coordination.

1a-9. There is significant student interest in the Water Science concentration of the Environmental Science Program (EVSC), which is administered through the Faculty of Environment. The result is an almost unmanageable demand for hydrogeology and groundwater modelling courses in EASC, and "too many students" to accommodate in the existing course offerings. This interest represents an area to be capitalized on by the program, both internally and in terms of collaborative initiatives with other departments and faculties.

1b) TEACHING (GRADUATE PROGRAM):

Strengths

1b-1. The graduate students praise the quality and quantity of interaction with EASC faculty, speak of the strong sense of community within EASC, and recognize the overall breadth and excellence of research conducted in the department. Students are happy with the graduate student program and the dedication and enthusiasm of their supervisors.

1b-2. The graduate student numbers are very healthy for the size of the department and the graduate students have a good track record in attracting industrial and other scholarships.

1b-3. As with the undergraduates, the MSc and PhD students have excellent job prospects, with placements in academia, government, industry etc.

1b-4. EASC has an effective and dedicated chair of the graduate committee who is considerate in her treatment of the graduate students. Her efforts

to clarify the 'Terms of Reference' regarding graduate student training, funding and supervision are outstanding.

1b-5. The departmental seminar series was seen as a major strength that brings the graduate students together.

1b-6. The lack of a differential tuition fee for foreign students (domestic and international students pay equal tuition fees) is a significant advantage for the EASC graduate program.

Challenges

1b-1. The uncertainty regarding student funding stemming from the lack of predictable numbers of TAships makes effective planning difficult for faculty and prospective graduate students. The Dean of Graduate Studies did indicate that plans are in place to bring greater clarity to funding packages.

1b-2. TA budgets across the Faculty of Science are based to a significant extent upon enrolment in first year courses. Hence the lack of a required Earth Science course for Faculty of Science undergraduates results in significantly diminished TA support for Earth Science graduate students. There is a clear conflict here: TA support constitutes essential research support. Therefore, required science courses, which significantly increase student numbers in specific departments, provide a desirable research supplement, but it needs to be a supplement that is provided to all departments. TAships are both a source of research funding, and a form of experiential education, providing many students with their first experience teaching in a University setting and the opportunity to further refine and broaden their knowledge of their field of study. Hence the low numbers of TAships in EASC are both a financial and pedagogical issue.

1b-3. The recommended (but not guaranteed) minimum compensation for graduate students (currently k$21) is low in comparison to other departments at SFU and across Canada - stipulated minimums of k$24 are common - and in respect to Vancouver's high cost of living, and transparency in funding sources appears to be somewhat lacking. The low stipend commonly requires that students take on jobs outside of the full-time program and results in long completion times for graduate students that hurt the department's resource allocation. The Graduate Committee clearly recognizes the problem and is working hard to provide the students with a livable income. In addition, students taking internships and jobs could be asked to take official study leaves.

1b-4. The long completion times additionally have adverse effects on the student's financial survival. EASC might consider reducing the course requirements (e.g. from 4 to 3 mandatory courses) for their graduate

students as a means of reducing completion times. Alternatively, replacing one of the required courses with a common course for all graduate students (e.g. Geoscience graduate skills) would provide students with greater certainty in course planning and would help build relationships within student cohorts and across disciplines.

1b-5. The course offerings in the calendar are large, however, courses are only intermittently taught if at all. A consolidated set of regularly offered graduate courses would allow for improved student and departmental planning and would further build interdisciplinarity within the department. Space and lack of a common room that would support the interaction between students of different sub-disciplines continues to be an issue. Since some sub-disciplines are represented by only one faculty member, those students feel isolated. EASC is encouraged to submit a space proposal to the Dean of Science that addresses the need for common space as well as adequate laboratory and office space for graduate students.

1b-6. The low level of internal recruitment (9%) of EASC undergraduates into the graduate program suggests that an 'InReach' effort aimed at recruiting the best local students could be worthwhile.

2) RESEARCH

Strengths

2-1. EASC has a cohort of moderately to highly productive and respected faculty making important contributions in the Geosciences. The department's demography (12 Full Professors including 1 Teaching Professor; 1 Associate Professor; 1 Assistant Professor) is mature; the faculty have mostly moderate but fairly stable soft-money funding, are productive and involved in a diverse array of research activities, and demonstrate a significant dedication to the department and to undergraduate and graduate student education. There is an opportunity for the newest hire (B. Dyck) to apply for CFI funding, which we strongly encourage. The VP Research is open to any and all research initiatives and does not see lack of space as a barrier to supporting good proposals. There is a determination that space will be found if needed for good initiatives.

2-2. Filling the vacancy created by Dr. J. Clague's retirement with a Tier II CRC in Natural Hazards provides EASC with the opportunity to build on its strong reputation in this field, potentially convert it into a departmental strategic strength, and pursue a CFI proposal to fund a well-resourced "Centre for Natural Hazards Research" (CNHR) at SFU that would be unique in Canada. Crystallizing the department's efforts around a CNHR

would place EASC and SFU at the forefront of research, education and advocacy of natural hazards posed by climate change, mega-earthquakes and related tsunamis and mass wasting events, flooding, and other geological hazards. All research groups that we met with, articulated a connection to this theme, and coherence around a common vision would help the University and the community understand the department's focus (independent of degree of individual contribution). Pursuit of a CNHR theme should be revisited for the next CFI round (Innovation Fund; Major Science Initiatives Fund; and Exceptional Opportunities Fund). This is a tough process, but the VP-Research office offered strong support. The existence of a past proposal, and a 15 year history of Natural Hazards research at SFU means that this is a proposal that could be pursued with reasonable effort and which has a realistic chance to succeed.

2-3. The phased retirement in the field of Resource Geoscience & Geotechnics provides the department with time to determine how best to fill this endowed position and to ensure that the department builds on its strong reputation in Geological Engineering and resource-based Geotechnics.

2-4. The Teaching Professor in EASC, whose focus is on Earth science education and awareness, can effectively draw attention to Earth Sciences for recruitment purposes. The cross-appointment with the Faculty of Science can also act as a bridge to foster collaborations within the Faculty. And the Teaching Professor aids in the outreach work and initiatives of the Instructors, who are responsible for the bulk of the department's outreach. Hence because of this position, the department has a very strong outreach portfolio.

2-5. The strong program and research in Hydrogeology in EASC has been enhanced by the building of strong links to the Environmental Science programs. This is a collaborative success story that is to be celebrated and which could be further emulated by other areas of strength in EASC.

Challenges

2-1. The very diverse research activities in EASC need to be presented in a more unified and strategic way. We are not advocating for a change in direction, merely for the presentation of a unified front. Departmental research is fragmented into too many research groups resulting in "low visibility", a lack of critical mass and a lack in reputation for key research areas. The presentation of so many research 'groups' in such a small department may give the appearance of a fractured department, not a diverse one, which is contrary to the intention. The splintering of the department into many groups, some represented by only one or two

faculty members, does not resonate with the VP Research and Provost and his colleagues who look for interdisciplinary collaboration and cross-pollination. For example, a more unified EASC can push harder on the upper levels of administration for enhanced support for new faculty appointments, who are the future of the department. In addition, building research groups with a retirement replacement should be carefully weighed against the automatic replacement with the same discipline as the retiring one to maintain the status quo.

2-2. Grant revenue generation is modest (circa 1M $ per year) for the size of the department and the quality of its faculty members. A significant percentage of the department's research funding sits with two researchers who are either recently retired or are in the process of retiring. Research support is an important metric in terms of the faculty member's ability to support graduate students but also in terms of institutional impact.

2-3. The VP Research is engaged in a research planning process for research infrastructure and CFI projects that encourage 'Big Ideas'. The university has a good CFI envelope available and is expecting strong proposals to come forward, which the department needs to take advantage of. A call went out from VP Research for proposals, but none were forthcoming from Earth Sciences. There appears to be no or only limited departmental initiatives aimed at applying for major equipment (CFI) and associated expanded space. The result is very limited success with big federal granting programs by EACS faculty. The current space limitations can be addressed (in part) with the VP Research office by writing proposals to programs like the CFI Innovation Fund. By demonstrating leadership and initiative, the Department stands a better chance of being heard as it will be seen as attempting to solve its own problems, rather than waiting for a solution to appear.

2-4. The Dean of Science is expecting strategic plans from each of the science departments in spring 2018. These strategic plans are to address each department's vision for replacing retiring faculty as well as outlining new initiatives that have the potential for significant external funding. These departmental plans will be the basis for a five year (2018 – 2023) faculty plan. EASC might have, in addition to one ongoing phased retirement, three retirements during this period. Hence a strong vision and a shared sense of the department's future, crafted through department-wide consultation and discussion, is crucial. However, our committee sensed a reluctance for discussing or implementing change, a preference for maintaining the status quo, and a failure to explore expansion of key strategic strengths in the department. The department needs to overcome its reluctance to discuss future hiring priorities, a behavior that appears to stem from past disagreements, which are now

settled. Our committee was struck by the degree of common thought amongst seemingly disparate groups in the department and we are confident that consensus regarding strategy and priorities is possible. And the time cannot be better for the development of a strong departmental strategic plan. The VP Research recognizes the strength of the Earth Sciences and is open to discussion and brainstorming. A strong departmental strategic plan is required in order to provide the new Dean of Science with a reason to invest in EASC.

2-5. Postdoctoral fellows bring high quality research and productivity and are a good way to expand research groups and limit the isolation that occurs when sub-disciplines are represented by one faculty member only. An environment that is more conducive to post-doctoral recruitment and support is necessary. For example, externally funded postdocs have no benefits. There also appears to be no internal SFU funds for post-doctoral fellows to provide (full or partial) salary or indirect research costs (e.g. conferences and travel). This results in a low number of postdoctoral fellows, to the detriment of the research productivity and impact of EASC.

3) ADMINISTRATION

Strengths

3-1. The administrative burden has been well shared amongst faculty, with the department having had 6 different chairs over the past 15 years, and effective contributions from various faculty in Graduate and Undergraduate Chair roles.

3-2. Faculty are aware of and understand the administrative constraints within which the department has to operate.

3-3. SFU is committed to offering Earth Sciences. The university's commitment to the Earth Sciences should not, however, be taken for granted.

Challenges

3-1. Given the high autonomy of departments at SFU, strong departmental leadership is necessary, but the succession planning process does not appear to reflect this urgency/importance; the mid-career faculty members should be encouraged and empowered to participate/lead the mid-term and long-term planning.

3-2. The lack of common space for faculty and students is a lost opportunity. Common space fosters interdisciplinary research and an Earth System approach to teaching and research. The lack of common space is in part

responsible for fragmentation of the department. Current space is limited and a group-based reallocation of laboratory space may be suitable to foster innovative initiatives, but has not been fully explored. Despite limited space having been an identified problem since before the last external review, only limited efforts for innovative space solutions (re-organization of existing laboratory space, CFI initiatives etc.) have been explored. The space issue will not be seen as critical by the institution if EASC is not prepared to work toward a solution.

3-3. There needs to be greater attention to the effective communication of departmental concerns to the Dean. Although the lack of space is a concern that was raised by every faculty member, the Dean and VP were not fully aware of a space problem in EASC.

3-4. Communication with the VP Research could be improved. The VP Research is eager to discuss innovative research ideas and faculty replacements, and is keen to support strengthening of selected disciplines with the department.

3-5. The suggestion that a first year Earth Science course be required as part of Science undergraduate student education was made in the previous external departmental review of EASC, but was never acted upon. This lack of action cannot be blamed on a lack of administrative effort by EASC. Because the other Science departments have a vested interest in the status quo, the elevation of a first year Earth Science course to 'required' status (e.g. EASC 101) is in part a decanal responsibility, and there must be a commitment to do so if there is a goal to increase programmatic uptake and associated increase in enrolment.

3-6. Staff members have invaluable insights regarding teaching, administration and policy, but there is no good mechanism that would allow them to contribute to departmental governance and hence they do not feel that their opinions are as valued as they should be.

3-7. The departmental constitution has not been updated, although this was requested in a previous review. This lack of action suggests that the constitution is viewed as a low priority, however departmental governance and policy are important, particularly in the context of strategic planning. Hence we reiterate that the departmental constitution should be updated in a timely fashion.

4) WORK ENVIRONMENT

Strengths

4-1. The department is extremely collegial. Faculty and staff exhibit significant respect for one another and for undergraduate and graduate students. The current leadership has been in place for a relatively extended period

of time and has provided the department with some much needed stability. A collegial and harmonious work environment has been established after a period of significant internal dissension and friction. This is no small achievement.

4-2. The small size of the department (the smallest in the Faculty of Science) engenders a 'family' like environment that constitutes a significant strength, especially for the students.

4-3. The housing of the department within relatively close quarters in a single building further helps build and maintain respect and a family environment (the downside of such restricted space is recounted elsewhere).

Challenges

4-1. Flexibility should be granted to instructors to team teach during the summer term to allow longer vacation times. Lecturers and Senior Lecturers are entitled to take up to 4 weeks of vacation, and it is desirable to allow that in one block when they choose. Course scheduling should be adapted accordingly and co-teaching arrangements should be made to provide time in the summer term for extended holidays. This is a significant issue: the program leans very heavily on its Lecturers and Senior Lecturers who by all accounts do an exceptional job. The lack of clear contractual workload allocation (particularly service), and the inability to accommodate blocks of vacation time because of teaching commitments across all three terms has the core teaching staff closer to the edge than the department may recognize. Following the existing rules regarding vacation time is a requirement not a choice, and is necessary so that these colleagues may continue to love the department that they are all so clearly committed to.

4-2. Instructors would benefit from longer term planning regarding their extensive teaching duties and outreach work.

5) FUTURE PLANS

5-1. The department's administrative philosophy has been essentially 'reactive' as opposed to 'proactive'. We strongly encourage EASC to make proactivity part of the departmental mission. Casting forward with widely-supported strategic plans will ensure that there is a response to questions about hiring priority, programmatic mission, and the critical role of Earth Science literacy in the undergraduate curricula at SFU. Such proactive strategic planning will serve the department well in times when

fiscal austerity measures supersede other considerations at the institutional level.

5-2. There is significant risk in the high number of retirements that are likely to occur over the next review cycle, especially if undergraduate enrolment decreases further. There are, however, highly variable opinions across the department about what impact this may have on the program, ranging from an expectation that all the positions will be replaced "like for like", to a resignation that positions will not be replaced and courses will have to be taught by adjuncts and sessionals to meet accreditation criteria. A clear and prioritized strategic plan and associated hiring plan developed with input from all department members is urgently needed.

5-3. The problems of EASC (declining enrolment, size, visibility within the Faculty of Science, isolation of single-faculty research groups, etc.) are part of a larger institutional issue around the Earth and Environmental Sciences at SFU. SFU is unique among western Canadian universities having a Faculty of Science and Faculty of Environment, both of which house natural scientists and programming in Environmental Earth Sciences. EASC is in the Faculty of Science and there is a popular EVSC program in the Faculty of Environment with an abundance of undergraduate majors, but with just one limited-term lecturer. There is also a Geography Department in the Faculty of Environment with several environmental Earth scientists and the same enrolment problems as EASC, in the natural science dominated Physical Geography program. This arrangement needs to be examined by all levels of the university administration. The status quo separates undergraduates, graduates and faculty who are arguably in the same fields on campus. This seems detrimental to students who are forced into narrow programs, often without courses and faculty interactions that would benefit their training.

5-4. There is scope for uniting the Earth and Environmental Sciences at SFU into one strong and sizable unit, either in the Faculty of Science, in the Faculty of Environment or by some formal arrangement across the faculties. Renewed discussions become a necessity due to fiscal pressures, societal pressures and, to say the least, lost opportunities. With an improved structure addressing these issues, SFU has considerable potential to more aggressively pursuing training and research on one of the most pressing issues of our time; the dynamics of the Earth system, its past, present and future.

6) SPECIFIC QUESTIONS

6.1. How can we better attract graduate students to our program and meet their needs?

6.1-1. Address the uncertainty in EASC graduate student funding. Given the high cost of living in the Vancouver region, providing students with certainty and clarity regarding the funding they will receive over the course of their degree is particularly important.

6.1-2. Continue with the department's initiative to ensure a required base-level funding provided to students, and work toward increasing this level.

6.1-3. Increase the department's quota of TAs to a fair level (the present TA quotas are low given that they are based largely on first year student enrolment in required courses provided by other departments).

6.1-4. Increase 'Inreach' efforts to recruit SFU undergraduate students into the graduate program. At present <10% of the department's graduate students are SFU graduates.

6.1-5. Build upon the department's strong reputation in Hazards and Environmental Earth Science: the department is well placed to submit a CREATE proposal which would provide $1.65 M over 6 years to support training of HQP and Post-Doctoral Fellows.

6.2. Are there aspects of our undergraduate program that do not fully meet the current needs of industry/community?

6.2-1. The department does an excellent job producing high-quality BSc graduates across a breadth of Geoscience sub-disciplines who are eligible for professional accreditation in Geology and Environmental Earth Sciences, and whose job prospects and placements are exceptional.

6.2-2. GIS-fluency is becoming a standard in Earth and Environmental Sciences. EASC students have to be provided with a means of more readily accessing applied GIS-training related to Geoscience problems as part of their undergraduate program.

6.2-3. Some Environmental Earth Science courses, particularly those pertaining to water, are oversubscribed and suggest that the department could capture these and other students through well-coordinated, collaborative initiatives with other departments and faculties (see point 1a-9).

6.3. How can the Department and Faculty of Science work together to increase enrolment, better attract excellent students to our undergraduate program, and meet their needs?

6.3-1. A required first year Introductory Earth Science course such as EASC 101 for all Faculty of Science students would: a) meet the Faculty's obligation to provide their students with an adequate level of scientific literacy, particularly in light of the climate and seismic hazards that are unique to the Vancouver region; b) effectively address the decreasing enrolment in the Earth Science department; and c) in doing so rectify the department's low and somewhat unfair TA quota.

6.3-2. The hands-on, experiential education provided by the department, which includes a significant commitment to field schools, necessarily limits the number of students that the department can teach. Earth Science can never aspire to teach the numbers of students taught in Biology or Chemistry; therefore decisions on faculty allocations cannot be simply based on student numbers.

6.3-3. There should be an effort to offer properly coordinated joint programs with other departments (Chemistry, Biology, Physics, Geography). The current joint program with Chemistry is not a joint program: it is in essence simply two degrees stuck together requiring 6 years for students to complete.

6.3-4. Opportunities for distance education using online approaches are not being sufficiently exploited. Arbitrary maximum enrolment limits (that may not even be real) need to be removed. There needs to be an effort to satisfy the demand amongst students outside the department for Earth Science education (Earth History; Hazards; Climate Change; Dinosaurs).

6.4. How can we plan for upcoming retirements to maintain the unique qualities of our program while adapting to a changing geoscience landscape?

6.4-1. The current departmental approach to impending retirements, best described as 'maintain the status quo', needs to be abandoned. The declining student numbers and the overall moderate levels of research funding do not justify simply maintaining disciplinary expertise in response to retirements. And neither do the constraints placed upon the department by the need to offer an undergraduate program that leads to professional accreditation: there is enough flexibility in the accreditation constraints to allow the department to explore an alternative approach.

6.4-2. The department needs to rally around one or two common theme(s) and a low number of strategic strengths. The current approach celebrates the diversity within the department (nine main divisions that correspond to seven research groups represented by only 14 tenure-track faculty). The unintended result is a lack of critical mass, low visibility, and limited impact.

6.4-3. Reaching consensus on one or two departmental umbrella theme(s) or focus groups is a necessary first step in the development of a Strategic Plan that addresses hiring priorities. One example could be Natural Hazards, which is a good local fit and would be unique in Western Canada. We are suggesting that the department revises how it sees itself and sells itself. We are not suggesting an abandonment of specific fields of research.

6.4-4. A departmental commitment to one or several major funding initiatives (e.g. CREATE, or a CFI Major Science Initiative or Exceptional Opportunities proposal) would go a long way toward helping craft a

departmental vision, and could address a number of departmental concerns (most notably the need for new space).

6.4-5. Faculty of Science support, in the form of adequate start-up funding and strong financial support of CFI J.R. Evans Leaders proposals for new faculty is necessary to attract top quality talent. A unified and coherent departmental strategic plan, including prioritizing replacement positions, will necessarily help justify such investments.

6.4-6. Ensure that the department's staff and lecturers are adequately rewarded and recognized for their substantial efforts and contributions; they constitute a significant component of the department's success.

EXTERNAL REVIEW – ACTION PLAN

Section 1 – To be completed by the Responsible Unit Person e.g. Chair or Director

Unit under review	Date of Review Site visit	Responsible Unit person	Faculty Dean
Earth Sciences	March 21-23rd, 2018	Brent Ward	Paul Kench

Notes

1. *It is **not** expected that every recommendation made by the External Review Committee be covered by this Action Plan. The major thrusts of the Report should be identified and some consolidation of the recommendations may be possible while other recommendations of lesser importance may be excluded.*
2. *Attach the required plan to assess the success of the **Educational Goals** as a separate document (Senate 2013).*
3. *Should any additional response be warranted, it should be attached as a separate document.*

1. PROGRAMMING

1.1 Action/s (description what is going to be done):

1.1.1 Undergraduate:

- 1.1.1.1. Develop comprehensive plan to increase undergraduate enrollment of both Majors and FTEs. The plan will be prioritized in the following manner:
- 1.1.1.1.1. First year courses will be made more appealing by better communicating the relevance of the course content to other natural and social science disciplines: course descriptions will be enhanced; some titles may be changed; and advertising will be sent to specific departments.
- 1.1.1.1.2. An additional one or two of our present breadth courses will be developed for on-line presentation. These on-line courses will not replace the traditional delivery of these courses, but provide greater flexibility for students. The undergraduate committee will establish a priority list of courses for on-line development and bring these to the department for approval.
- 1.1.1.1.3. Develop and implement a recruitment strategy for local high schools, in order to raise the profile of Earth Sciences as a career choice, emphasizing not just the relevance of an Earth Science degree in today's world (see 1.1.1.1.4) but also as the pathway to Professional registration with Engineers and Geoscientists of British Columbia. A Recruitment Committee will be created and tasked with developing a communications package for high school science classes and high school advisors. This package will include promotional material such as handouts, PowerPoint presentations, short videos, and social media content for in person and digital delivery.
- 1.1.1.1.4. Revisit with FoS Departments, with support from the Dean, how EASC 101 can be made mandatory or, at least, listed as an option, for all science degrees. The rationale is to provide Earth Science literacy, so that science students have the knowledge to better understand critical issues surrounding climate change, natural resources and natural hazards.

EASC 101 has recently been added as a required "one of" course from a list of EASC courses in the BSc general science, joint minor program.

- 1.1.1.1.5. Continue to build interdisciplinary programme offerings.
    a. Discuss with School of Environmental Science about facilitating access for ENVS students to take more of our courses. There are no apparent access issues with the various required or optional courses for the Water Science Stream students, as that stream was designed specifically to remove barriers related to prerequisites and sequence of offerings. A minor issue was identified last fall with one of our courses and a Geography course being offered in the same time slot; this issue was rectified prior to registration, and both Geography and Earth Sciences are aware of the need not to overlap the timing of the lectures/labs. We will, however, work with Environmental Science to see whether there are avenues to streamline access to more of our courses for EVSC students.
    b. Streamline the Joint Major with Chemistry to make it more accessible and better integrated. It is currently difficult to finish the Joint Major in less than 5 years, which may result in low student up-take.
- 1.1.1.2. Examine ways to increase the numbers of students taking a minor degree in Earth Sciences. We will explore this with School of Environmental Science and possibly other Departments. It should be noted that most of our previous minors were Physical Geography majors who wished to register with Engineers and Geoscientists of British Columbia. However, Geography has now created a stream that allows professional registration. Since many of our courses are required for this stream, they cannot use the same courses twice for the minor. This has been the main reason for the drop in number of minors. In addition to revising the minor degree requirements, we will also examine our existing certificate programs to see whether these can be made more attractive to students pursing majors in other disciplines.
- 1.1.1.3. Examine required courses in the two streams for professional registration (Geology, Environmental Science) to see if we can streamline them to allow more flexibility for students to explore other related courses. However, a proper balance must be struck between just meeting the course syllabus for professional registration and ensuring well-trained Professional Geoscientists for the work force or future graduate studies research.

1.1.2 Graduate:

- 1.1.2.1. Explore reducing required courses from 4 to 3 for MSc students, to assist with decreasing completion times. This will require increasing the credit for the thesis from 18 to 21. This, along with increased graduate student funding, will help to reduce completion times.
- 1.1.2.2. Actively seek more funding for graduate students. Our efforts to strengthen our research profile (outlined elsewhere in the response) go hand-in-hand with increasing success in attracting scholarship-worthy students. We will also investigate opportunities to increase funding for all graduate students, either through the EASC TA budget or alternative sources; alternative sources such as MITACS grants are already utilized and although temporary, other sources such as CREATE will be explored.
- 1.1.2.3. Explore the possibility of a course-based professional M.Sc.

- 1.1.2.4. Regularly and systematically increase the recommended minimum graduate student stipend. This will reduce the gap growth between cost of living and student stipends, and the necessity for some students to seek outside employment.

1.2 Resource implications (if any):

1.1.1.1. See below

1.1.1.1.1. None. Faculty will make modifications to the courses they presently teach.

1.1.1.1.2. Little to none. These on-line courses will be developed in conjunction with VPA Teaching and Learning who provide funds for course buy out.

1.1.1.1.3. Yes. Recruitment visits will take time and everyone is already very busy. Teaching relief may have to be offered. A graduate student and/or fourth year undergraduate may be hired to undertake school visits and present developed material. Production of videos will have monetary and time costs.

1.1.1.1.4. Yes. If successful it will require more TA positions; however, increased enrolment will increase TA resources and provide more funding for Graduate Students (see 1.1.1.2.2).

1.1.1.1.5. None.

1.1.1.2 to 1.1.1.3 None.

1.1.2.1 None.

1.1.2.2 Positive resource.

1.1.2.3 Yes. If a course-based M.Sc. were to be developed, credit would have to be granted for stand-alone graduate courses taught, and so would result in some shifting of resources from undergraduate to graduate teaching.

1.1.2.4 Will affect Faculty members' research grants, reducing the number of graduate student numbers unless alternative sources of funding are available.

1.3 Expected completion date/s:

1.1.1.1. See below

1.1.1.1.1. September 1, 2020

1.1.1.1.2. September 1, 2021

1.1.1.1.3. December 15, 2018 for the development of recruitment strategies; January 2019 – site visits to high schools and councilors start; September 1 2019 – suite of promotional videos created.

1.1.1.1.4. September 1, 2020

1.1.1.1.5. March 31, 2019 - We will start discussions with the School of Environmental Science this summer.

1.1.1.2. December 15, 2019

1.1.1.3. December 15, 2019

1.1.1.4. September 1, 2020

1.1.2.1 April 1, 2019
1.1.2.2 April 1, 2019
1.1.2.3 April 1, 2020
1.1.2.4 Already completed. Minimum annual graduate salary in EASC is $22,000 starting September 1st, 2018 and will increase 2% per year after that.

2. RESEARCH

2.1 Action/s (what is going to be done):

- Develop strategic plan that includes:
  a. Identification of a narrower set of research themes for the department (3 – including natural hazards)
  b. Create a mission statement and a description of the Department that can aid with marketing
  c. Establish a plan to increase analytical/equipment capability to support the research programmes. Logically, this may be used to inform CFI initiatives.
  d. Development of a medium-term faculty hiring plan to realise the strategy (which will account for impending retirements).

2.2 Resource implications (if any):

None

2.3 Expected completion date/s:

- December 15, 2018 - A subcommittee consisting of the youngest members of the faculty has been struck and tasked with its development. Meetings are already taking place, results so far are: a mission statement; a description of the department and what we do; three encompassing research themes (1. Hazards and Surface processes, 2. Resources, 3. Solid Earth Processes); and a medium-term faculty hiring plan. Still on the agenda is space reconfiguration. This draft strategic plan will be brought to the Department for discussion and approval before the end of term.

3. ADMINISTRATION

3.1 Action/s (what is going to be done):

3.1.1 Finalize constitution

3.1.2 We will strive to increase communication between the Department, the Dean and VP Research.

3.2 Resource implications (if any):

3.1.1. None

3.1.2 None

3.3 Expected completion date/s:

3.1.1 January 31, 2019

3.1.2. Ongoing

4. WORKING ENVIRONMENT

4.1 Action/s (what is going to be done):

4.1.1 Ensure lecturers have suitable opportunity to take summer holidays.

4.1.2 Better engage administrator and staff in decisions. If the Department approves, the administrator and some staff will be given the right to vote on relevant committees.

4.2 Resource implications (if any):

4.1.1 Likely none, as this could be accommodated with team teaching or sharing the teaching of courses with no loss in resources.

4.1.2 None

4.3 Expected completion date/s:

4.1.1 April 1st, 2020 (but preferably sooner), the teaching schedule will have been modified with input from lecturers as to the best solution.

4.1.2 September 1, 2018

5. UNIVERSITY ADMINISTRATION

5.1 Action/s:

5.1.1 Through the Faculty of Science Undergraduate Curriculum Committee, continue to explore with University Administration putting controls or oversight on the type(s) of courses that qualify as breadth science courses.

5.1.2. Obtain space for a common area for faculty and graduate students. Presently there is no common space and afternoon coffee is held in the foyer of the building, or sometimes outside the building when the weather is suitable.

5.2 Resource implications (if any):

5.1.1 None

5.1.2 There is presently no space available; although we reiterate that the Computing Science space at the northwest end of the lower level of TASC 1 remains highly under-utilized.

5.3 Expected completion date/s:

5.1.1 September 1, 2019 – This is just a deadline for exploring this option.

5.1.2 Ongoing

The above action plan has been considered by the Unit under review and has been discussed and agreed to by the Dean.

Unit Leader (signed) Brent Ward.	**Date** Nov. 9, 18
Name: Dr. Brent Ward **Title: Professor and Chair**	

Section 2 - Dean's comments and endorsement of the Action Plan:

It is pleasing to observe that the Department has risen to the challenges laid down in what is a robust review document.
Importantly, the Department has recognised the need to build a stronger student base in Earth Sciences. This challenge is a global one and will necessitate some bold thinking in terms of the recruitment of students and design and delivery of curriculum.

A major element of this challenge is the need to embrace the interdisciplinary opportunities afforded from students gaining knowledge of Earth processes and their relevance to contemporary society. From this perspective knowledge of Earth Science should have equal footing as other science disciplines in occupying core lower level material for students. Consequently, I endorse the approach to vigorously explore existing as well as new interdisciplinary programme opportunities, while also examining ways of mainstreaming Earth Science in education programmes.

I would caution the department regarding the development of new courses without careful consideration of removal of other courses to ensure the teaching loads are kept manageable.
The department has also reflected on the need to consolidate its areas of research strength. Such an approach is not exclusionary, but rather provides more focused opportunities to develop strategies related to research funding and curriculum development.

Faculty Dean	Date
	November 9, 2018

Earth Sciences Department Program-Level Educational Goals

The Department of Earth Sciences has developed the following Educational Goals for our undergraduate and graduate programs:

Upon successful completion of the Earth Sciences **BSc** Program, students will be able to:

- demonstrate a broad knowledge and understanding of essential Earth materials, features, processes, and history over a range of spatial and temporal scales;
- use the scientific method to obtain and critically evaluate scientific information;
- effectively describe, analyse, synthesize, document, and communicate scientific findings;
- use technical, analytical and field skills in a broad range of applications;
- work independently and in groups, in the laboratory and the field;
- meet all academic requirements for registration with Engineers and Geoscientists British Columbia; and
- articulate the applications and importance of the Earth Sciences to society.

Upon successful completion of the Earth Sciences **MSc** Program, students will be able to:

- demonstrate specialized knowledge in one or more areas of Earth Sciences;
- implement a strategy to conduct exploratory or hypothesis-driven research using appropriate scientific methods;
- defend and communicate orally and in writing the results and interpretations of this research;
- perform original research in Earth Sciences.

Upon successful completion of the Earth Sciences **PhD** Program, students will be able to:

- demonstrate expert knowledge in one or more areas of Earth Sciences;
- demonstrate an enhanced level of scholarship;
- define and implement a strategy to conduct exploratory or hypothesis-driven research using appropriate scientific methods;
- critically evaluate and communicate research results to the broader scientific community;
- perform independent and original research in Earth Sciences.

Appendix G – Undergraduate Program Details

G1: Course Mapping

Undergraduate Course Mapping Schema

	Program Educational Goals																	
	Demonstrate a broad **knowledge & understanding** of essential Earth materials, features, processes, and history over a			Use **scientific method** to obtain & critically evaluate scientific information			Effectively **describe**, analyse, synthesize, document, and **communicate** scientific findings			Use technical, analytical and field skills in a broad range of applications;			Work independently and in groups, in the laboratory and the field;			Articulate the applications and importance of the Earth Sciences to society		
Required Courses for All Majors	1) EG Statement I E	2) Level I E R A	3) Direct Measures T W P L	1) EG Statement I E	2) Level I E R A	3) Direct Measures T W P L	1) EG Statement I E	2) Level I E R A	3) Direct Measures T W P L	1) EG Statement I E	2) Level I E R A	3) Direct Measures T W P L	1) EG Statement I E	2) Level I E R A	3) Direct Measures T W P L	1) EG Statement I E	2) Level I E R A	3) Direct Measures T W P L
101: Dynamic Earth	E	I	T,W	E	I	T,W	E	I	T,W	I	I	T,W	I	I	T,W	E	I	T, W
201: Strat & Sed	E	E	T,L	E	E	T,W,L	E	E	T,W,L	E	I	T,L	I	I	T,L	I	I	L
202: Mineralogy	E	E	T,L	I	E	T, L	E	E	T,W,L	E	I	T,L	I	E	T,L	I	I	T
204: Struct Geol I	E	E	T,L	I	E	T, L	E	E	T,W,L	E	E	T,L	I	E	T,L	I	I	T
205: Petrology	E	E	T,L	I	E	T, L	E	E	T, L	E	E	T,L	I	E	T, L	I	I	T
206: Field Geol I	E	E	T, L	I	E	T, L	E	E	T, L	I	E	T, L	I	E	T, L	I	E	T, L
207: Intro Geophys	E	I	TL	I	E	T,L	I	I	T,L	E	I	T,L	I	I	L	I	I	T,L
208: Intro Geochem	E	E	T,L	I	E	T,L	E	I	T,L	E	I	T,L	E	I	T,L	I	I	T,L
209W: Enviro Geosci	E	E	T,W,L	I	E	T,L	E	E	T, W, L	E	E	T, W, L	I	E	T,L	E	E	T, W, L
210: Historical Geol	E	E	T, L	I	E	T, L	E	E	T, W, L	I	E	T, L	I	E	T, L	E	E	T
306: Field Geol II	E	A	T,W, O, P	E	A	T,W, O, P	E	A	T,W, O, P	E	A	T,W, O, P	I	A	T,W, O, P	I	I	T,W, O, P
308: Field Geol III	E	A	T,W,L	I	A	T,W,L	E	A	T,W,L	E	A	T,W,L	I	A	T,W,L	I	E	T,W,L
301: Ig Pet	E	R	T,L	E	R	T,L	E	R	T,L	E	R	T,L	I	R	T,L	I	I	T,L
302: Sed Pet	E	R	T,L	E	R	T,L	E	R	T,L	E	R	T,L	I	R	T,L	I	I	T,L
309: Glob Tectonics	E	R	T,L	I	R	T,L	E	R	T,L	E	R	T,L	I	R	T,L	I	I	T,L
310W: Paleo	I	R	T, W, L	I	R	T, W, L	E	R	T, W, L	E	R	T, W, L	E	R	T, W, L	E	R	T, W, L
311: Met Pet	E	E	T,L	I	R	T,L	E	R	T,L	E	R	L,W	I	E	L	I	E	T,W
304: Hydrogeol	E	A	T,W, L	E	A	W, L, P	E	A	P	E	A	W, L, P	I	A	P	I	R	T,L
313: Intro Soil Rock Eng	E	A	T,W,L	I	A	T,W,L	E	A	T,L	E	A	L,W,T	I	A	L	I	R	T,L
315W: Geochem Nat Waters	E	R	T,W, L	E	R	T,W, L	E	E	W,L	E	E	L	E	R	L	E	E	WL
403: Quat Geol	E	R	T,W, L	I	R	T,W, L	E	R	T,L	E	A	T, W, L	I	R	L	I	R	T,L

Legend

Courses common to all	Geology Stream	Environmental Geoscience Stream

EG STATEMENT (Column 1)
The program EG is (E) EXPLICITY or (I) IMPLICITLY stated in the course syllabus as being one of EGs for this course.

LEVEL OF CONTENT DELIVERY (Column 2)
(I) INTRODUCES- Students are not expected to be familiar with the content or skill at the collegiate or graduate level. Instruction and learning activities focus on basic knowledge, skills, and/or competencies and an entr-level complexity.
(E) EMPHASIZES- Students are expected to possess a basic knowledge and familiarity with the content or skills at the collegiate or graduate level. Instruction and learning concentrates on enhancing and strengthening knowledge, skills, and expanding complexity.
(R) REINFORCES- Students are expected to possess a strong foundation in the knowledge, skill, or competency at the collegiate or graduate level. Instructional and learning activities continue to build upon previous competencies and increased complexity.
(A) APPLIES- Students are expected to possess an advanced level of knowledge, skill, or competency at the collegiate or graduate level. Instructional and learning activities focus on the use of the content or skills in multiple contexts and at multiple levels of complexity.

DIRECT MEASURES (Column 3)
Students are asked to demonstrate their learning on the goals through tests (**T**), written work (**W**), oral presentations (**O**), and/or projects (**P**) and laboratory (**L**) are provided with formal feedback. In some cases, individual departments have tailored this legend to include discipline-specific EGs.

Educational Goals for Courses Required for All Earth Science Majors in Second Year and Courses Required for Majors in the Environmental Geoscience and the Geology Stream.

EASC 101 Dynamic Earth (Common to all)

Students successfully completing this course will be able to:

- Understand and describe the physical processes that are responsible for the solid and liquid materials that compose the interior and surface of our planet.
- Demonstrate a full understanding of plate tectonic theory, its evolution and predecessor theories, and its influence on the processes and features within and at the Earth's surface.
- Understand the approach of studying the different spheres (atmo-, bio-, cryo-, geo-, hydro-) of the Earth from a systems perspective.
- Understand and apply the scientific method to formulating testable questions about the world around you, and successfully communicate results of those questions to a broad audience.
- Think about the Earth on a variety of spatial (size) and temporal (time) scales, and the relationship of features to the processes that create them on these scales.
- Appreciate the inextricable relationship between human society and the environment, and the impact human activities have on the planet's resources, climate, and life.

EASC 201 Stratigraphy and Sedimentation (Common to all)

Students successfully completing this course will be able to:

- Understand the theoretical basis of sedimentology, how sedimentary structures form, how to identify sedimentary facies and their depositional interpretation.
- Identify current- and wave-generated sedimentary structures, soft-sediment deformation structures, and biogenic structures.
- Show a familiarity with the sedimentary characteristics of a variety of depositional environments.
- Show a familiar with the most common stratigraphic frameworks and understand correlation.
- Be able to construct a stratigraphic cross-section and correlate it, as well how to construct a Wheeler Diagram (chronostratigraphic cross-section), and will understand how to relate the two section types with one another.

EASC 202 Introduction to Mineralogy (Common to all)

Students successfully completing this course will be able to:

- Identify the point group symmetry of a variety of crystals and crystal models.
- Classify given crystal models into crystal classes and systems.
- Explain the principles of translational symmetry and the chemical criteria governing the variation of crystal structure.
- Show an understanding of the various physical and chemical techniques used to identify minerals.
- Identify a wide variety of rock forming and economically important minerals.
- Explain the most important chemical and structural characteristics of the major sulfide, silicate, carbonate and oxide minerals.
- Show an understanding of the use and care of a petrographic microscope and accessories.
- Show an understanding of the optical properties exhibited by common rock forming minerals.
- Determine the optical characteristics of a variety of minerals.

- Identify a selection of common rock forming minerals in their section.

EASC 204 Structural Geology I (Common to all)

Students successfully completing this course will be able to:

- demonstrate a sound understanding of the concepts of deformation, stress and strain, and the processes responsible for the development of geologic structures (e.g. plate tectonics)
- identify, describe using proper terminology and measure most of the common deformational structures (e.g. planes, lines, folds and faults)
- demonstrate a basic understanding of how to carry out a structural analysis, including the use of stereonets and drawing a deformed-state cross section
- demonstrate a basic knowledge of how to carry out a kinematic analysis
- have an awareness of how to infer the states of stress and strain in deformed rocks

EASC 205 Introduction to Petrology (Common to all)

Students successfully completing this course will be able to:

- Describe the modal mineralogy and texture of a rock in a hand specimen
- Use fundamental petrographic observations to identify minerals and rock textures in thin section
- Classify (assign complete names to) rocks, using published schemes employed by professionals
- Describe rock-forming processes
- Evaluate the petrogenesis of rocks and rock associations in a plate tectonic context

EASC 206 Field Geology I (Common to all)

Students successfully completing this course will be able to:

- Understand geological time, fossil ages, isotopic dating and stratigraphic principles.
- Comprehend igneous and metamorphic processes and environments, and crustal structure.
- Read a range of geological maps and legends and identify features and infer geological processes from published surficial and bedrock geological maps of various scales.
- Identify sedimentary, igneous and metamorphic rocks and their textures and mineral constituents in outcrop and interpret field data to produce a geological history of a field site.
- Recognize faults, fractures, folds, veins, dykes, lineations and foliations in the field and be able to measure structural information from these features using a Brunton compass.
- Record clear, concise field notes and traverse summaries in a systematic format, draw neat, oriented, labelled sketches at distant mountain, outcrop and hand specimen scales.
- Create a good copy stratigraphic log from field data with appropriate symbols, legends and other essential map components.
- Use Latitudes, Longitudes and UTM grid system to locate themselves and geomorphic features on topographic maps in the field.

207 Introduction to Applied Geophysics (Common to all)

Students successfully completing this course will be able to:

- Demonstrate an understanding of the physical properties related to, and applicability of, geophysical surveys employing gravity, magnetic, electrical, and seismic refraction methods.
- Demonstrate an understanding how field data are manipulated or processed to produce useful information about the subsurface.

EASC 208 Introduction to Geochemistry (Common to all)

Students successfully completing this course will be able to:

- use geochemical analyses and principles to describe the geochemical evolution of the solar system and Earth, and apply chemical concepts to predict the outcome of geologic and tectonic processes
- know the appropriate instrumentation to investigate geochemical challenges
- perform the appropriate mathematical strategies for solving applied geochemical problems
- understand radiogenic and stable isotope studies for the purposes of geochronology and reservoir sourcing
- apply thermodynamics to predict fluid-rock interaction for a variety of geochemical systems

EASC 209 Environmental Geoscience (Common to all)

Students successfully completing this course will be able to:

- understand and use terrain and applied maps to solve geologic problems;
- recognize and understand mitigation techniques for natural hazards such as floods, earthquakes, mass wasting and volcanic;
- solve geologic problems and reduce risk in both the urban environment and associated with resource development;
- communicate geologic knowledge via field notes and synthesizing geologic information for various stakeholders and other geologists.
-

EASC 210 Historical Geology (Common to all)

Students successfully completing this course will be able to:

- Reproduce the geologic time scale
- Demonstrate an understanding of geologic principles used to analyze Earth history;
- Interpret a sequence of geologic events using relative age-dating concepts, maps, cross sections, and stratigraphic sections.
- Understand how Earth's continents, oceans and climate evolved over geologic time, with an emphasis on North America
- Demonstrate knowledge about the evolution of life on Earth
- Identify key invertebrate fossil groups, types of fossil preservation, and use fossils to refine interpretations of Earth history.

EASC 301 Igneous Petrology (Geology Stream)

Students successfully completing this course will be able to:

- describe volcanic and plutonic rocks using macroscopic and microscopic observations;
- classify igneous rocks according to mineralogy, geochemistry and texture;
- describe relations among magma chemistry, temperature, volatile content, viscosity, and style of emplacement or eruption;
- describe processes of melting, mixing, assimilation, crystallization and volatile exsolution;
- perform petrologic calculations based on phase diagrams and geochemical compositions;
- relate chemical and physical characteristics of magmatism to tectonic processes.

EASC 302 Sedimentary Petrology (Geology Stream)

Students successfully completing this course will be able to:

- describe and classify sedimentary rocks in both hand specimen and thin section, particularly with respect to fabric, texture, and composition.
- identify the main fossil groups from thin section characteristics and apply them to the interpretation of carbonate sedimentary facies.
- demonstrate an appreciation of diagenetic changes to sedimentary rocks, ranging from shallow burial to deep burial.
- Interpret detrital zircon and geochemical datasets as related to sediment provenance.

EASC 304 Hydrogeology (Environmental Geoscience Stream)

Students successfully completing this course will be able to:

- Demonstrate an understanding of the basic principles of subsurface fluid flow, encompassing measurement of hydraulic head, hydraulic gradients, and the hydraulic properties of the subsurface to quantify fluid pathways and rates of movement in the subsurface.
- Demonstrate an understanding of the controls on fluid movement at different spatial and temporal scales, encompassing natural flow and flow that may be altered, for example, due to pumping, interaction with surface water, and interactions at the near surface (infiltration).
- Employ scientifically-based approaches to analyze and interpret data (geological, geophysical, hydrological and hydrogeological) and critically evaluate the scientific findings.
- Write a comprehensive report, in the form of a consulting report, which describes and synthesizes data and scientific findings.
- Develop transferrable skills in spreadsheet calculations and graphing, time management, and organization of a long document.

EASC 306 Field Geology II (Common to all)

Students successfully completing this course will be able to:

- undertake mapping projects that integrate observations from a range of scales;
- map and interpret sedimentary, igneous and metamorphic rocks features;
- map and interpret brittle and ductile structures;
- understand how to use isotopic dating in geological interpretations;
- combine information from individual studies to constrain the geological history of a region.

EASC 308 Field Geology III (Common to all)

Students successfully completing this course will be able to:

- demonstrate acquired field skills and data analysis/interpretation relating to environmental geoscience, sedimentology, and applied geophysics
- describe geologic units and sections, construct a terrain map, reconstruct glacial history, sample groundwater, and conduct a geophysical survey
- integrate a variety of digital data sets into a simple graphical visualization.

EASC 309 Global Tectonics (Geology Stream)

Students successfully completing this course will be able to:

- demonstrate a basic understanding of the principles of Plate Tectonics and the various lines of evidence used in support of the Plate Tectonics paradigm
- demonstrate knowledge of the fundamental importance of Plate Tectonics in the context of Earth evolution and how the theory accounts for the development of Earth's geological features, both past and present
- identify and describe lithospheric plates, plate boundaries, relative movements of the plates, and place them within a Global Tectonics context
- assess first motions data and apply it to focal mechanism solutions
- calculate and assess relative plate motions

EASC 310W Paleontology (Geology Stream)

Students successfully completing this course will be able to:

- recognize, describe and classify a wide range of invertebrate fossil groups and understand their temporal position in Earth history.
- understand functional morphology and evolutionary pathways for fossil groups and their roles in biostratigraphy and paleoecological interpretations.
- identify a number of zone fossils from different time periods.
- understand the role plate tectonics played in the evolution and extinction of life through Earth history.
- demonstrate improved technical writing skills through a series of writing exercises.

EASC 311 Metamorphic Petrology (Geology Stream)

- Identify the point group symmetry of a variety of crystals and crystal models.
- Classify given crystal models into crystal classes and systems.
- Explain the principles of translational symmetry and the chemical criteria governing the variation of crystal structure.
- Show an understanding of the various physical and chemical techniques used to identify minerals.
- Identify a wide variety of rock forming and economically important minerals.
- Explain the most important chemical and structural characteristics of the major sulfide, silicate, carbonate and oxide minerals.
- Show an understanding of the use and care of a petrographic microscope and accessories.
- Show an understanding of the optical properties exhibited by common rock forming minerals.
- Determine the optical characteristics of a variety of minerals.
- Identify a selection of common rock forming minerals in their section.

EASC 313 Introduction to Soil and Rock Engineering (Environmental Geoscience Stream)

Students successfully completing this course will be able to:

- Review the essential methods of Geological Engineering practice, including site characterization, field work, laboratory testing, various types of analysis, hazard and risk assessment and professional issues such as loss control and professional ethics.
- Describe examples of true life engineering geological problems and discuss solutions.
- Explain the limitations of "textbook approaches" to geological engineering problems.
- Use the professional literature and understand the need for lifelong learning.
- Be able to keep good records and produce written and oral professional communication.
- Be prepared for the transition from the university environment to practical work.

EASC 315 Geochemistry of Natural Waters (Environmental Geoscience Stream)

Students successfully completing this course will be able to:

- demonstrate an understanding of the physical and chemical processes that control the geochemistry of water
- demonstrate an understanding of geochemical thermodynamics and its application to determining the factors impacting water quality
- demonstrate the ability to develop a conceptual model of groundwater water quality problems and identify the geochemical processes impacting water chemistry
- evaluate water composition data using the appropriate plotting methods and construct simple geochemical models to identify data trends and processes impacting water composition
- plan a groundwater quality field study
- demonstrate improved technical writing skills in the form of consulting or government reports

EASC 403 Quaternary Geology (Environmental Geoscience Stream)

Students successfully completing this course will be able to:

- understand the recent geologic record in four dimensions (space and time)
- evaluate important natural processes that have shaped the landscape during the Quaternary
- recognize and interpret Quaternary processes, sediments and landforms