A Proposal to Establish a
Doctorate of Philosophy Program in

Earth and Environmental Sciences

Department of Earth and Environmental Sciences
Vanderbilt University

May 6, 2014

Calvin F. Miller, Director of Graduate Studies
615-322-2232, calvin.f.miller@vanderbilt.edu

John C. Ayers, Chair
615-322-2976, john.c.ayers@vanderbilt.edu
# Table of Contents

List of Acronyms and Acknowledgements ................................................................................................ iv  
Executive Summary ....................................................................................................................................... v  
1. Vision and Objectives .............................................................................................................................. 1  
   1.1 A Center of Excellence in Key Areas of the Earth and Environmental Sciences ................... 1  
   1.2 Timing in Relation to Workforce Demand .................................................................................. 3  
   1.3 Educational Objectives and Programmatic Impacts ................................................................. 4  
2. Well Placed Foundations ....................................................................................................................... 6  
   2.1 EES Mission Statement .................................................................................................................. 6  
   2.2 Faculty Size .................................................................................................................................... 7  
   2.3 Faculty Expertise .......................................................................................................................... 9  
   2.4 Small but Fierce: Measures of Faculty Quality ........................................................................ 11  
   2.5 Status of Current Graduate Program ....................................................................................... 13  
   2.6 Comparison with Other Geoscience Programs ....................................................................... 14  
3 Program Structure ................................................................................................................................. 16  
   3.1 Program Elements ......................................................................................................................... 16  
      3.1.1 Foundation of Knowledge and Skills ................................................................................. 16  
      3.1.2 Degree Requirements ......................................................................................................... 17  
      3.1.3 Advising and Committees .................................................................................................. 21  
      3.1.4 Expectations and Academic Performance ....................................................................... 22  
      3.1.5 Building Career Perspective ............................................................................................. 24  
      3.1.6 Program Evaluation ........................................................................................................... 25  
   3.2 Admissions ..................................................................................................................................... 26  
      3.2.1 Targets ............................................................................................................................... 26  
      3.2.2 Timing ............................................................................................................................... 27  
   3.3 Relation to Other Programs ........................................................................................................... 27  
4 Resources .............................................................................................................................................. 29  
   4.1 Intellectual Foundation .................................................................................................................... 29  
   4.2 Staffing ........................................................................................................................................ 30  
   4.3 Infrastructure ............................................................................................................................... 30  
   4.4 Funding ....................................................................................................................................... 32  
Appendix 1: Selected Faculty Activities ................................................................................................... 34  
Appendix 2: External Federal Grants to EES faculty in Active Status during 2005-2013 .................... 37  
Appendix 3: Internal Grants in Active Status During 2005-2012 ....................................................... 40
List of Acronyms and Acknowledgements

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAREER</td>
<td>NSF Faculty Early Career Develop Program</td>
</tr>
<tr>
<td>CEE</td>
<td>Department of Civil and Environmental Engineering</td>
</tr>
<tr>
<td>CRESSP</td>
<td>Consortium for Risk Evaluation with Stakeholder Participation</td>
</tr>
<tr>
<td>CSDMS</td>
<td>Community Sediment Dynamics Modeling System</td>
</tr>
<tr>
<td>CZO</td>
<td>Critical Zone Observatory</td>
</tr>
<tr>
<td>DGS</td>
<td>Director of Graduate Studies</td>
</tr>
<tr>
<td>DOD</td>
<td>Department of Defense</td>
</tr>
<tr>
<td>DOE</td>
<td>Department of Energy</td>
</tr>
<tr>
<td>EAR</td>
<td>Earth Sciences Division of the National Science Foundation</td>
</tr>
<tr>
<td>EES</td>
<td>Department of Earth and Environmental Sciences</td>
</tr>
<tr>
<td>EGE</td>
<td>Enhancing Graduate Education grant through the Vanderbilt Graduate School</td>
</tr>
<tr>
<td>EPA</td>
<td>National Environmental Protection Agency</td>
</tr>
<tr>
<td>ES</td>
<td>Environmental Science option in Environmental Engineering degree program</td>
</tr>
<tr>
<td>ISI</td>
<td>ISI Web of Science</td>
</tr>
<tr>
<td>MARGINS</td>
<td>NSF research initiative focused several aspects of continental margins</td>
</tr>
<tr>
<td>NCED</td>
<td>National Center for Earth-surface Dynamics</td>
</tr>
<tr>
<td>NOAA</td>
<td>National Oceanic and Atmospheric Administration</td>
</tr>
<tr>
<td>NSF</td>
<td>National Science Foundation</td>
</tr>
<tr>
<td>ONR</td>
<td>Office of Naval Research</td>
</tr>
<tr>
<td>PIRE</td>
<td>Partnerships for International Research and Education</td>
</tr>
<tr>
<td>SC</td>
<td>Stevenson Center complex</td>
</tr>
<tr>
<td>STEM</td>
<td>Science, Technology, Engineering and Mathematics</td>
</tr>
<tr>
<td>USGS</td>
<td>United States Geological Survey</td>
</tr>
<tr>
<td>VIEE</td>
<td>Vanderbilt Institute for Energy and Environment</td>
</tr>
</tbody>
</table>

Acknowledgements. Some of the material in this proposal is excerpted or paraphrased from previous documents prepared by members of the faculty of the Department of Earth and Environmental Sciences, some of which have involved collaborations with colleagues in other departments at Vanderbilt and elsewhere. These include internal Earth and Environmental Sciences documents, a Proposal to Revise the Option of Graduate Study in Environmental Science, a proposal for the Transdisciplinary Initiative on Environmental Systems (TIES), a report entitled TIES: Bangladesh Seminar and Field Trip, a final project report submitted to the National Science Foundation concerning a National Cross-Disciplinary Workshop in Engineering and Geoscience: Process-Driven Risk Assessment and Sustainable Mitigation Strategies, and a Proposal to Establish the Vanderbilt Institute for Energy and Environment. Finally, we acknowledge the critically important and valuable contributions of Professor David Furbish, who wrote much of this proposal while serving as department chair.
Executive Summary

The intellectual breadth and richness of the Earth and Environmental Sciences have exploded in the last half century, involving questions that beg new, creative insights into the complex workings of Earth. With this breadth has also emerged an increasing expectation of Earth scientists to weigh in on compelling questions in other fields such as biology and ecology, planetary science, atmospheric chemistry, anthropology, and engineering, as well as pressing questions concerning the health and well-being of humanity. Our essential challenge involves melding an understanding of Earth’s dynamic history over geologic timescales with an understanding of the behavior of modern Earth and environmental systems over human timescales. Moreover, national leadership in the Earth and environmental sciences during the 21st century will come from individuals capable of excelling in their chosen specialties, yet possessing the skills and a flare for communicating effectively across disciplines. Within this context, the Department of Earth and Environmental Sciences proposes to establish a Ph.D. program in Earth and Environmental Sciences, solidifying this critical area of science and graduate education at Vanderbilt. We are propitiously positioned to establish a Ph.D. program that is nationally distinguished in its focus and design.

Our vision for a Ph.D. program in Earth and Environmental Sciences at Vanderbilt is a center of excellence in research and graduate education focused on three key areas of our science:

1. Solid-Earth dynamics: transport, reaction and evolution of fluids and magmas in the crust;
2. Life processes: Earth’s record of life in changing climates and ecosystems; and
3. Surface and atmosphere dynamics: Impacts of environmental change on processes occurring on the surface and in the atmosphere of the Earth.

In addition, by design this program will involve a distinguishing, overarching focus on excellence in education and communication, in which students fully engage in cultivating skills needed to: (i) excel as science educators while distinguishing themselves as young researchers; and (ii) excel in communicating across disciplines, whether involving collaborative research, teaching, or communication of science to non-experts.

These three science focus areas: (i) provide an intellectual core that will allow us to continue to individually and collectively excel in our research and teaching missions, competing at the highest levels with other outstanding programs nationally; (ii) ensure ample breadth for a Ph.D. curriculum from which our students will gain both essential depth in their studies, and exposure to ideas and skills that facilitate communication across disciplines; (iii) serve as an important part of our blueprint for program development, including our targeting of future faculty hires; and (iv) serve as a clear identity to students considering options for graduate studies, and to the faculty who are advising them. Moreover, these science focus areas represent the juxtaposition of compelling intellectual opportunities with growing funding opportunities involving several agencies. And, when combined with the focus on fostering excellence in education and communication, these areas are tuned to opportunities involving several programs at Vanderbilt. The Ph.D. program in Earth and Environmental Sciences will build on the successes of the existing Environmental Science Ph.D. option that has been jointly administered since 2005 by the Departments of Civil and Environmental Engineering and Earth and Environmental Sciences, and it will contribute significantly toward solidifying a broader interdisciplinary core of scholarship in the
Earth, environmental and engineering sciences at Vanderbilt.

Essential pieces are in place. The Department of Earth and Environmental Sciences possesses the “critical mass,” expertise and stature needed to establish and sustain a high-quality Ph.D. program, particularly given our connections and interactions with other programs on campus such as VIEE, as well as geoscience programs nationally and internationally. The quality and strong record of successes of our former and current students (Ph.D. and M.S.) reflect that our Department is one in which graduate students are exposed to a culture of aiming at the highest standards of scholarship, wherein academic and professional citizenship are valued.

The structure of the proposed Ph.D. program involves a straightforward set of elements (consistent with University policies) aimed at ensuring that students gain a solid foundation of knowledge in the Earth and environmental sciences together with skills that will allow them to be competitive in the academic marketplace on completion of their studies, and provide them with the flexibility to respond to current and future high-priority research needs. In addition, students will be expected to individually develop a Career Perspective — a personal vision of how their knowledge and skills can be applied to science disciplines within and outside of their field, and can impact society beyond the scientific community — as they move through the Ph.D. program.

We anticipate that the number of students enrolling in the Ph.D. program may grow to more than five per year over a timescale of five years or so as we transition to a Ph.D.-centric program. This involves a ratio of about 2.5 students per tenure-stream faculty (our current ratio is 2.7), consistent with top-quality programs nationally, and commensurate with available resources, internal and external. Here we note that the vision and timing of the Ph.D. program are well aligned with research and educational priorities of the National Science Foundation and other national funding agencies.

This proposal has the full support of the EES faculty, who voted 10-0 in favor of starting a Ph.D. program in Earth and Environmental Sciences.
1. Vision and Objectives

The intellectual breadth and richness of the Earth and Environmental Sciences have exploded in the last half century. Our questions are compelling. What are the essential ingredients of magma dynamics that control crustal evolution and lead to explosive volcanism, including supervolcanoes capable of influencing global climate and impacting landscapes and life at continental scales? How does life evolve, adapt and interact with Earth’s dynamic landscapes and ecosystems — terrestrial and marine — in the presence of changing climate and ocean conditions? What are the unifying ingredients of transport and reaction of fluid-rock constituents that control the evolution of Earth materials at molecular to crustal scales? How do the great rivers of the world transport and disperse sediment at river-reach to subcontinental scales, influencing water resources and aquatic habitats over generational to millennial timescales? These are big questions that beg new, creative insights into the complex workings of Earth.

With this intellectually rich breadth of topics has also emerged an increasing expectation of Earth scientists to weigh in on compelling questions in other fields such as biology and ecology, planetary science, atmospheric chemistry, anthropology, and engineering, as well as pressing questions concerning the health and well-being of humanity — questions that require Earth scientists to clearly articulate how Earth works. This expectation emerges from the recognition that, among the natural sciences, ours is the quintessential interdisciplinary science, providing vital perspective on how Earth’s physicochemical template — involving processes whose range of operative timescales is second only to cosmology — simultaneously sustains and threatens life, and influences human interactions with Earth. The essential challenge thus involves melding an understanding of Earth’s dynamic history over geologic timescales with an understanding of the behavior of modern Earth and environmental systems over human timescales.

Earth scientists also are becoming increasingly engaged in collaborative multi-disciplinary efforts involving the natural and social sciences, engineering, mathematics and statistics, humanities, law and education communities — efforts where advances and innovations require the knowledge and perspectives of multiple disciplines, notably including problems of increasing societal importance and complexity. The reasons for this are compelling. Projected population growth within the U.S. and worldwide over the next several decades will lead to demands for Earth resources, including habitable space, at unprecedented scales, and with this an equally unprecedented need for strategies and technologies aimed at achieving the sustainable use of these resources — balancing utilization of resources and habitat with their protection and preservation for the long-term well-being of ecological systems and humans alike. Moreover, national leadership in these issues during the 21st century will come from individuals capable of excelling in their chosen specialties, yet possessing the skills and a flare for communicating effectively across disciplines.

Within this context the Department of Earth and Environmental Sciences proposes to establish a Ph.D. program in Earth and Environmental Sciences, solidifying this critical area of science and graduate education at Vanderbilt. Moreover, we are propitiously positioned to establish a Ph.D. program that is nationally distinguished in its focus and design, as outlined next.

1.1 A Center of Excellence in Key Areas of the Earth and Environmental Sciences

The Department of Earth and Environmental Sciences (EES) is by national measures an unusually vibrant, cohesive department aimed at the highest standards of scholarship. It has a rich history of educating
students at the baccalaureate and masters levels, and, since 2005, at the doctoral level through an Environmental Science (ES) option in Environmental Engineering jointly administered by EES and the Department of Civil and Environmental Engineering (CEE). Faculty and students at all levels pursue studies that address fundamental questions in the Earth and Environmental Sciences, spanning deep geological timescales to human timescales. As fully elaborated in Section 2, our success in graduate education at both the M.S. and Ph.D. levels solidly positions us to establish a high-quality Ph.D. program.

Our vision for a Ph.D. program in Earth and Environmental Sciences at Vanderbilt is a center of excellence in research and graduate education focused on three key areas of our science:

1. Solid-Earth dynamics: transport, reaction and evolution of fluids and magmas in the crust;
2. Life processes: Earth’s record of life in changing climates and ecosystems; and
3. Surface and atmosphere dynamics: Impacts of environmental change on processes occurring on the surface and in the atmosphere of the Earth.

In addition, by design this program will involve a distinguishing, overarching focus on excellence in education and communication. Namely, the Ph.D. program will be one in which students fully engage in cultivating skills needed to: (i) excel as science educators while distinguishing themselves as young researchers; and (ii) excel in communicating across disciplines, whether involving collaborative research, teaching, or communication of science to non-experts. Here are essential elements of the design.

First, the three science focus areas build from our existing strengths and ongoing collaborations. Our current graduate program, which focuses on research and education in these three areas, is highly successful (Section 2). Moreover, these areas balance our current and anticipated faculty size with an appropriate breadth of coverage of Earth and Environmental Sciences topics. These focus areas therein: (i) provide an intellectual core that will allow us to continue to individually and collectively excel in our research and teaching missions, competing at the highest levels with other outstanding programs nationally; (ii) ensure ample breadth for a Ph.D. curriculum from which our students will gain both essential depth in their studies, and exposure to ideas and skills that facilitate communication across disciplines, critical to excelling as Earth and Environmental Scientists in the 21st century; (iii) serve as an important part of our blueprint for program development, including our targeting of specialties of future faculty hires; and (iv) serve as a clear identity to students considering options for graduate studies, and to the faculty who are advising them. Moreover, our expertise and stature in these focus areas are a fundamental key to success in recruiting top students and faculty as we mold ourselves into a center of excellence.

Second, the three science focus areas represent the juxtaposition of compelling intellectual opportunities with growing funding opportunities. We do not yet fully understand, for example, why ascending magmas either stop within the crust or move to the surface and erupt, nor how supervolcanoes work or what conditions precede catastrophic eruptions. We do not fully understand why certain species are resilient to climate change and others are not. We do not fully understand what is in store for coastal regions of the world as sea level rises, nor how associated changes are likely to impact the large human populations that so depend on the natural resources of these regions. Thus, the focus areas listed above understandably are priority areas identified by several key funding agencies, and an important measure of the commensurate growth in funding is reflected in recent large initiatives at several funding agencies, notably including the National Science Foundation and the National Oceanic and Atmospheric Administration. As described
in Section 4.4, these initiatives are aimed at landscape dynamics, climate change and associated biological responses, critical zone processes, and coastal and near-shore marine processes. Our faculty has taken advantage of these opportunities, bringing in three grants of over $1M in the last three years for interdisciplinary research (Office of Naval Research $4.5M, NSF PIRE $1.1M, NSF $3.7M).

Third, these focus areas will serve as a key part of our identity that distinguishes us from other Ph.D. programs nationally. That is, rather than attempting to maintain a broad coverage of disciplines that fully define the Earth and Environmental Sciences, a strategy that can be successful for some large programs (Section 2.5), our approach instead is to focus on a set of compelling areas in the Earth and Environmental Sciences, and aim at them from a position of strength (Section 2) and through judicious program development (Section 4.1). For this reason the three science focus areas are purposefully thematic rather than disciplinary — and thematic with an eye for longevity in that they represent clear areas of intellectual growth in the foreseeable future — yet are centrally keyed to Earth’s solid crust, its surface environments, and life processes. In this way the program will gain identity in its emphasis on bringing disciplinary expertise to bear on particularly compelling problems in the Earth and Environmental Sciences. Moreover, with our explicit focus on excellence in education and communication, our graduating Ph.D. students will be particularly competitive for positions in academics as well as other sectors.

Fourth, in addition to involving intellectual opportunities and collaborations nationally and internationally, the three science focus areas listed above — when combined with the focus on fostering excellence in education and communication — are tuned to opportunities involving several programs at Vanderbilt. As elaborated in Section 3.3, we envision this Ph.D. program in Earth and Environmental Sciences as building on the successes of the existing Environmental Science (ES) Ph.D. option in Environmental Engineering that has been jointly administered since 2005 by the Departments of Civil and Environmental Engineering and Earth and Environmental Sciences. The EES department plans to maintain our close ties to Environmental Engineering, as our research and teaching collaborations and shared equipment make both programs stronger. We note, for example, that the existing joint ES venture is punctuated by a spectacularly successful one-of-a-kind course in the Nation. In its most recent version entitled Water and Social Justice in Bangladesh, this course involved taking students from Earth and Environmental Sciences, Civil and Environmental Engineering, Anthropology, and the Peabody School of Education on a spring trip to Bangladesh to study aspects of the Bangladeshi environment that demand the joint attention of earth scientists, engineers, and social scientists, along with local citizens, to address the multiple water-related hazards facing urban and rural populations in Bangladesh. We see this and similar types of efforts on campus as an important part of our curricular strategy, namely, as an effective way to challenge students to develop and exercise skills of communication across disciplines. Equally important, we envision the Ph.D. program in Earth and Environmental Sciences as contributing significantly toward solidifying a broader interdisciplinary core of scholarship in the Earth, environmental and engineering sciences at Vanderbilt.

1.2 Timing in Relation to Workforce Demand

Is this the time to establish one more Ph.D. program in the Earth and Environmental Sciences, and is now the right time to do so at Vanderbilt? Here we address the first part of this question in practical terms in relation to the current and projected status of the US geoscience workforce, with a focus on the Ph.D. degree.
According to the 2011 AGI Geoscience Workforce Report, in 2006 (most recent year for which data are available), 67% of Ph.D. graduates went into academia, 18% went into government, 10% went into the private sector, and 3% went into non-profit/other positions. The employment rate for recent Geoscience PhD graduates compares favorably with those of the other physical sciences, Chemistry and Physics/Astronomy (Table 1). Moreover, according to projections by the Department of Labor, the number of geoscientist jobs in the US will increase 23% between 2008 and 2018 (AGI, 2011). The greatest growth will be in the areas of environmental sciences (28%) and environmental engineering (31%), suggesting that the EES program is well positioned to help meet this demand by training students in these fields.

Table 1: Labor market rates for recent doctorate recipients in the Physical Sciences 1–3 years after receiving doctorate*

<table>
<thead>
<tr>
<th></th>
<th>Geosciences</th>
<th>Chemistry</th>
<th>Physics/astronomy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unemployment rate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>1.5</td>
<td>0.8</td>
<td>1.9</td>
</tr>
<tr>
<td>2003</td>
<td>1.9</td>
<td>1.2</td>
<td>0.0</td>
</tr>
<tr>
<td>2006</td>
<td>1.5</td>
<td>1.9</td>
<td>1.0</td>
</tr>
<tr>
<td>Involuntary out-of-field rate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>3.0</td>
<td>3.2</td>
<td>8.2</td>
</tr>
<tr>
<td>2003</td>
<td>0.0</td>
<td>4.3</td>
<td>4.3</td>
</tr>
<tr>
<td>2006</td>
<td>0.0</td>
<td>0.9</td>
<td>5.9</td>
</tr>
</tbody>
</table>

*2010 Science and Engineering Indicators issued by the National Science Foundation (http://www.nsf.gov/statistics/seind10/pdf/seind10.pdf [NSF pdf], Table 3-17, p. 3-42).

Universities are hiring Ph.D. geoscientists. Within 4-6 years after the degree, 30.5% of Ph.D. geoscientists have tenure-stream appointments at academic institutions, which compares favorably to 22.2% in chemistry and 22.5% in physics and astronomy (Table 3-18, p. 3-43, NSFpdf). It also is noteworthy that the Ph.D. workforce in geosciences is aging: 41% of Ph.D. geoscientists are over 50. This is the highest percentage of the fields studied by the NSF. For comparison, in science and engineering as a whole, 26.4% of those with a Ph.D. degree are over 50 (pp. 3-30, 31 and Figure 3-25, NSFpdf).

This combination of low unemployment, low involuntary employment outside the field, an aging workforce, and a bright outlook for future employment supports the case for establishing a Ph.D. program that will contribute to meeting the increasing national demand for geoscience expertise as outlined in the introductory paragraphs above. We address the second part of the question above — whether now is the time to establish a Ph.D. program at Vanderbilt — in the remaining sections below.

1.3 Educational Objectives and Programmatic Impacts

As outlined above, our objective is a nationally distinguished program wherein we excel in our research and teaching missions, competing at the highest levels with other programs nationally. Toward this end, the Department of Earth and Environmental Sciences is committed to nurturing student interests spanning traditional and emerging Earth-science fields, building from a foundation of understanding the
fundamentals of Earth processes and their importance at local to global scales. We emphasize unifying themes and tools in the study of Earth and Environmental Sciences, and we aim at educating students so that they gain both essential depth in their studies, and exposure to ideas and skills that facilitate communication across disciplines. Our goal is to educate students such that they are poised to excel as scientists in a diversity of life opportunities in all sectors of society. Moreover, this vision permeates all aspects of how we do business, from recruiting new faculty, to the design and revision of courses and curriculum, to our mentoring of students at all levels. An overarching educational objective of the proposed Ph.D. program, therefore, is to provide an intellectual setting at Vanderbilt for educating a select pool of students fully capable of becoming our Nation’s next-generation leaders in the Earth and Environmental Sciences. Moreover, these students will be fully prepared to articulate the significance of their work to those in their discipline, and the importance of the Earth and Environmental Sciences to the broader community.

We fully anticipate that a Ph.D. program will have a strong positive effect on our efforts to recruit top students to Vanderbilt. The Department has a long, strong record of recruiting top students primarily from high quality liberal-arts geoscience programs around the nation, as well as from larger state colleges and universities. A relatively small percentage of students come from abroad. Until 2005, prior to our participation in the Environmental Science Ph.D. option, many of the students completing the M.S. degree in Earth and Environmental Sciences proceeded on to Ph.D. programs at other schools. Since 2005, we have successfully recruited some of the most talented of our M.S. students into the Environmental Science option, in addition to students coming to us from other programs. Many of the students applying for graduate studies from outside Vanderbilt, and virtually all of those students recruited from this outside pool, have a clear sense of the Department, its specialties and stature, and target Vanderbilt as one of their preferred choices for graduate studies. Students who are lukewarm to Vanderbilt during the recruiting process, or who are not within the pool at all, are those who want a Ph.D. in Earth and Environmental Sciences rather than the Ph.D. in Environmental Engineering that students in the existing Environmental Science option receive. These students come from geoscience programs that, because of their background and sense of identity, are aimed at programs wherein Earth science and/or Environmental science, or similar wording, will appear on their diplomas. This pool of students should be a part of our recruiting target, as it represents an important set of particularly talented students. There is little doubt that a Ph.D. program in Earth and Environmental Sciences will have a strong impact on student recruiting, leading to an increase both in the size and the quality of the pool of applicants for graduate studies.

We also anticipate that a Ph.D. program will have a strong positive effect on our efforts to recruit top faculty to Vanderbilt. Certainly there will continue to be a pool of outstanding faculty candidates who would enthusiastically pursue an academic career — and excel — within a program that involves supervising M.S. students but not Ph.D. students. But unquestionably the larger pool of candidates coming out of top programs who are aimed at academic careers, whether as freshly minted Ph.D. graduates or from postdoctoral positions, is comprised of individuals aimed at Ph.D. granting programs. We have a strong sense that the opportunity to supervise Ph.D. students within the current Environmental Science option of Environmental Engineering is, and will continue to be, a strong selling point in our recruitment efforts. Nonetheless, our experience suggests that, as with students having a strong sense of identity in the geosciences, the effect of a Ph.D. program in Earth and Environmental Sciences will be to enhance significantly our faculty candidate pools.
The relative intellectual maturity and experience that Ph.D. students bring to their studies and to their roles as teaching and research assistants can have a positive impact on the overall quality of the education of our students at both undergraduate and graduate levels. This positive impact is particularly manifest through classroom (laboratory) instruction and interactions with undergraduate students, and through interactions and informal mentoring of younger graduate students in relation to both research and teaching. We note that an important part of the Department culture involves coaching and encouraging our graduate students to excel as teachers while they are beginning to distinguish themselves as young researchers — a particularly important goal for Ph.D. students intending to pursue careers in academics, inasmuch as academic programs in the Earth and Environmental Sciences at all levels are increasingly expecting faculty candidates to have significant teaching experience.

By its nature a high-quality Ph.D. program will contribute to increasing the visibility of Earth and Environmental Sciences at Vanderbilt: (i) by serving as a beacon for top students aiming at graduate studies in the Earth and Environmental Sciences; (ii) through the attention generated by creative Ph.D. students participating with other students and faculty in various professional activities across the nation and internationally; (iii) through the attention to the program generated as other schools aim at recruiting our Ph.D. graduates; and (iv) through the scholarship of high-quality faculty recruited to Vanderbilt as a result of the appeal of participating in a Ph.D. program in Earth and Environmental Sciences. Moreover, as outlined in Sections 1.1 and 3.3, we are confident that a Ph.D. program will increase the visibility of the broader activities and scholarship in the Earth, environmental and engineering sciences at Vanderbilt.

2. Well Placed Foundations

The timing of this proposal to establish a Ph.D. program in *Earth and Environmental Sciences* at Vanderbilt is ideal. Within the context of Vanderbilt’s stated goals of enhancing graduate education, EES is well poised to take this step. Essential pieces are in place to grow a nationally distinguished Earth and Environmental Sciences Ph.D. program in which students will excel, solidifying this critical area of science and graduate education at Vanderbilt.

This section outlines the set of foundations that EES has put in place — things we do particularly well — which are critical for a high-quality educational program in general, and which, more specifically related to this proposal, will ensure success in establishing a healthy, thriving program for graduate studies at the Ph.D. level. These foundations concern: the size, quality and stature of the faculty, and the success of the existing graduate program in EES; the intellectual culture of EES, including the mentoring of students; the record of funding in support of graduate education, and the future outlook for funding; the establishment of a high-quality graduate curriculum; and key connections with other disciplines and programs across Vanderbilt. In addition to providing a summary of the state of the Department, this outline provides important context for our vision for a Ph.D. program in Earth and Environmental Sciences (Section 1) as well as other topics covered in this proposal.

2.1 EES Mission Statement

The Department of Earth and Environmental Sciences at Vanderbilt is committed to nurturing student interests and capabilities in interpreting Earth’s dynamic history, and in understanding the behavior of modern Earth and environmental systems. The curriculum is aimed at understanding Earth processes, their global importance in the context of deep time, and their influence on humans and society. The goal is to educate students so that they gain both essential depth in their studies, and exposure to ideas and
skills that facilitate communication across disciplines, such that they are poised to excel in a diversity of life opportunities in all sectors of society.

2.2 Faculty Size

The EES faculty (Table 2) currently consists of eight faculty members who hold tenure in EES, including six at the rank of Full Professor (John Ayers, Ralf Bennartz, David Furbish, George Hornberger (primary appointment in CEE), Calvin Miller, and Molly Miller) and two at the rank of Associate Professor (Steven Goodbred, Guilherme Gualda). EES faculty also include one tenure-track Associate Professor (Jonathan Gilligan), two tenure-track Assistant Professors (Larisa DeSantis and Jessica Oster), and four non-tenure-stream faculty members, including two at the rank of Assistant Professor (Maria Luisa Jorge and Chris Vanags) and two at the rank of Senior Lecturer (Daniel Morgan and Lily Claiborne). In addition, James Clarke (Professor of the Practice) from Civil and Environmental Engineering holds a joint appointment in EES. David White, Professor of Biological Sciences at Murray State University, and Mark Ghiorsso, Vice President & Senior Research Associate in OFM Research Inc., hold the position of Adjoint Professor of Earth and Environmental Sciences in EES. Four individuals hold the status of Professor Emeritus (Leonard Alberstadt, Arthur Reesman, William Siesser, and Richard Stearns). In fall 2015 Professor Molly Miller will retire and be succeeded by new Assistant Professor Simon Darroch.

With 10 tenure-stream faculty with primary appointments in EES, the Department of Earth and Environmental Sciences is by national standards a small-to-medium sized department, although geoscience departments are typically smaller than those for physics, chemistry and biology. In 2010 the median number of faculty in geoscience departments was eight (AGI, 2011). Moreover, the University has made the commitment to increase the number of faculty by one or two within the next few years. Whereas our current size is entirely adequate for establishing and sustaining a high-quality Ph.D. program at Vanderbilt (Section 2.5) — particularly given our connections and interactions with other programs on campus (Section 3.3) as well as with other programs nationally and internationally — additional faculty hires will continue to enhance our effort to establish the Department as a national center of excellence at the Ph.D. level (Section 1.1).

As a point of reference, data presented in the text, in tables, and in figures within the sections that follow normally are associated with the tenure-stream faculty plus Morgan. But note that in a few cases we include data associated with two individuals formerly on the EES faculty (Brendan Bream, formerly Senior Lecturer, currently with ExxonMobil; Kaye Savage, formerly Assistant Professor, currently Associate Professor and Director of Environmental Studies at Wofford College). Inclusion of these data is intended to provide a complete record of the ongoing level of activity within the Department during the data period.
<table>
<thead>
<tr>
<th>Faculty</th>
<th>Position</th>
<th>Education</th>
<th>Areas of Expertise</th>
</tr>
</thead>
<tbody>
<tr>
<td>John C. Ayers</td>
<td>Professor</td>
<td>Ph.D., 1991, Rensselaer Polytechnic Institute</td>
<td>geochemistry, experimental petrology, and sustainability</td>
</tr>
<tr>
<td>Ralf Bennartz</td>
<td>Professor</td>
<td>Ph.D., 1997, Free University of Berlin</td>
<td>Atmospheric physics, clouds and climate, and satellite remote sensing</td>
</tr>
<tr>
<td>Lily Claiborne</td>
<td>Senior Lecturer</td>
<td>Ph.D., 2011, Vanderbilt University</td>
<td>igneous petrology, geochemistry, magma chamber processes</td>
</tr>
<tr>
<td>James H. Clarke¹</td>
<td>Professor of the Practice</td>
<td>Ph.D., 1973, The Johns Hopkins University</td>
<td>contaminated site restoration, environmental policy, environmental forensics</td>
</tr>
<tr>
<td>Larisa R. G. DeSantis</td>
<td>Assistant Professor</td>
<td>Ph.D., 2009, University of Florida</td>
<td>vertebrate paleontology, paleoecology and paleoclimates</td>
</tr>
<tr>
<td>Simon Darroch (beginning fall 2015)</td>
<td>Assistant Professor</td>
<td>Ph.D. exp. 2014, Yale University</td>
<td>paleoecology, mass extinctions and conservation paleontology</td>
</tr>
<tr>
<td>David J. Furbish</td>
<td>Professor</td>
<td>Ph.D., 1985, University of Colorado</td>
<td>hydrology, geomorphology and fluid mechanics</td>
</tr>
<tr>
<td>Jonathan M. Gilligan</td>
<td>Associate Professor</td>
<td>Ph.D., 1991, Yale University</td>
<td>atmospheric science and science policy</td>
</tr>
<tr>
<td>Steven L. Goodbred, Jr.</td>
<td>Associate Professor</td>
<td>Ph.D., 1999, College of William and Mary, Virginia Institute of Marine Science</td>
<td>sedimentology and Quaternary environments</td>
</tr>
<tr>
<td>Guilherme Gualda</td>
<td>Associate Professor</td>
<td>Ph.D., 2007, University of Chicago</td>
<td>igneous petrology and volcanism</td>
</tr>
<tr>
<td>George M. Hornberger²</td>
<td>Distinguished University Professor</td>
<td>Ph.D., 1970, Stanford University</td>
<td>hydrology</td>
</tr>
<tr>
<td>Maria Luisa Jorge</td>
<td>Assistant Professor</td>
<td>Ph.D., 2007, University of Illinois at Chicago</td>
<td>movement ecology, trophic interactions, conservation biology</td>
</tr>
<tr>
<td>Calvin F. Miller</td>
<td>Professor</td>
<td>Ph.D., 1977, University of California, Los Angeles</td>
<td>igneous petrology and continental tectonics</td>
</tr>
<tr>
<td>Molly F. Miller</td>
<td>Professor</td>
<td>Ph.D., 1977, University of California, Los Angeles</td>
<td>paleoecology and sedimentology</td>
</tr>
<tr>
<td>Daniel Morgan</td>
<td>Senior Lecturer</td>
<td>Ph.D., 2009, University of Washington</td>
<td>geomorphology and geochronology</td>
</tr>
<tr>
<td>Jessica Oster</td>
<td>Assistant Professor</td>
<td>Ph.D., 2010, University of California, Davis</td>
<td>environmental geochemistry, climate change, paleoclimates</td>
</tr>
<tr>
<td>David White³</td>
<td>Adjunct Professor</td>
<td>Ph.D., 1974, University of Louisville</td>
<td>aquatic ecology, ecosystem level stream and lake processes</td>
</tr>
<tr>
<td>Mark Ghiorso⁴</td>
<td>Adjunct Professor</td>
<td>PhD Univ. California, Berkeley</td>
<td>igneous petrology, thermodynamics</td>
</tr>
</tbody>
</table>

¹ Holds primary appointment in Civil and Environmental Engineering  
² Holds joint appointments in Civil and Environmental Engineering and Earth and Environmental Sciences  
³ Professor of Biological Sciences, Murray State University  
⁴ Vice President & Senior Research Associate, OFM Research Inc.  
⁵ Only continuing faculty listed.
2.3 Faculty Expertise

The specific expertise of the EES faculty include the following (see Figure 1):

**John Ayers:** *geochemistry, experimental petrology, and sustainability.* Ayers’ work focuses on measuring the compositions of fluids on the Earth’s surface and at conditions corresponding to the Earth’s crust and upper mantle. He also studies the stability of accessory minerals and their use in dating the timing of fluid events. More recently Ayers is pursuing research on soil development and contamination and the scientific basis of sustainability.

**Ralf Bennartz:** *atmospheric physics and radiative transfer, clouds and climate, meteorological satellite remote sensing.* Bennartz’s research focuses on the role of water vapor, clouds, and precipitation in the climate system. He uses models and observations to enhance our understanding of physical processes in the atmosphere that might affect the climate on earth. Ground-based and space-borne remote sensing observations serve as a means for understanding these complex processes.

**Simon Darroch:** *paleoecology, mass extinctions and conservation paleontology.* We hired Darroch in spring 2014. He plans to finish his dissertation under Derek Briggs at Yale University in summer 2014, and then spend one year as a post-doctoral fellow at the Smithsonian Institution before joining us in fall 2015.

**Larisa DeSantis:** *vertebrate paleontology, paleoecology and paleoclimates.* DeSantis pursues interdisciplinary work focused on understanding long-term ecological dynamics, using modern ecosystems to constrain environmental reconstruction of fossil locations, and on understanding how mammalian communities and their floral environments have responded to climate change during the Cenozoic.

**David Furbish:** *hydrology, geomorphology and fluid mechanics.* Furbish’s work involves environmental fluid mechanics and transport theory applied to problems in hydrology and geomorphology, and the intersection of these fields with ecology. He combines theoretical, experimental, computational and field-based components aimed at understanding the dynamics of Earth-surface, and near-surface, systems spanning human to geomorphic time scales.

**Jonathan Gilligan:** *atmospheric science and science policy.* Gilligan’s work is primarily at the intersection of science, ethics, and public policy with a focus on the ways in which scientific knowledge and uncertainty affect policy decisions about the environment.

**Steven Goodbred:** *sedimentology and Quaternary environments.* Goodbred’s work involves the interaction of environmental systems along the boundary of land and ocean — particularly within rivers, deltas and coastal wetlands, and bears on fundamental questions about past environmental change, about the recurrence and impact of coastal hazards, and the effect of human alterations to the landscape.

**Guil Gualda:** *igneous petrology and volcanism.* Gualda’s work is aimed at understanding the evolution of magma bodies — in particular silica-rich magma bodies — and the processes that constrain their
physical state at various stages of evolution, with particular attention to the stages leading to eruption, and in the conditions that make eruptions possible, likely, or inevitable.

George Hornberger: *Hydrology*. Hornberger studies how hydrological processes affect the transport of dissolved and suspended constituents through catchments and aquifers, including current projects on the transport of dissolved organic carbon through catchments.

Maria Luisa Jorge: *movement ecology, trophic interactions, conservation biology*. Jorge's research is aimed at understanding how large mammals choose the habitats they use and how human activities (especially land-use) affect large mammals’ long-term persistence.

Calvin Miller: *igneous petrology and continental tectonics*. Miller’s work is focused on the makeup and architecture of magma chambers, how materials are transported into, within, and out of them, the relationships between the processes and products at volcanoes and at plutons, and the processes that determine when and whether magma chambers erupt.

Molly Miller: *paleoecology and sedimentology*. Miller's work is focused on the relationship between soft-bodied animals and physical and biologic components of their environment, how this relationship has changed through the Phanerozoic, and whether the history is different for marine versus freshwater conditions. She integrates sedimentologic data with the ecology of living organisms to reconstruct ecological controls on ancient soft-bodied organisms.

Dan Morgan: *geomorphology and geochronology*. Morgan’s work involves the use of cosmogenic nuclides to study landscape evolution and how landscapes reflect environmental change, with particular emphasis on the glacial history of Antarctica, and Cenozoic climate change.

Jessica Oster: *environmental geochemistry, climate change and paleoclimates*. Oster uses uranium-series and stable-isotope geochemistry of cave and soil waters to trace hydroclimate variability across a range of terrestrial environments with the aim of understanding climate variations over the past tens-of-thousands to hundred-thousand years.

These areas of faculty expertise collectively provide the intellectual and curricular foundation of the focus areas of the proposed Ph.D. program, as described in Section 1.1. We emphasize that these focus areas, by design, involve important overlaps in substance and in faculty expertise.

The first area of solid-earth dynamics — *transport, reaction and evolution of fluids and magmas in the crust* — currently centers on the collective, and collaborative, work of Ayers, Gualda and C. Miller, with supporting roles provided by Furbish and Hornberger concerning transport phenomena. The second area of life processes — *Earth’s record of changing climates and ecosystems* — centers on the work of DeSantis, M. Miller, and Oster, with supporting roles provided by Furbish and Gilligan concerning physical aspects of geomorphology and climate change. The area of Earth’s surface and atmosphere — *impacts of environmental change on processes occurring on the surface and in the atmosphere of the Earth* — centers on the work of Bennartz, Furbish, Gilligan, Goodbred, Hornberger, Oster, and M. Miller, with a supporting role provided by Morgan. The addition of Bennartz in fall 2013 has greatly strengthened our program's atmospheric research component. We also note that Gilligan’s expertise concerning the intersection of science, ethics and public policy significantly enhances all areas of our graduate and undergraduate programs inasmuch as this intersection of topics is an essential part of our collective dialogue. This includes Gilligan’s leadership role in the TIES course, recently involving the TIES Bangladesh seminar and field trip (Sections 1.1 and 3.3), and in activities of the Vanderbilt Institute for Energy and Environment (VIEE).
EES has successfully completed its search to fill a tenure-track position in the field of Earth Systems Science with the hire of upcoming Yale graduate, Simon Darroch. Earth Systems Science is a relatively new, holistic approach to understanding the Earth that integrates many subdisciplines of Geosciences by treating Earth components such as the atmosphere, hydrosphere, lithosphere, and biosphere as part of a complex system. It seeks to quantify exchanges of matter and energy between these spheres in the present and during Earth’s distant past. Our hire will focus on the biosphere as part of the Earth system and would take over teaching of EES 202 Earth Systems through Time, a required course for undergraduate majors that we started offering in 2011 and that uses an Earth Systems approach. This and future hires will cement the strengths within our three focus areas (Fig. 1) and will bring us to a critical mass necessary to maintain a high-quality Ph.D. program. We reiterate that these focus areas define a core of scholarship that provides a foundation for competing at the highest levels nationally, for ensuring the right balance of depth and breadth in educating students at the Ph.D. level, and for the continued growth of a world-class faculty.

2.4 Small but Fierce: Measures of Faculty Quality

EES faculty members are well respected in the scientific community and in the Vanderbilt community, as evidenced by a variety of metrics that are commensurate with the time-in-rank of individuals. These metrics include, for example, external and internal awards, citations of publications, editorships and associate editorships, and requests to serve on key advisory panels and review committees (Appendix 1).

Our early-career tenure-stream faculty are rapidly distinguishing themselves as leaders in their fields. Guil Gualda, together with colleagues in EES and around the world, is challenging the core of how Earth scientists think about the magmatic conditions that lead to explosive volcanic eruptions. Larisa DeSantis is pioneering methods for understanding how mammalian communities and their floral environments have responded to climate change during the past 65 million years. And Jessica Oster is ramping up her research program aimed at unraveling climate records from cave deposits and soils.

Our senior faculty in turn have a solid record of substantive contributions to several fields in the Earth and Environmental Sciences and to the academic community, and provide high visibility to EES and to Vanderbilt. For example, Molly Miller received the 2005 Educator of the Year award from the Association of Women Geoscientists; she was recently honored with the 2007 Chancellor’s Cup, given annually for the greatest recent contribution outside the classroom to undergraduate student-faculty relationships, involving educational importance and relevant to the central purpose of the university; and she received the 2004 A&S Nordhaus Award for Excellence in Undergraduate Teaching. Calvin Miller was selected as the 2005 Daly Lecturer by the Volcanology, Geochemistry and Petrology section of the American Geophysical Union, one of the premier professional societies in the geosciences; he received the 2006 A&S Award for Excellence in Graduate Teaching at Vanderbilt; and he has delivered six keynote addresses at national and international meetings in the past five years. Both Calvin Miller and Molly Miller are Fellows of the Geological Society of America, another premier professional society in the geosciences. John Ayers presented keynote lectures at the 2001 and 2006 Goldschmidt Conferences sponsored by the Geochemical Society and the European Association of Geochemistry. David Furbish recently received the 2010 A&S Earnest A. Jones Faculty Advisor Award, and the 2010-2011 Harvie Branscomb Distinguished Professor Award.

Seven members of the faculty have served on NSF and NOAA review panels, several of them multiple times (Appendix 1). This role is a particularly significant measure of the respect that agency personnel, representing the views of the Earth and Environmental Sciences community, hold for the scientific
accomplishments, stature and perspective of our faculty. Moreover, these panels represent programs from several divisions of NSF, including Geosciences, Graduate Education, Mathematical Sciences, Ocean Sciences, and the Office of Polar Programs — a measure of the recognized breadth of expertise of EES faculty.

Members of the faculty have served as editors, guest editors, and associate editors for 17 journals (Appendix 1). They have served on (and chaired) numerous scientific advisory committees, including high-visibility NSF sponsored initiatives, for example, the National Center for Earth-surface Dynamics (NCED), the Community Surface Dynamics Modeling System (CSDMS), and the NSF Critical Zone Observatory network (CZO). In addition, several faculty members have served on external review committees for academic programs around the nation.

Current EES faculty (not including affiliated faculty) have authored or co-authored over 430 peer-reviewed papers listed in the ISI Web of Science. These papers collectively have been cited more than 17,460 times, following an exponential-like distribution. This record is consistently represented by high-impact journals, including broad-audience journals such as *Nature* and *Science* and flagship journals of premier professional societies of the Earth and Environmental Sciences (e.g. the American Geophysical Union, the Geological Society of America). One faculty member (Furbish) has published a highly regarded text on fluid physics and is writing a second book, and another (Ayers) currently is writing a text on the scientific basis of sustainability.

EES faculty have a strong, sustained record of external funding (Appendix 2), notably from the National Science Foundation (NSF), but also including the National Oceanic and Atmospheric Administration (NOAA), the National Environmental Protection Agency (EPA), the Department of Defense (DOD), and the Department of Energy (DOE), both directly and through the Consortium for Risk Evaluation with Stakeholder Participation (CRESP). Grants to Vanderbilt in active status during the period 2005 to 2012 total $14M, giving an average level of external funding of approximately $227,000 per year per tenure-stream faculty member. These grants include prestigious NSF CAREER awards to Goodbred and Gualda. As a point of reference, the median annualized award for the NSF EAR Division was about $95,000 in 2007. In addition to sole-PI grants, this record includes collaborations among EES faculty and with members of other programs at Vanderbilt, as well as internationally-acclaimed scientists outside of Vanderbilt. In fact, most of the grants are collaborative, with Vanderbilt as the lead institution, so total funding for Vanderbilt and the supported collaborators is significantly greater than the $14M in active status during 2005-2012. In addition, recent funding not listed in this $14M includes pending NSF grants to C. Miller ($332,921), Furbish ($207,413), and Oster ($166,466).

EES faculty members also have a strong record of competitive internal funding (Appendix 3). During the past five years EES faculty, partly in collaboration with individuals in other programs, have secured $707,459 in grants from the Discovery and the Venture Fund programs (including a recent collaborative Discovery Grant to Gualda as part of the purchase of a new Scanning Electron Microscope), and from the Enhancing Graduate Education (EGE) program. The EGE grant, involving a collaboration with faculty in CEE, funded our *Transdisciplinary Initiative on Environmental Systems* (TIES), the centerpiece of which is a unique transdisciplinary course that focuses each year on an environmental issue that is of global significance, and which is embodied in a particular field site studied by TIES participants. Over the past five years, this course has involved two trips to Yucca Mountain, Nevada, to study the scientific, engineering and social issues associated with the (then) proposed national repository for high-level
radioactive waste, and, as mentioned above, two trips to Bangladesh to study aspects of the Bangladeshi environment that demand the joint attention of earth scientists, engineers, and social scientists, along with local citizens, to address the multiple water-related hazards facing urban and rural populations in Bangladesh and the world.

With respect to our proposal for a Ph.D. program, the description here of faculty activities and stature attests to a vibrant department in which graduate students are exposed to a culture of aiming at high standards of scholarship, wherein academic and professional citizenship are valued — an important foundation for growing a healthy, thriving program for graduate studies at the Ph.D. level.

2.5 Status of Current Graduate Program

Between 2001 and 2013, 55 students have received M.S. degrees (37 since 2005; Appendix 4). Of these, 27 have gone on to pursue a Ph.D., 13 in the Environmental Science Ph.D. option at Vanderbilt and 14 at other universities. Of the 13 who have completed their doctorates, two are now tenure-track faculty members, three are lecturers at universities, one has a position with the National Research Council and another with the Nuclear Regulatory Commission, three are research scientists (university, petroleum industry), one is a post-doc, and one is in environmental consulting. The remaining 28 with M.S. degrees have entered careers in a variety of fields, almost all related to their Earth and Environmental Science training, primarily with government agencies (USGS, NOAA) and environmental NGOs, the environmental industry, and community college and secondary education.

Between 2006 and 2013 seven students completed the Ph.D. degree (ES option) under the supervision of EES faculty; five have completed since 2010 (Table 3). Four more earned the Ph.D. in 2014. Eleven students are currently in the program as full-time students and two are part-time. Six of the seven former Ph.D. students are pursuing careers in academics (one tenured, one tenure-track, one senior lecturer, one research associate, two post-docs), and one is a research scientist in the private sector (Appendix 4). Of the four 2014 EES PhD graduates two have tenure track faculty positions, and one previous MS graduate who also served as EES Instructor in spring 2014 obtained a tenure track faculty position.

Table 3. EES PhD student statistics, Env. Science option, 2010-2013

<table>
<thead>
<tr>
<th>Women</th>
<th>Minority</th>
<th>Disabled</th>
<th>Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. applicants to PhD program</td>
<td>36</td>
<td>13</td>
<td>0</td>
<td>13</td>
</tr>
<tr>
<td>No. applicants accepted by program</td>
<td>11</td>
<td>1</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>No. that matriculated</td>
<td>10</td>
<td>1</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>No. students who withdrew</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>No. PhDs awarded</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>No. enrolled in 2013</td>
<td>9</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

*Including two students on one-year leaves

Currently there are 25 graduate students whose financial aid is provided by EES funds or by external grants to faculty in EES. Of these, thirteen are at the Ph.D. level and twelve are at the M.S. level. This gives a ratio of 2.5 students per tenure-stream faculty. Fifty to sixty percent of Ph.D. student support is through external grant-funded research assistantships, 30% through teaching assistantships, and the remaining 10-20% through external support directly to the students. We note that one current Ph.D. student is funded by a prestigious three-year Graduate Research Fellowship from the National Science Foundation and another Ph.D. student is funded for one year as a Fulbright Scholar.
Over the past 12 years, our retention rate for students enrolling in graduate studies has been 90 percent. For those students remaining in residency until completing the degree, the average time to completion for M.S. students is two years, excluding seven students who spent an extra year as NSF GK-12 Teaching Fellows, and the average post-M.S. time to completion for our nine Ph.D. students is ~4 years. Three M.S. and two Ph.D. students left the program for lack of satisfactory progress toward their degrees.

Our students attend national, international and regional meetings of professional societies (e.g. American Geophysical Union, Geological Society of America) to deliver oral and poster presentations of their work. A high proportion of our M.S. students, and all of our Ph.D. students, co-author peer-reviewed papers based on their thesis work. As outlined in Section 3.1.2, our Ph.D. students, particularly those aimed at academic careers, are expected to prepare their thesis chapters in manuscript form with target journals identified. The five Ph.D. graduates (Appendix 4) collectively had 21 papers related to their dissertation work either published, in press, or submitted by the time they completed their degrees, and they also had published several other papers not directly related to their dissertations, including papers that grew from M.S. research.

<table>
<thead>
<tr>
<th>Table 4. Institutions and Departments Participating in 2009 Survey of Geoscience Programs, Compiled by Department of Earth Sciences, Dartmouth College</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Institution</strong></td>
</tr>
<tr>
<td>Baylor University</td>
</tr>
<tr>
<td>Boston University</td>
</tr>
<tr>
<td>Brown University</td>
</tr>
<tr>
<td>Case Western Reserve University</td>
</tr>
<tr>
<td>Dalhousie University</td>
</tr>
<tr>
<td>Dartmouth College</td>
</tr>
<tr>
<td>Harvard University</td>
</tr>
<tr>
<td>Lehigh University</td>
</tr>
<tr>
<td>McGill University</td>
</tr>
<tr>
<td>Princeton University</td>
</tr>
<tr>
<td>Rensselaer Polytechnic Institute</td>
</tr>
<tr>
<td>Rice University</td>
</tr>
<tr>
<td>Syracuse University</td>
</tr>
<tr>
<td>University of Cincinnati</td>
</tr>
<tr>
<td>University of Maine</td>
</tr>
<tr>
<td>University of New Hampshire</td>
</tr>
<tr>
<td>University of Notre Dame</td>
</tr>
<tr>
<td>University of Oregon</td>
</tr>
<tr>
<td>University of Pennsylvania</td>
</tr>
</tbody>
</table>

2.6 Comparison with Other Geoscience Programs

As a point of reference, data concerning certain metrics for other departments are available from a survey compiled by the Department of Earth Sciences at Dartmouth College and distributed among participating programs. These represent a mixture of private and public institutions, and department sizes that range from 5.5 to 26 full-time teaching faculty (Table 4). The five smallest departments are Vermont (5.5), Case Western (7), Rensselaer (7), Penn (8), and Vanderbilt (9); the five largest departments are Harvard (26), Brown (22), Notre Dame (20), Princeton (18) and Rice (16). The data pertain to the five-year period 2005-2009. Although we cannot provide updates or verification for other programs, we have added notes to the EES data (Table 5).
Our current student-faculty ratio of 2.7 is above the average student-faculty ratio of 2.1 (computed separately). We are at the median of applications per year (45) with a lower acceptance rate (13%) and a higher yield rate (70%). Our enrolled students are slightly above the median average GRE total (1240 for M.S. students, 1250 for Ph.D. students), and the four entering Ph.D. students have an average score of 1340. The nine EES students who have completed their Ph.D. degrees did so after an average of ~4 years after completion of the M.S., below the median 5.7 years to completion. With respect to external awards and publications, our numbers are favorable relative to median values and reported ranges (Figures 2 and 3), and we note that reported values include three programs (Brown, Harvard, Princeton) that support only Ph.D. students, and one program (Vermont) that supported only M.S. students during the data period. Since data were compiled in 2010 for the period 2005-2009, our level of external funding has risen substantially to $227K per faculty per year.
3 Program Structure

3.1 Program Elements

3.1.1 Foundation of Knowledge and Skills

The success of a doctoral education — both its process and outcome — involves a defined program structure that is shared among students and faculty. Here we identify the general knowledge areas and skill sets, crossing all three focus areas described in Section 1.1, that will serve as a foundation for our students’ success in this program and their professional careers beyond. Achievement in these knowledge and skill areas will be fostered through an individually tailored selection of course work, mentoring, and practical experience detailed in the following sections.

Students will be expected to master a fundamental understanding of:

- **materials** — the physicochemical nature of solid and fluid Earth materials;
- **processes** — the physical, chemical and biological processes affecting the evolution of Earth materials, life, and environments;
- **systems** — the behavior of Earth systems wherein materials and processes are coupled over a wide range of spatial and temporal scales, and interpreting the record of this behavior.

Moreover, students will be expected to become skilled in:

- **quantitative methods** — defining the rates, scale, and magnitude of Earth processes and systems, plus our uncertainty in measuring them; and
- **communication** — effective conveyance of knowledge and outcomes in written and oral form.

Expertise in these key knowledge areas coupled with practical skills will allow students to be competitive in the academic and professional marketplace on completion of their studies, and provide them with flexibility to respond to current and future high-priority research needs. We describe below (Sections...
the process of designing individual student programs of study consistent with these knowledge and skill areas. In addition, students in the Ph.D. program will be expected to individually develop a *Career Perspective* as they move through the program (3.1.5).

### 3.1.2 Degree Requirements

Requirements for the Ph.D. degree in Earth and Environmental Sciences will adhere to those of the University as described in the Graduate School Bulletin. Here we elaborate on key expectations of EES within the context of University requirements.

**Residency and Course Work.** Consistent with University requirements, the Ph.D. degree requires at least three years of graduate study, a minimum of 36 credit hours of formal course work, of which at least 18 credit hours must be completed at Vanderbilt, passage of the Ph.D. qualifying examination, and acceptance and defense of a written dissertation. A total of 72 credit hours are required, including course work, transfer credit (when appropriate) and dissertation research.

In addition:

- students will have flexibility in choosing courses from a menu of courses provided to them, with their Ph.D. Committees insuring balance amongst the distribution (see Section 3.1.3 below for additional recommendations concerning direction and oversight);
- No more than 18 transfer credit hours may count toward the requirement of 36 course credit hours.
- No more than four 200-level courses may count toward the 36 credit hour course requirement;
- Directed Study research credit hours (up to 6 credit hours) may be included to meet the required 36 credit hours of formal course work; and
- students with a Masters degree from Vanderbilt will typically be allowed to count Vanderbilt graduate credit hours toward the required 36 hours of formal course work and the total 72 hours of course work, subject to the approval of their Ph.D. Committees; students entering with a Masters degree from another institution will need to complete a minimum of 18 course credit hours at Vanderbilt.

Like most Geosciences PhD programs\(^1\), our program will not have any required courses. However, PhD committees will advise students to take a set of courses that give both breadth and depth in the discipline, including at least one course in each of the three course groupings (Materials, Processes, and Systems).

---

\(^1\) We recently compiled a list of Peer and Aspirational programs (with NRC 2010 5\textsuperscript{th} and 95\textsuperscript{th} percentile rankings in parentheses) for Academic Analytics. The peer programs include Duke University Earth and Ocean Sciences (26-84), Johns Hopkins University Earth and Planetary Sciences (33-80), Northwestern University Earth and Planetary Sciences (33-80), University of Pennsylvania Earth and Environmental Science (42-102), and University of Rochester Geological Sciences (23-87). Aspirational programs include Boston University Earth Sciences (21-72), Brown University Geological Sciences (18-59), Cornell University Geological Sciences (26-76), Rice University Earth Science (24-76), and Yale University Geology & Geophysics (21-61). Based on our survey of the PhD curricula for these programs, we have learned that most do not have required courses. However, Duke does require four courses, including Responsible Conduct in Research (which Vanderbilt graduate students are also required to take when they matriculate), Introduction to Modeling, Analyzing Time and Space Series, and Introduction to Fluid Dynamics. Northwestern requires 2 courses in mathematics, physics, chemistry, or engineering. Boston University requires at least 10 non-research courses, including at least one graduate-level course from two of the three disciplines Geodynamics, Geochemistry, and Earth History.
Our department regularly offers twelve 200-level and twelve 300-level courses (Appendix 5), and frequently offers numerous one-time EES390 Special Topics courses. This near-equal distribution of courses between the 200- and 300-levels reflects our department's historical model in which each faculty member teaches one course in each of the 100-, 200-, and 300-levels. The apparent shortage of 300-level courses is also an artifact of the current course numbering system. College courses will soon be renumbered, which will be an opportunity for EES to split Catgrad courses (200-level courses eligible for graduate credit) into 200-level and 300-level courses with different syllabi. That will greatly increase the number of 300-level courses offered.

The courses a student takes fundamentally depend on what the student chooses to specialize in. Our PhD students have included paleontologists, volcanologists, meteorologists, and geochemists, to name just a few subdisciplines. They may have had undergraduate majors in Biology, Physics, Chemistry, or Ocean Sciences. As a result, most students will not follow the sample course schedules below; they are simply presented to show that an EES PhD student can easily develop a curriculum of coursework that will prepare him/her well for their academic career. Here is what a volcanology student might take:

<table>
<thead>
<tr>
<th>Year</th>
<th>Fall</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Geochemistry (3) Earth Fluids (3) Volcanic Processes (3)</td>
<td>Geomorphology (3) Adv. Topics in Earth Materials (3) Isotopes and the Env. (3)</td>
</tr>
<tr>
<td>2</td>
<td>Statistical Methods in EES (3) Anth 280 Intro to GIS and Remote Sensing (3) Microscopic Image Acquisition (3)</td>
<td>Magmatic Processes and Construction of Earth's Crust (3) Geochemical Modeling (3) Special Topics (3)</td>
</tr>
</tbody>
</table>

Preliminary Exam (after 2-3 semesters completed)

<table>
<thead>
<tr>
<th>Year</th>
<th>Fall</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Special Topics (3) Dissertation Research</td>
<td>Intro to Atmospheric Physics (3) Dissertation Research</td>
</tr>
</tbody>
</table>

Qualifying exam (after 4 or 5 semesters completed; includes dissertation proposal)

<table>
<thead>
<tr>
<th>Year</th>
<th>Fall</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Dissertation Research</td>
<td>Dissertation Research</td>
</tr>
</tbody>
</table>

Here is what a student majoring in geobiology might take (we are in the process of hiring a new faculty member in this area, so the list of courses is incomplete):

<table>
<thead>
<tr>
<th>Year</th>
<th>Fall</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Paleoecological methods (3) Source to Sink (Sedimentology) (3) Statistical Methods in EES (3)</td>
<td>Geomorphology (3) Macroeoclogy and Biogeography (3) Problems in Sed. and Paleobiology (3)</td>
</tr>
<tr>
<td>2</td>
<td>Paleoclimates (3) Microscopic Image Acquisition (3)</td>
<td>Special Topics (3) Isotopes and the Environment (3)</td>
</tr>
<tr>
<td>Special Topics (3)</td>
<td>Topics in Macroevolution (3)</td>
<td></td>
</tr>
<tr>
<td>--------------------</td>
<td>----------------------------</td>
<td></td>
</tr>
<tr>
<td>Preliminary Exam (after 2-3 semesters completed)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Special topics (3)</td>
<td>Special topics (3)</td>
<td></td>
</tr>
<tr>
<td>Dissertation Research</td>
<td>Dissertation Research</td>
<td></td>
</tr>
<tr>
<td>Qualifying exam (after 4-5 semesters completed; includes dissertation proposal)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Dissertation Research</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dissertation Research</td>
<td></td>
</tr>
</tbody>
</table>

Each student takes twelve 3 credit hours courses to meet the 36 credit hours course requirement. They can take more courses, or take 36 hours of dissertation research to meet the 72 credit hours requirement. We will continue the practice of the Environmental Science PhD option of accepting graduate credits from other institutions following review of the courses in question. The PhD committee will recommend which courses should be allowed for credit transfer based on criteria such as relevance of course topic, value for subsequent study, grade earned, and quality of the other institution's equivalent degree program. The final decision on which courses will be accepted for credit transfer will be made by the Director of Graduate Studies in consultation with the Department Chair.

Up to 18 transfer credit hours may count toward the 36 credit hour course requirement. This reflects a compromise: PhD students should take courses at Vanderbilt to maintain the integrity of the PhD program, to keep course enrollments high, and to ensure that students have the background training necessary to perform their dissertation research. On the other hand, to maintain consistency with our current PhD program (the Environmental Science option offered through CEE), and to avoid putting rules in place that would keep students in residence longer, which would decrease the annual number of graduates and hurt our recruiting efforts, we want to allow students with Master's degrees who apply to our PhD program (more than half of our PhD applicants fall in this category) to have some of their Master's courses count toward their PhD course requirements.

**Preliminary Examination.** Each Ph.D. student will be required to take a preliminary examination normally after completion of two to three semesters of study, depending on the student’s background (e.g. whether the student has completed a master’s degree) and preparation. The preliminary exam must be passed by the end of the second academic year. The Ph.D. Committee, with input and participation from the faculty, will be responsible for developing and administering the preliminary examination. The preliminary examination will consist of written and oral parts, including presentation of a critical review of a published manuscript.

**Qualifying Examination.** As described in the Graduate School Bulletin, “Admission to the Graduate School does not imply admission to candidacy for the Ph.D. degree. To be admitted to candidacy the student must... pass a qualifying examination. The examination will be administered by the student’s Ph.D. committee, which will supervise subsequent work toward the degree. Upon completion of these requirements the Ph.D. committee will recommend to the Graduate School that the student be admitted to candidacy.”

Further “The purpose of the qualifying examination is to test the student’s knowledge of the field of specialization, to assess familiarity with the published research in the field, and to determine whether the
student possesses those critical and analytic skills needed for a scholarly career. The examination is conducted by a Ph.D. committee appointed by the Graduate School on advice of the chair or director of graduate studies of the program. The committee consists of not fewer than four members of the Graduate Faculty. Three of the members must be graduate faculty from within the student’s department/program and one from outside the program. Any variation of the committee makeup must be approved by the Graduate School. The committee must be appointed by the Graduate School no less than two weeks before the time the student expects to take the qualifying examination.”

After passing the preliminary exam and completing a minimum of 36 credit hours of coursework each student will be required to take the qualifying examination, normally after completion of four to five semesters of study depending on the student’s background. The Ph.D. Committee, with input and participation from the faculty, will be responsible for developing and administering the qualifying examination, which will consist of an oral exam and presentation of a dissertation research proposal. The exam must be passed after the first or second attempt no later than the end of the third academic year.

Dissertation. As described in the Graduate School Bulletin, “A candidate for the Ph.D. degree must present an acceptable dissertation. The dissertation demonstrates that the candidate has technical competence in the field and has done research of an independent character. It must add to or modify what was previously known, or present a significant interpretation of the subject based upon original investigation. The subject of the dissertation must be approved by the student’s faculty advisor and Ph.D. committee.”

Moreover, EES expects that dissertation research should begin in earnest no later than the third semester in residence. The research program should be well planned by this time as the result of extensive consultation between the student, advisor, and Ph.D. committee. The project should be designed so as to be completed within the context of a four- to five-year Ph.D. program. The dissertation research is expected to be original, timely and innovative, and the student is expected to contribute these qualities to the research. This is not to say that formal and informal advisors are not also contributors, but rather that the student is expected to demonstrate the competence and creativity to independently pursue similar research in the future. Ph.D. research should be conducted in such a way as to meet or exceed accepted standards for professional research in the field. Each student should endeavor to define new and higher standards with his or her Ph.D. work. The dissertation should be written so as to qualify for publication in a standard professional journal. Ph.D. students are strongly encouraged to prepare their dissertation as a compilation of several manuscripts that are either published, submitted, or ready for submission to first-tier, refereed journals, along with appendices of data and other appropriate material not generally accepted for publication. Following successful defense of the dissertation, unpublished portions should be prepared for publication at the earliest possible date. In general, only research performed while a student is pursuing a degree at Vanderbilt University and under the supervision of a faculty member at Vanderbilt may be used to fulfill the degree requirements. In special cases this rule may be waived by unanimous written approval of the student’s Ph.D. committee, and approval of the department chair.

Final Examination. As described in the Graduate School Bulletin, “The candidate must pass his or her dissertation defense... The final oral examination is administered by the student’s Ph.D. committee and is on the dissertation and significant related material; the student is expected to demonstrate an understanding of the larger context in which the dissertation lies.” Consistent with University policy, the final examination will be open to the public.

20
The expected typical time progression of students through the PhD program is summarized in Fig. 4. Students who fail to make satisfactory progress (e.g., failure to pass qualifying exam after two attempts) will either be asked to leave the program or be granted a non-thesis Masters degree on recommendation of the Director of Graduate Studies.

**Figure 4**: PhD Program Timeline. Each year lists goals PhD student should aim to achieve by the end of that year. These are not intended as deadlines, but rather as guidelines. Some students may take longer to complete the program, depending on their experience (prior MS degree) and initiative.

### 3.1.3 Advising and Committees

**Selection of Advisor and Ph.D. Committee.** Each student’s Ph.D. Committee, chaired by the student’s Advisor, will be composed of members of the Graduate Faculty, appointed by the Director of Graduate Studies in consultation with the Chair and the student. The Director of Graduate Studies may serve as an ex-officio member of Ph.D. Committees on which he/she is not a primary member. In addition, the Director of Graduate Studies will provide initial academic guidance to incoming students prior to the selection of their individual Ph.D. Committees.

As described in the Graduate School Bulletin, “The functions of the Ph.D. committee are (a) to administer the qualifying examination, (b) to approve the dissertation subject, (c) to aid the student and monitor the progress of the dissertation, and (d) to read and approve the dissertation and administer the final oral examination.” In addition, EES expects members of the Ph.D. Committee to serve in an advisory capacity concerning course work selection, defining career goals and options, and providing perspectives on research and teaching.

Once a PhD student matriculates the Director of Graduate Studies will assign a temporary PhD committee. The Advisor and permanent Ph.D. Committee for each student will be selected no later than the middle of
the second semester of study. It is recognized that some students will have, prior to initial enrollment, identified faculty members with whom they wish to work based on mutual agreement between these students and the faculty members. Otherwise, students will be encouraged to discuss research opportunities with faculty during their first semester of study, then propose possible research topics, Advisors, and potential members for the Ph.D. Committee, to the Director of Graduate Studies.

Appointment of the Advisor and Ph.D. Committee will then occur as described in the first paragraph above. In each case, the preference of the student and potential faculty Advisor will be key considerations. The Advisor serves as the primary faculty mentor and advocate for the student, and is expected to work with the student to obtain financial support, provided that the student maintains satisfactory progress.

Selection of Course Work. Each Ph.D. Committee, in consultation with the student, will be responsible for designing a program of study, including selection of specific required course work, for the student. Course selection will be based on: (i) the student’s background, including course work completed; (ii) the student’s intended area of research; and (iii) insuring that the student has a program of study that is consistent with the Expected Knowledge and Skill Areas (Section 3.1.1) and the Degree Requirements (Section 3.1.2). Specifically, each student will be expected to complete substantial course work in the focus area (Section 1.1) representing the student’s dissertation research, and selected course work in each of the other two focus areas, consistent with the Expected Knowledge and Skill Areas. The program of study may include additional course work selected from programs other than EES.

A list of currently available courses tentatively assigned to the three Expected Knowledge and Skill Areas (Section 3.1.1) is included (Appendix 5). The assignment of courses in this list will be reviewed annually by the EES Faculty as the content and emphasis of individual courses naturally evolve, and as new courses are developed.

Within each of the three Areas (Appendix 5), courses at the level of 200 and above are listed. Courses with numbers of 250-300 normally are assumed to be acceptable as graduate-level courses, with expectations of enrolled graduate students that are beyond those for enrolled undergraduates. Nonetheless, in order to accommodate students with diverse backgrounds whose training is limited in certain (undergraduate) background material, we can envision that select 200-249 courses, within EES as well as from other programs, could be appropriate as graduate-level courses for certain students in the Ph.D. program. For example, Physical Chemistry (CHEM 230) could be appropriate as a graduate-level course for students with undergraduate backgrounds in Earth science pursuing graduate research related to transport phenomena in environmental or Earth-crustal systems. Similarly, EES 230 (Sedimentology) and Ecology (BSCI 238) could be appropriate as graduate-level courses for students pursuing graduate research related to Earth-surface dynamics or paleoecology. Similar remarks pertain to courses in Mathematics and Engineering. Any 200-249 level course that is approved for a student’s program of study under these conditions must involve an arrangement with the instructor wherein the student undertakes and completes ancillary work at the graduate level.

3.1.4 Expectations and Academic Performance

EES policies regarding expectations and academic performance, notably pertaining to satisfactory progress toward the degree, will adhere to those of the University as described in the Graduate School Bulletin. Here we elaborate on key items specific to EES.
Mutual Expectations of Students and Faculty. An important element of a healthy, thriving Ph.D. program is a setting where mutual expectations of students and faculty are openly and clearly communicated — expectations of students that encompass academic performance, responsibilities as Teaching Assistants and Research Assistants, professionalism and citizenship, and expectations of faculty in terms of supporting the goals and aspirations of students and providing academic and career advising. Appendix 6 is a statement of Mutual Expectations fashioned after the document covering this set of topics prepared by the Department of Physics. It will be provided to all graduate students and discussed during their initial orientation. Key items are summarized here.

Academic Progress and Performance. Each student will be required to prepare a Progress Report near the end of the Fall and Spring semesters, to be reviewed and discussed with the Ph.D. Committee and the Director of Graduate Studies; both the Ph.D. Committee and the DGS will approve the report. The report will consist of two parts: a) Academic Progress and b) reflections on Career Perspective (see Section 3.1.5).

For those students serving as Teaching Assistants, teaching evaluations will be reviewed after each semester by the Director of Undergraduate Studies and the Director of Graduate Studies, in consultation with the Chair. Faculty will provide continuing advisement and coaching to all Teaching Assistants.

Each student will formally meet with his/her Ph.D. Committee and Advisor at least once each semester. As part of the review of the Progress Report, the Committee will discuss the student’s program of studies. This program may be adjusted from semester to semester to insure that it provides breadth in course work as well as expertise in the student’s specialty area, within the context of the student’s intellectual growth and evolving career perspective and goals.

Professional Activities. The EES faculty expects all of its graduate students to participate in professional activities as a fundamental ingredient of their graduate studies and experience at Vanderbilt. Such activities include, for example, preparing and presenting results of their research at international, national and regional meetings of professional societies, and preparing manuscripts for publication in high-quality peer-reviewed journals. In addition, our students are expected to pursue external funding for their research in situations where Requests for Proposals are targeted at students, as well as contribute to faculty efforts in preparing proposals for external funding in support of student research. Faculty are expected to fully engage with students in the writing process.

Department Citizenship. The EES faculty expects its students to participate in and contribute to departmental activities that are of an academic nature. This includes, for example: attendance (and participation) at departmental seminars presented by invited speakers, and at student presentations of senior thesis research, M.S. thesis research, and Ph.D. thesis defenses; participation in the hosting of visitors (e.g. seminar speakers, prospective students, faculty candidates); and participation in special departmental events (e.g. our annual commencement reception for graduating students and their families and friends). Students attending meetings of the Geological Society of America also contribute to student recruiting efforts.

In addition, students are expected to act professionally with respect to issues of laboratory safety and cleanliness, the care and feeding of departmental equipment (laboratory, field and computational), and upkeep of shared offices and work spaces.


3.1.5 Building Career Perspective

Students in the Ph.D. program will be expected to develop and act on a personal vision of how their knowledge and skills can be applied to science disciplines within and outside of their field, and can impact society beyond the scientific community. Creating and implementing a personal vision will entail: (i) identification, investigation and evaluation of multiple career options; (ii) connecting to other sciences and to the broader society; (iii) developing skills required for an academic career, including teaching, mentoring, advising and participation in the academic community; and (iv) outreach to the non-academic community. Within this context, we envision four primary, positive outcomes of implementing a Career Perspective component of the proposed Ph.D. program.

First, this component highlights that completing the Ph.D. degree is a step in the process of building a career, rather than an end in itself. It requires students to investigate career options outside of as well as within academia beginning in their first semester in the program. Evaluating careers outside of academia is especially important in the Earth and Environmental Sciences, where there are diverse, intellectually challenging and well-paying employment opportunities. Encouraging students to identify and communicate with diverse Earth scientists (e.g., visiting speakers, professional colleagues) will help them develop their personal vision. In the long run, encouraging each student to find an optimal career niche for him/her will help build a cadre of EES Ph.D. alums who will serve as sources of information and inspiration for students, and ultimately as advocates for the Ph.D. program.

Second, a Career Perspective component of the EES Ph.D. program will help prepare students as researchers, in academia, the private sector, or in government. For any research project to be funded, the proposer must effectively communicate why the proposed work is important and how it fits into larger scientific, institutional and/or societal contexts. EES Ph.D. students will be practiced in answering these questions about significance and able to put their research into broad context because they will have been expected to do so throughout the course of their graduate studies.

Third, EES students will be prepared for careers in academia. All Ph.D. students will be expected to gain teaching experience in the classroom. The departmental culture is one where teaching is an intellectually challenging endeavor requiring knowledge, excellent communication skills, sensitivity and dedication. Moreover, because most college students have not had a high school course in Earth and environmental sciences, virtually none intend to major in Earth and environmental sciences when they enter Vanderbilt. Building student interest and curiosity about Earth is a major EES focus, and teaching assistants are vital partners with faculty in this endeavor. Faculty and Teaching Assistants discuss learning outcomes and how they can be achieved, they organize field trips, they jointly design evaluation rubrics, and they commonly work together to creatively resolve student issues that arise. Graduate students in EES take responsibility for organizing the Speakers Program under the guidance of a faculty member. Through this and other departmental activities, including teaching, students gain experience in working collaboratively, a skill essential for an academic career.

A fourth outcome of a Career Perspective component in the EES Ph.D. program will be a heightened awareness of social responsibility. When faculty and Teaching Assistants work together to build student interest using current Earth-events, they are drawn to question their personal responsibility to those affected. When EES receives queries from curious citizens about Earth phenomena, or when the press publishes misinformation on controversial issues, faculty and graduate students wrestle with defining the appropriate reaction/response as scientists. Through this process, and in pondering NSF-like questions
such as “What outreach activities have you undertaken?,” students develop a sense of their responsibility to society as scientists.

There is compelling evidence that a Career Perspective emphasis is needed within Ph.D. programs and would be attractive to potential students. First, NSF has recently required that proposals requesting funds for support of postdoctoral researchers include mentoring plans. The implications are that mentoring in Ph.D. programs currently may not be at a satisfactory level, and that mentoring may not occur unless it is specifically required. Second, the popularity of NSF-sponsored workshops on Preparing for a Career in the Geosciences underscores the need for a Career Perspective component. Of the ~130 applicants for the junior faculty position in EES in 2008, a majority listed participation in one of those workshops. The popularity of these NSF-sponsored workshops suggests that the Career Perspective component would be an additional factor drawing talented, forward-thinking students to the EES Ph.D. program.

3.1.6 Program Evaluation

In order to ensure the long-term success of the program we propose some measures of program success, and two methods of evaluating progress toward these benchmarks. Throughout the academic year we will collect data according to our Learning Outcomes Assessment Plan described in Appendix 8. For each committee meeting students will prepare a progress report. After meetings committees will compile a brief summary of progress toward student’s developing breadth and depth in EES based on:

- Completed coursework (contribution toward developing breadth and depth in EES):
- Performance in coursework (partially based on grades, but more on committee’s impression of overall quality of effort, engagement, and product)
- Value added (how much has the student “grown” as an Earth scientist?; how much has she/he learned, matured, gained independence, developed as researcher and critical thinker? - based on comparison of the above with performance on entrance exam
- Progress on thesis research (obviously expectations differ depending on semester in grad school and on whether enters with an idea of what she/he will work on; most important comparison is to where student was the semester before).

For each dissertation research proposal prepared for the qualifying exam committee members will evaluate:

- clarity of scientific writing: clarity, correctness, conciseness
- quality and appropriateness of illustration for enhancement of scientific communication
- appropriate use and citation of relevant scientific literature
- soundness of the research design
- appropriateness of proposed methods
- likelihood that objectives will be achieved and project will be completed in timely fashion

After each qualifying exam oral presentation and dissertation defense committee members will write a report that evaluates the following criteria:

- Has the importance of the research been made clear?
- Are the research questions clearly stated?
- Are collected data accurate and precise, and do they help to answer the research questions?
- Does the student understand assumptions implicit in the research and inherent uncertainties in data and interpretations?
- Are the results interpreted correctly?
- Are the conclusions consistent with the results?
Has the relevance of the results to the field of study been made clear?

The results of evaluations of written and oral exams will be shared with students so that they can use the constructive criticism to improve their communication skills. We will also regularly update a student database that will contain information on time to graduation, job placement, and publication statistics. These data will be analyzed and presented in our Annual Graduate Assessment report for the EES graduate program (Appendix 8). In addition to the Annual Graduate Assessment, each year we will have a department review of the annual Academic Analytics report. We will also be able to review annual VIRG reports for our program, which we currently cannot do because our Ph.D. students are lumped together with other CEE students (there is no EES report because only Ph.D. programs are reported).

Finally, we propose to create a committee of external reviewers who will visit the department every five years and conduct a thorough review of the success of our graduate program. Measures of success will include effectiveness of recruiting as measured by number of applicants, yield, and average GRE and GPA scores of applicants; annual number of Ph.D. graduates; average time to program completion; quality and quantity of publications for each Ph.D. student and faculty member; amount of grant support; and job placement for graduates.

3.2 Admissions

3.2.1 Targets

A case-by-case approach to reviewing student applications will be used, with the following target criteria as guidelines: Graduate Record Exam (GRE) — a combined target verbal and quantitative score of 1300 or better (315 on the new scoring scale) and a target analytical writing score of 5 or better; and Grade Point Average (GPA) — a target of 3.5 on a 4.0 scale. Other factors that will be critical in the application review include: the school(s) at which the applicant has completed prior undergraduate/graduate work; research experience while the applicant was a student or after graduation; the intellectual maturity of the applicant and any prior experience the applicant might have; and the match between the stated research interests of the student and those of the faculty.

For international students, the ability to communicate in English, both orally and in writing, is essential. The Vanderbilt Graduate School has minimum acceptable TOEFL scores for admission of 570 for the paper-based test and 88 for the Internet-based test. Communication skills of foreign applicants will be confirmed through personal verbal communication with the applicant (for example, through a telephone interview when a campus visit is not possible) prior to admission.

Based on currently matriculated graduate students and current and past graduate applicant pools, we draw top students with interests well matched with our core strengths in Earth-surface dynamics, crustal dynamics, and modern and ancient life processes. Our M.S. program typifies this diversity; however, students enrolled in the joint Ph.D. option in Environmental Science typically have interests that are complemented by the strengths of both EES and Environmental Engineering. For example, past and current Ph.D. students have engaged in projects where there is either a practical engineering application to their research or an aspect of their research benefits from an engineering perspective.

In contrast, a Ph.D. in Earth and Environmental Sciences will draw a broader group of students interested in working on research questions that fall wholly within the Earth and Environmental Sciences and/or interdisciplinary questions involving key aspects of disciplines such as biology, anthropology, chemistry,
physics, etc. — as well as questions that might involve aspects of engineering. Important examples include topics in paleobiology and paleoclimates, as well as topics in Earth-surface dynamics, sedimentary systems and crustal processes. Thus, we will target this broader group for the Ph.D. program — students with Earth and environmental sciences interests that are well matched with any and all EES faculty members, and which would benefit from ready access to expertise and courses from other programs on campus.

3.2.2 Timing

The number of students admitted to the Ph.D. program will depend on availability of funding, both internal and external. We anticipate that the number of new graduate students enrolling in the Ph.D. program may grow to more than five per year over a timescale of five years, as related research support and interest in the program grow.

As described in Section 2.4, a little more than half of our current graduate students are at the Ph.D. level, with a ratio of 2.7 students (M.S. and Ph.D.) per tenure-stream faculty. This is above the average ratio of 2.1 for a group of 21 comparison programs (including Brown, Dartmouth, Harvard, Penn, Princeton, Rensselaer, Rice) presented in Section 2.5. A target ratio of 2.5 is appropriate in transitioning to a Ph.D.-centric program, notably given the increased residence time of Ph.D. students relative to M.S. students, and the expectation of increased external funding per student — although the total cost per student per year will remain the same as with M.S. students. Also as described in Section 2.4, the average time to degree is two years for our M.S. students, and four years for our Ph.D. students (although this is a statistic of small numbers). Our target for completing the Ph.D. is four years for those students having an M.S. degree, and five years for those coming straight from a B.A. or B.S. degree. (The reported range of average time-to-degree is 4.4 to 6.3 years in the survey data presented in Section 2.5.) For a faculty size of eight, this represents a steady-state flux of 4.4 Ph.D. students per year (student-faculty ratio of 2.5, assuming half of the students start with M.S. degrees). For a faculty size of 10, this represents a steady-state flux of 5.6 students per year.

3.3 Relation to Other Programs

We reiterate that, in addition to involving intellectual opportunities and collaborations nationally and internationally, the three science focus areas listed in Section 1.1 — when combined with the focus on fostering excellence in education and communication — are tuned to opportunities involving several programs at Vanderbilt. Foremost, we envision this Ph.D. program in Earth and Environmental Sciences as both building on the successes of, and mutually complementing, the existing Environmental Science Ph.D. option in Environmental Engineering that has been jointly administered since 2005 by CEE and EES. We envision most of our future Ph.D. students enrolling in the new Earth and Environmental Sciences degree program. However, students will still have the option to enroll in the Environmental Science Ph.D. option in Environmental Engineering. Because the ES option is primarily administered by Environmental Engineering, there is little overhead for our department; its existence simply provides our students with another degree option, but it can also be an effective recruiting tool for students interested in both science and engineering. The new Ph.D. program in Earth and Environmental Sciences, through its overall impact on student recruiting as outlined in Section 1.2, will be to further increase the number and quality of applicants for EES.

Equally important, we reiterate that in the presence of a Ph.D. program in Earth and Environmental Sciences, the exposure of geoscience-focused students to the intellectual orientation of the Environmental Science option and the mindset of students in this degree option — and vice versa — will provide added
intellectual value to both programs. As outlined in the Section on Program Structure above, we plan to continue the TIES capstone course as an essential curricular element for those students in the Earth and Environmental Sciences Ph.D. as well as for those in the existing ES Ph.D. option. We see this course as having an important role in our efforts to challenge students to develop and exercise skills of communication across disciplines.

We note that several EES faculty and their students currently are collaborating with faculty, post-doctoral associates and students affiliated with other programs, notably the Vanderbilt Institute for Energy and Environment (VIEE), Anthropology, and the School of Law. As with the TIES course, these collaborations represent important opportunities for students to develop and exercise skills of communication across disciplines, and we anticipate that such collaborations will grow. We also note that students enrolled in the Ph.D. program will likely add modest numbers in certain courses offered by Physics and Astronomy, Chemistry, Biological Sciences, and Mathematics, as well as in Engineering, inasmuch as students are advised to pursue advanced topics in these fields as a result of the relative sophistication of Ph.D.-level research. Currently, for example, it is not uncommon for M.S. students in EES and Ph.D. students in the ES option to selectively take courses in upper-level or advanced calculus, statistics, mathematical probability, and chemistry; and by design students in the ES Ph.D. option supervised by EES faculty take courses in CEE.

The establishment of a Ph.D. program in Earth and Environmental Sciences will involve a transition in relation to the existing M.S. program in EES. Namely, we anticipate that a significant number of applications for graduate studies will continue to involve students who target Vanderbilt specifically because of the strong reputation of its M.S. program, many of whom are aimed, at least initially, at an M.S. degree. As we are currently doing, we plan to recruit the most talented of these students into the Ph.D. program. Until the external reputation of the Ph.D. program is fully established such that applicants are aiming at this program in the same way that students currently aim at the M.S. program, we would be remiss to not recruit talented students initially aimed at an M.S. degree. We also note that, based on our experience over the past five years, the numerous interactions amongst our M.S. and Ph.D students contribute to a positive graduate experience — intellectually and culturally — for both groups.

Thus, our intention is to maintain the M.S. program in EES. The M.S. program has been very successful as measured by the quality and quantity of applications, the graduation rate, the average time to degree completion, and the publication record and placement of our graduates. Furthermore, the M.S. degree is the preferred degree in geoscience industries, so most applications are for our M.S. program. We have found that the best model for identifying students most likely to succeed in the Ph.D. program is by having students first complete the M.S. program. Students who wish to continue into the Ph.D. program must apply, and by that time the faculty are very familiar with the students’ strengths and weaknesses and therefore can make a fully informed decision on whether to admit the applicant. Other students may choose to go into industry with a M.S. degree or apply to other Ph.D. programs. Because our department has had Ph.D. students since 2005, and roughly half of our graduate students are enrolled in the Environmental Science Ph.D. option, our department has already made the transition from a Masters-only to a combined M.S. + Ph.D. program.

The proposed Ph.D. program should not have a significant effect on programs in other departments in the College of Arts and Science. In the University outside of A&S the only program that will be affected is the Environmental Science option offered by the Department of Civil and Environmental Engineering.
While EES faculty plan to maintain our participation in this program, we expect that the number of EES students enrolled will decrease. However, we believe there will occasionally be EES students who would prefer to enroll in the the Environmental Science option, so as long as Civil and Environmental Engineering continues to offer this program we expect that EES faculty and students will participate.

4 Resources

4.1 Intellectual Foundation

As described in Section 2, the Department possesses a solid intellectual foundation for growing a healthy, thriving Ph.D. program in Earth and Environmental Sciences. To reiterate key points from Section 1.1, the three science focus areas build from our existing strengths. Moreover, these areas balance our current and anticipated faculty size with an appropriate breadth of coverage of Earth and Environmental Sciences topics. These focus areas therein: (i) provide an intellectual core that will allow us to continue to individually and collectively excel in our research and teaching missions, competing at the highest levels with other outstanding programs nationally; (ii) ensure ample breadth for a Ph.D. curriculum from which our students will gain both essential depth in their studies, and exposure to ideas and skills that facilitate communication across disciplines; (iii) serve as an important part of our blueprint for program development, including our targeting of specialties of future faculty hires; and (iv) serve as a clear identity to students considering options for graduate studies. In addition, by design the Ph.D. program will involve a distinguishing, overarching focus on excellence in education and communication in which students fully engage in cultivating skills needed to: (i) excel as science educators while distinguishing themselves as young researchers; and (ii) excel in communicating across disciplines, whether involving collaborative research, teaching, or communication of science to non-experts.

Moreover, in addition to recruiting individuals — students and faculty — who are likely to excel within our program, our attention to the potential for intellectual engagement is particularly important, as this is part of an explicit strategy to artificially grow the (intellectual) size of our program. Using our current faculty as an example, each of us collaborates with at least one other faculty member in the department, and several of us collaborate with faculty in other departments. This involves Co-PI research projects, student thesis projects wherein two or more faculty members are actively helping in the design and implementation of the project, or similar collaborations involving unfunded, exploratory projects. In addition, we have a departmental culture that aims to involve our students (both graduate and undergraduate) in work with our collaborators around the nation and internationally, sometimes involving student travel to the labs and field sites of these colleagues as well as visits by these colleagues to Vanderbilt. These collaborations, within and outside the department, thus have the form of faculty-student working groups that naturally evolve over time. In effect, this is our version of achieving “critical mass” in certain areas; and it has the benefit of teaching, by example, desirable (collaborative) research habits and skills.

We also reiterate that the three science focus areas are purposefully thematic rather than disciplinary, yet are centrally keyed to Earth’s solid interior, its surface and atmospheric environments, and life processes (Figure 1). Indeed, the structure of this Venn diagram illustrates how we view the interconnectedness of our specialty areas in covering essential Earth “spheres,” while serving as a guide in our thinking about programmatic issues, from the recruiting of new faculty, to the design and revision of courses and curriculum, to our mentoring of students at all levels. From this foundation the Ph.D. program will gain identity in its emphasis on bringing disciplinary expertise to bear on particularly compelling problems in
the Earth and Environmental Sciences. And, with our explicit focus on excellence in education and communication, our graduating Ph.D. students will be well prepared to succeed in academics as well as other sectors.

4.2 Staffing

The EES staff consists of an Administrative Assistant II (Jewell Beasley-Stanley), an Office Assistant III (Teri Pugh), and a Lab manager (Aaron Covey).

Beasley-Stanley has administrative oversight of departmental affairs and is primarily responsible for fiscal matters including the departmental budget, staff and student appointments, grants and contracts, purchasing, and reimbursement. Pugh is primarily responsible for administration involving student affairs, faculty and student travel, scheduling, purchasing, and day-to-day office operation. The office staff are cross-trained in certain areas (e.g. purchasing, reimbursement and travel), and both staff members contribute to the organization of recurring departmental activities (e.g. hosting visitors, orientation, commencement activities, etc.)

Covey’s responsibilities include: (i) management, maintenance and administration of EES computational equipment and facilities including software support, and administration and maintenance of the EES server and webpages; (ii) oversight, maintenance and operation of EES laboratory, analytical and field equipment and instruments (including instructional), and fabrication of research and instructional equipment; (iii) oversight and administration of EES safety protocols and procedures pertaining to research and instructional labs, including management of hazardous materials; (iv) oversight and management of EES inventory, and organization and minor repair of equipment; and (v) providing technical and physical assistance to EES faculty and students pertaining to ongoing research projects and instructional activities, including instrument operation.

The day-to-day demands on our administrative and technical staff have grown exponentially during the past seven years. This was partly addressed when T. Pugh went to full-time status six years ago. Of continuing, pressing concern is our technical staff. Four years ago a discussion between EES and the College was initiated concerning the idea of growing our technical staff to two positions, with appropriate division of the responsibilities listed above, and plans to move forward with this ensued. This process should be restarted as soon as possible. In spring 2014 we also submitted a request to hire a third full-time administrative assistant, as the workload for Beasley-Stanley and Pugh has become unmanageable. Our needs for technical staff expertise and assistance will unquestionably grow further with a Ph.D. program in place, expanded analytical facilities, and more grant funding.

The number of faculty in EES is sufficient to meet the needs of our undergraduate and graduate students. Usually faculty members teach one 100-level, one 200-level, and one 300-level course per year, although this is not a strict rule. As the number of department faculty has increased some faculty have started offering only 200 and 300-level courses. Courses required for the undergraduate major and minor will be offered on the same schedule they have always been offered. Growth in the number of 200 and 300-level courses gives those students more choices for electives.

4.3 Infrastructure

The Department is housed in three buildings within the Stevenson Center (SC) complex on the Vanderbilt campus. The principal area occupied by the Department, including the main departmental office, is in two wings of the seventh floor of SC Buildings 5 and 6. The Department also occupies classroom and
laboratory space in the first floor of SC Building 1. The numbers in parentheses below denote square footage. A more detailed listing of space, square footage and equipment is provided in Appendix 7. The department went through three phases of renovation between 2005 and 2010, so laboratories and offices are in excellent condition. However, our current space is fully utilized, so any program growth must be coupled with growth in building space.

**SC Buildings 5 and 6.** The area in these buildings occupied by EES currently includes the departmental office complex (1,302), offices for faculty and staff (2,324), including faculty emeriti, and office space for graduate students (1,661). There are two classrooms (1,421) with specialized equipment and materials dedicated to majors courses, one classroom (592) used for numerous courses and department seminars, and one room (588) that doubles as a classroom and as a departmental conference room. Research space includes a General Purpose Research Lab (1,344), a Polishing and Mount Preparation room (360), the Clean Separation Lab (193), the Tomography Lab (170), a student Computer Lab (220), the Experimental Petrology Lab (608), a Clean Lab (437), a Sedimentology Lab (297), Sample Storage and General Research (434) and Field Equipment Storage (186). Four fume hoods are located in three of the labs.

**SC Building 1.** The area in this building occupied by EES includes two teaching laboratories, one dedicated to our Dynamic Earth laboratory classes (1,000), one dedicated to our Oceanography laboratory classes (955), and an office (107) for “on-duty” Teaching Assistants assigned to these laboratory classes. Research space includes the Fluids Lab (605), the Rock Preparation room (113), the Mineral Separation room (68), the Rock Saw room (160), a General Chemistry Lab (299), the Sedimentology Lab (353), and an SEM lab (113). One fume hood, designed for HF, is located in the General Chemistry Lab.

In addition to standard equipment used in research and teaching laboratories, the department features an SEM, Gamma Ray Spectroscopy facilities, specialized teeth microwave measurement equipment, a high pressure-temperature apparatus, a Malvern particle-size analyzer, and a Geo-tek core logger. EES has access to a Laser-ablation ICP-MS through Engineering (see Appendix 7 for a complete list of research facilities), but will be purchasing its own Laser-ablation ICP-MS in spring 2013.

Moreover, the Department manages a server with storage space for faculty and student projects; student desktop computers; general use computers, including work stations with specialized software accessible to all departmental members; work stations dedicated to specialized computational work; black-and-white and color printers; and a large-format plotter.

In the short term the addition of this Ph.D. program should not significantly affect the demand by EES faculty and students on University resources such as the libraries and computing. The total number of graduate students in our program will likely grow only modestly. This is because increases in the number of EES faculty are likely to be modest, and given the current funding climate the number of grant dollars to support graduate students is unlikely to dramatically increase. These expected modest increases in the numbers of faculty and graduate students will, however, require modest increases in the amount of physical space occupied by EES.

Overall, our facilities have been sufficient to meet the research needs of our M.S. and Ph.D. students. As our funding levels have grown, so has our investment in research facilities, many of which are new. However, instituting a new PhD program with greater numbers of PhD students than we currently have will require an expansion of research labs and facilities.
4.4 Funding

EES currently has 11 Teaching Assistantships funded by the College of Arts and Science. These Assistantships are critical for coverage of teaching associated with laboratory courses as well as assistance with recitations and grading in certain non-lab courses. As a science that fundamentally combines field-based and experimental/laboratory components, EES has a relatively large number of courses, notably introductory and majors courses, that have laboratory sections, and thus a relatively large TA demand for the department size. These Assistantships also are an important ingredient of support for Ph.D. students in relation to our objective of having them engage in cultivating skills needed to excel as science educators and communicators. Our current curriculum is such that there is a high demand for all Teaching Assistants. Indeed, we often employ particularly talented undergraduate seniors to help with introductory courses (rather than reassigning graduate students supported on Research Assistantships). As we have articulated in previous documents and in discussions regarding our graduate program and curricular needs, we continue to anticipate the need to increase the number of Teaching Assistantships with the addition of new courses and the addition of laboratory/recitation components to existing courses. This will become increasingly critical with growth to a size of 10 tenure-stream faculty.

The vision and timing of the Ph.D. program proposed herein are well aligned with research and educational priorities of the National Science Foundation (NSF) and other national agencies such as the National Oceanic and Atmospheric Administration. Currently there are numerous core programs and focused initiatives at NSF that represent viable opportunities for funding. Among these are several core programs within the Earth Sciences (EAR) organization, including Petrology and Geochemistry, Sedimentary Geology and Paleobiology, Geobiology and Low-Temperature Geochemistry, Geomorphology and Land Use Dynamics, Hydrologic Sciences, and EAR Education and Human Resources. In addition, key recent Special Programs include Integrated Earth Systems, Critical Zone Observatories, Paleo Perspectives on Climate Change, Emerging Topics in Biogeochemical Cycles, Frontiers in Earth System Dynamics, and Partnerships for International Research and Education. The expanding role of environmental sciences in our department positions our department well for securing external funding, as most recent growth in federal research funding for the Geosciences has been in environmental sciences (Figure 5).
In addition, several other national activities are notable in that they embody growing efforts to blend components of Earth and environmental sciences, and present a view of where NSF and other agencies are likely to invest in the future. These include, for example, the National Center for Earth-surface Dynamics (NCED), the National Center for Airborne Laser Mapping (NCALM), and the Community Sediment Dynamics Modeling System (CSDMS). On this point, we note that the establishment of the Geomorphology and Land Use Dynamics program as a permanent part of the EAR Directorate at NSF is a relatively new development.

We anticipate that the bulk of external funding to support EES research projects and graduate students will come from NSF — as is currently the case — with additional funding from the National Oceanic and Atmospheric Administration (NOAA), the Environmental Protection Agency (EPA), the Department of Energy (DOE) and the Office of Naval Research (ONR). As well, there may be merit in recruiting self-funded, organizationally sponsored candidates from National Laboratories. As mentioned in Section 2.4, approximately 40% of our students are supported by external funding at any one time, and we anticipate that this percentage will steadily increase over the next several years.

Given the uncertainty of future external funding, EES faculty have begun to diversify their funding sources. We are working with Julie Koh in Foundation Relations to identify Foundations that might fund our research programs. Calvin Miller was recently awarded a grant by the National Geographic Society (Appendix 2). David Furbish and John Ayers have met with Julie Koh to discuss applying to the Gordon and Betty Moore Foundation, and George Hornberger, Steve Goodbred and John Ayers are planning to apply to the Camille and Henry Dreyfus Foundation Postdoctoral Program in Environmental Chemistry. We expect that our faculty will maintain a steady flow of external grant funding in the future.
Appendix 1: Selected Faculty Activities

Editorships

*GSA Today*, Geological Society of America (M. Miller, Co-Editor with S. Kay, K. Karlstrom, 1998-2001)

*Journal of Applied Meteorology and Climatology*, American Meteorological Society (Bennartz, 2006-10)

*Sedimentary Record*, SEPM Society for Sedimentary Geology (M. Miller, S. Goodbred, D. Furbish, Co-Editors, 2006-09)

Guest Editorships

*Chemical Geology*, Special Issue: Geochemistry of Accessory Minerals, 110(1-3) (C. Miller, with E. B. Watson, T. M. Harrison and F. J. Ryerson, 1993)

*Elements*, Special Issue: Supervolcanoes, 4(1) (C. Miller, with D. A. Wark, 2008)

*Geomorphology*, Special Issue: Predicting Process from Form, 12(3) (Furbish, with P. Whiting, 1995)

*Geosphere*, Themed Issue: Advances in 3D Imaging and Analysis of Geomaterials, published beginning October 2010 (Gualda, with D. R. Baker and M. Polacci)

*Journal of Paleontology*, Special Issue: Trace Fossils and Paleoenvironments, Marine carbonate, Marginal Marine Terrigenous and Continental Settings, 58(2) year? (M. Miller, with A. A. Ekdale and M. D. Picard)

*Journal of Volcanology and Geothermal Research*, Special Issue: Large Silicic Magma Systems, 167(1-4) (C. Miller, with S. DeSilva, O. Bachmann, and K. Knesel, 2008)

*Sedimentary Geology*, Special Issue: Climate Impacts on Sedimentary Systems, 162(1-2) (Goodbred, with S. Kuehl, 2003)

Associate Editorships

*American Mineralogist* (Ayers, 2001-06)

*Geochemical Transactions of the American Chemical Society* (Ayers, 2006-2011)


*Geology*, Geological Society of America (Furbish, 1998-00)

*Journal of Applied Meteorology and Climatology*, American Meteorological Society (Bennartz, 2004-5)

*Journal of Geophysical Research – Earth Surface*, American Geophysical Union (Furbish, 2002-04)

*Journal of Geophysical Research – Solid Earth*, American Geophysical Union (C. Miller, 1995-98)


*Theoretical and Computational Fluid Dynamics* (Furbish, 2001-03)

NSF Review Panels and Committees

Advisory Committee for the Geosciences Directorate, NSF (Hornberger, 2011-present)

ANDRILL, Antarctic Geology and Geophysics, Division of Antarctic Sciences, Office of Polar Programs (M. Miller, 2003)

Antarctic Earth Sciences Panel (M. Miller, 2012)

Antarctic Geology and Geophysics, Division of Antarctic Sciences, Office of Polar Programs (M. Miller, 1999-2000)

Antarctic Sciences Committee of Visitors, Office of Polar Programs (M. Miller, 2003)

Antarctic Infrastructure and Logistics Committee of Visitors, Office of Polar Programs (M. Miller, 2009)

Arctic Natural Sciences, Office of Polar Programs (Furbish, 2010)
Chair, Committee of Visitors for the Surface Earth Processes Section (Hornberger, 2011)
Collaborations in Mathematical Geosciences, Mathematics and Physical Sciences Directorate (Furbish, 2002-2004)
Frontiers of Earth System Dynamics (Hornberger, 2010)
Geology and Paleontology Committee of Visitors, Division of Earth Sciences, Geosciences Directorate (M. Miller, 1996)
Geomorphology and Land-Use Dynamics, Geosciences Directorate (Furbish, 2006-07)
Joint Antarctic Glaciology and Geology/Geophysics, Division of Antarctic Sciences, Office of Polar Programs (M. Miller, 1999-2000)
Marine Geology and Geophysics, Ocean Sciences Division, Geosciences Directorate (Goodbred, 2002)
MARGINS, Ocean Sciences Division, Geosciences Directorate (Goodbred, 2006-08)
Mathematical Sciences Priority Area – New Mathematical and Statistical Tolls for Understanding Complex Systems in the Environment, Mathematics and Physical Sciences (Furbish, 2004)
National Young Investigators, Division of Earth Sciences, Geosciences Directorate (M. Miller, 1992)
Petroleum and Geochemistry, Geosciences Directorate (C. Miller, 2007-09)
Partnerships for International Research and Education, Science, Education and Engineering for Sustainability (Ayers, 2012)
Science and Technology Centers (Hornberger, 2011)
STEM Fellows in K-12 Education, Division of Graduate Education (DeSantis, 2010)
Tectonics, Geophysics, and Continental Dynamics Committee of Visitors, Division of Earth Sciences, Geosciences Directorate (M. Miller, 1995)

Other Review Panels
Intergovernmental Panel on Climate Change (IPCC) Expert Reviewer, Working Group 1, Fifth Assessment (Bennartz, 2012)
National Oceanographic and Atmospheric Administration, CREST: Coastal Restoration and Enhancement through Science and Technology (Goodbred, 2008-2009)
National Research Council of the National Academies: Hornberger has been on numerous committees, including serving as chair of the Committee on Opportunities and Challenges in Hydrologic Sciences (2010-2012) and the Committee to Review the NSF “WATERS” Plan (2007-2010)

Advisory Committees
Advisory Board for the School of Earth Sciences, Stanford (Hornberger, 2004-present)
Board of Directors, Consortium of Universities for the Advancement of Hydrological Sciences, Inc. (Furbish, 2001-02)
Board of Scientific Counselors, Office of Research and Development, U.S. Environmental Protection Agency: Review subcommittee on the National Center for Environmental Research (NERC) (Goodbred, 2002)
Chair, Government Affairs Program Advisory Committee, American Geological Institute (Hornberger, 2011-present)
Committee on Research Grants, Geological Society of America (M. Miller, 1991-93)
Consortium of Universities for the Advancement of Hydrologic Science Senior Advisory Committee (Hornberger, 2008-present)
External Advisory Board, National Center for Earth-surface Dynamics (Furbish, 2003-06, Chair, 2006-07)
External Advisory Committee, University of Texas Computed Tomography Laboratory (Gualda, 2012)
Lecture Program Committee, Mineralogical Society of America (Ayers, 2002-2006)
Moore Medal Selection Committee, Society of Sedimentary Geology (SEPM), (M. Miller, 1984, 2005-07; Chair 1985-87)
Pettijohn Medal Selection Committee, Society of Sedimentary Geology (SEPM), (M. Miller, 1998-2000)
Science Advisory Committee for the Geochemical Database Group and for the Vertebrates Database Group, NEOTOMA, on-line database (DeSantis, 2010-present)
Steering Committee, Community Surface Dynamics Modeling System (Furbish, 2007-present)
Steering Committee, NSF Critical Zone Observatory Network (Furbish, 2008-09, Chair, 2010)
Union Medals Committee, American Geophysical Union (Ayers, 2004-2006)

Elected Offices in Professional Organizations
Society of Sedimentary Geology (SEPM), Paleontology Councilor (M. Miller, 1985-1987)
Geological Society of America, Southeastern Section Chair (M. Miller, 1993-1994)

Department Program Reviews
Department of Earth Sciences undergraduate program, University of Southern California (M. Miller, 2011)
Department of Environmental Sciences, University of Virginia (Furbish, 2009)
Department of Geology, Bryn Mawr College (M. Miller, 2003)
Department of Geology and Geography, Mt. Holyoke College (M. Miller, 1997)
Department of Geology, College of William and Mary (M. Miller, 1990)
Department of Geology, Smith College (M. Miller, 1989)
Department of Geology, SUNY Buffalo (Hornberger, 2010)
Department of Geological Sciences, University of Delaware (Furbish, 2005)
Department of Geology and Geophysics, Boston College (Furbish, 2010)
Department of Geosciences, University of Massachusetts (C. Miller, 2005)
Department of Geosciences, Hamilton College (M. Miller, 2012)
### Appendix 2: External Federal Grants to EES faculty in Active Status during 2005-2013

<table>
<thead>
<tr>
<th>Sponsor Name</th>
<th>Sponsor Number</th>
<th>BudYrStart</th>
<th>BudYrEnd</th>
<th>Project Title</th>
<th>Dept.</th>
<th>Name</th>
<th>Award Amt.</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSF</td>
<td>EAR-0126020</td>
<td>01-Jan-02</td>
<td>31-Dec-05</td>
<td>Monazite as a Sensitive Indicator of the Timing and Type of Fluid Activity During Metamorphism</td>
<td>AS/EES</td>
<td>Ayers, J. and C. Miller</td>
<td>195,459</td>
</tr>
<tr>
<td>NSF</td>
<td>OPP-0126146</td>
<td>01-Jun-02</td>
<td>31-May-06</td>
<td>Collaborative Research: Late Paleozoic-Mesozoic Fauna, Environment, Climate and Basinal History: Beardmore Glacier Area, Transantarctic Mountains</td>
<td>AS/EES</td>
<td>Miller, M.</td>
<td>102,984</td>
</tr>
<tr>
<td>NSF</td>
<td>EAR-0125843</td>
<td>08-Aug-03</td>
<td>31-Jan-08</td>
<td>Diffusive Soil Transport and Hillslope Evolution</td>
<td>AS/EES</td>
<td>Furbish, D.</td>
<td>174,652</td>
</tr>
<tr>
<td>NSF</td>
<td>EAR-0409876</td>
<td>01-Jul-04</td>
<td>30-Jun-09</td>
<td>Collaborative Research: Elucidating Physical Processes in Upper Crustal Magma Systems</td>
<td>AS/EES</td>
<td>Miller, C. and D. Furbish</td>
<td>190,693</td>
</tr>
<tr>
<td>E.P.A.</td>
<td>GR83221201</td>
<td>01-Oct-04</td>
<td>28-Feb-06</td>
<td>Sequestration of Subsurface Elemental Mercury (Hg)</td>
<td>AS/EES</td>
<td>Savage, K.</td>
<td>81,654</td>
</tr>
<tr>
<td>NSF</td>
<td>ANT-0440954</td>
<td>01-Jul-05</td>
<td>30-Jun-10</td>
<td>Collaborative Research: Reconstructing the High Latitude Permian-Triassic: Life, Landscapes, and Climate Recorded in the Allan Hills, Antarctica</td>
<td>AS/EES</td>
<td>Miller, M.</td>
<td>112,254</td>
</tr>
<tr>
<td>NSF</td>
<td>EAR-0630220</td>
<td>31-Jul-05</td>
<td>31-Jan-08</td>
<td>Vertical Control of Groundwater Arsenic Concentrations</td>
<td>AS/EES</td>
<td>Goodbred, S.</td>
<td>31,273</td>
</tr>
<tr>
<td>D.O.C.</td>
<td>NA05NOS4781181</td>
<td>01-Aug-05</td>
<td>31-Jul-09</td>
<td>Ecological Effects of Sea Level Rise on Coastal North Carolina Marshes</td>
<td>AS/EES</td>
<td>Furbish, D.</td>
<td>195,021</td>
</tr>
<tr>
<td>NSF</td>
<td>n/a</td>
<td>01-Jun-06</td>
<td>31-May-09</td>
<td>Core Characterization: Connecting Modern Benthic Associations and Habitats to the Stratigraphic Record</td>
<td>AS/EES</td>
<td>Miller, M.</td>
<td>3,000</td>
</tr>
<tr>
<td>NSF</td>
<td>OCE-0630595</td>
<td>15-Sep-06</td>
<td>31-Dec-09</td>
<td>CAREER: Sediment Dynamics on the Bengal Shelf of the Ganges-Brahmaputra Floodpulse</td>
<td>AS/EES</td>
<td>Goodbred, S.</td>
<td>465,895</td>
</tr>
<tr>
<td>D.O.D</td>
<td>07ENG202900VU</td>
<td>01-Jan-07</td>
<td>31-Dec-08</td>
<td>In-vivo Testing of the Effects of Soil Properties on Decreasing Toxic Metal Bioavailability</td>
<td>AS/EES</td>
<td>Savage, K.</td>
<td>41,867</td>
</tr>
<tr>
<td>NSF</td>
<td>EAR-0617396</td>
<td>01-Jan-07</td>
<td>30-Apr-10</td>
<td>Characterization of Defect Energy Levels Due to As, Co, and Ni Impurities in Pyrite</td>
<td>AS/EES</td>
<td>Savage, K.</td>
<td>79,089</td>
</tr>
<tr>
<td>NSF</td>
<td>EAR-0510092</td>
<td>01-Jun-05</td>
<td>01-Jun-09</td>
<td>Zr-mineral Aqueous Solubilities and Zircon (fluid-melt) Partitioning</td>
<td>AS/EES</td>
<td>Ayers, J.</td>
<td>285,000</td>
</tr>
<tr>
<td>D.O.E.</td>
<td>Project ID</td>
<td>Start Date</td>
<td>End Date</td>
<td>Title</td>
<td>Agency</td>
<td>Investigator(s)</td>
<td>Amount</td>
</tr>
<tr>
<td>--------</td>
<td>------------------</td>
<td>------------</td>
<td>----------</td>
<td>----------------------------------------------------------------------</td>
<td>--------</td>
<td>--------------------------------------------------------</td>
<td>----------</td>
</tr>
<tr>
<td></td>
<td>4000068798</td>
<td>15-Apr-08</td>
<td>30-Sep-08</td>
<td>The Effect of Soil Properties on Decreasing Toxic Metal Bioavailability: Field Scale Validation to Support Regulatory Acceptance</td>
<td>AS/EES</td>
<td>Savage, K.</td>
<td>19,996</td>
</tr>
<tr>
<td>NSF</td>
<td>EAR-0744934</td>
<td>01-Jul-08</td>
<td>30-Jun-11</td>
<td>Soil-grain transport and dispersal by rainsplash, with implications for plant-soil interactions in deserts</td>
<td>AS/EES</td>
<td>Furbish, D.</td>
<td>182,706</td>
</tr>
<tr>
<td>NSF</td>
<td>EAR-0711109</td>
<td>01-Aug-07</td>
<td>31-Jul-10</td>
<td>Volcano-Pluton Connections: The Record in Crystal Populations of Rhyolites and Granites of the Colorado River Extensional Corridor, Nevada</td>
<td>AS/EES</td>
<td>Gualda, G.</td>
<td>68,602</td>
</tr>
<tr>
<td>NSF</td>
<td>ANT-0739496</td>
<td>01-Sep-08</td>
<td>31-Aug-13</td>
<td>Collaborative Research: Linking Modern Benthic Communities and Taphonomic Processes to the Stratigraphic Record of Antarctic Cores</td>
<td>AS/EES</td>
<td>Miller, M. and D. Furbish</td>
<td>115,529</td>
</tr>
<tr>
<td>NSF</td>
<td>EAR-0635922</td>
<td>01-Jan-07</td>
<td>31-Dec-10</td>
<td>Volcanic-Plutonic Evolution Evaluated Using Zircon Growth Histories at Mt. St. Helens Volcano</td>
<td>AS/EES</td>
<td>Miller, C.</td>
<td>189,635</td>
</tr>
<tr>
<td>NSF</td>
<td>EAR-0838391</td>
<td>01-Jun-09</td>
<td>31-May-12</td>
<td>Laboratory Measurements of Trace Element Partition Coefficients Between Zircon, Aqueous Fluid and Silicate Melt at High and Ultrahigh Pressures</td>
<td>AS/EES</td>
<td>Ayers, J.</td>
<td>261,031</td>
</tr>
<tr>
<td>DOE</td>
<td>DE-FRC01-06EW07053</td>
<td>04-Apr-10</td>
<td>18-Sep-11</td>
<td>Assessment of the River Mechanics and Riparian Conditions Influencing Erosion and Sedimentation Associate With Locke Island, Washington</td>
<td>ENGR</td>
<td>Furbish, D. and G. Hornberger</td>
<td>292,494</td>
</tr>
<tr>
<td>NSF</td>
<td>OISE-0968354</td>
<td>01-Sept-10</td>
<td>31-Aug-15</td>
<td>PIRE: Life on a Tectonically Active Delta – Convergence of Earth-Science and Geohazard Research in Bangladesh with Education and Capacity Building</td>
<td>AS/EES</td>
<td>Goodbred, S.</td>
<td>1,144,471</td>
</tr>
<tr>
<td>NSF</td>
<td>EAR-1151337</td>
<td>15-May-12</td>
<td>30-Apr-15</td>
<td>CAREER: The longevity and evolution of giant magma bodies: A textural study of selected supereruption deposits formed in different tectonic environments worldwide</td>
<td>AS/EES</td>
<td>Gualda, G.</td>
<td>$314,584</td>
</tr>
<tr>
<td>Agency</td>
<td>Award#</td>
<td>Start</td>
<td>End</td>
<td>Title</td>
<td>Division</td>
<td>PI</td>
<td>Amount</td>
</tr>
<tr>
<td>--------</td>
<td>--------</td>
<td>-------</td>
<td>-----</td>
<td>----------------------------------------------------------------------</td>
<td>----------</td>
<td>----</td>
<td>--------</td>
</tr>
<tr>
<td>NSF</td>
<td>EAR-1053839</td>
<td>01-Jun-12</td>
<td>31-May-15</td>
<td>Early Career: Acquisition of a White Light Confocal Microscope for Dental Microwear Texture Analysis of Ancient Mammalian Communities</td>
<td>AS/EES</td>
<td>DeSantis, L.</td>
<td>$270,218</td>
</tr>
<tr>
<td>NSF</td>
<td>EAR-1226076</td>
<td>01-Sept-12</td>
<td>31-Aug-16</td>
<td>Collaborative Research: The statistical mechanics of bed load sediment transport: Meshing theory, experiments &amp; advanced computations of coupled fluid-particle behavior</td>
<td>AS/EES</td>
<td>Furbish, D.</td>
<td>$207,413</td>
</tr>
<tr>
<td>NSF</td>
<td>AGS-1203701</td>
<td>01-Sept-12</td>
<td>31-Aug-14</td>
<td>Precipitation Variability in California from 70 to 8 ka: Using High Resolution, Multi-proxy Speleothem Records to Understand Past Climate</td>
<td>AS/EES</td>
<td>Oster, J.</td>
<td>$166,466</td>
</tr>
<tr>
<td>National Geographic</td>
<td>VU-DSR # 22830</td>
<td>25-July-12</td>
<td>24-July-13</td>
<td>Memories of Ancient Continents, Foreshadowing a New Continent: Zircon and the Icelandic Crust</td>
<td>AS/EES</td>
<td>Miller, C.</td>
<td>$20,360</td>
</tr>
<tr>
<td>NSF</td>
<td>EAR-1263310</td>
<td>15 Sept 13</td>
<td>14 Sept 17</td>
<td>REU site (Collaborative): Before and after a supereruption: Magmatic insights from the southern Black Mountains, AZ</td>
<td>AS/EES</td>
<td>Claiborne, Miller, C.</td>
<td>$297,164</td>
</tr>
<tr>
<td>NSF</td>
<td>PLR-1355654</td>
<td>01-July-13</td>
<td>30-Sept-16</td>
<td>Collaborative Research: Characterizing the Roles of Atmospheric Structure and Clouds on the Radiation and Precipitation Budgets at Summit, Greenland</td>
<td>AS/EES</td>
<td>Bennartz, R.</td>
<td>$279,093</td>
</tr>
</tbody>
</table>

**TOTAL** $18,896,917

*Note: totals include only the Vanderbilt portion of collaborative grants.*
## Appendix 3: Internal Grants in Active Status During 2005-2012

### Discovery Grants

<table>
<thead>
<tr>
<th>Grant ID</th>
<th>Project Title</th>
<th>Investigator</th>
<th>Start Date</th>
<th>End Date</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-48-999-9062</td>
<td>Synthesis and Characterization of Arsenian Pyrite: Preparation for Oxidation Rate Studies</td>
<td>Savage, K.</td>
<td>5/1/2003</td>
<td>2/1/2007</td>
<td>$48,000.00</td>
</tr>
<tr>
<td>4-48-999-9169</td>
<td>Establishing Direct Links Between Climate, Environmental Change, and Cultural Transformations in Early Peruvian Civilization</td>
<td>Goodbred, S.</td>
<td>5/10/2010</td>
<td>6/30/2012</td>
<td>$92,500.00</td>
</tr>
<tr>
<td>4-49-999-9213</td>
<td>Cathodoluminescence (CL) Detector and Spectrometer for Earth, Environmental and Materials Research</td>
<td>Gualda, G.</td>
<td>5/6/2011</td>
<td>6/30/2013</td>
<td>$171,399.00</td>
</tr>
<tr>
<td>4-20-999-1081</td>
<td>Clarifying the effects of climate change on Australian marsupials</td>
<td>DeSantis, L.</td>
<td>5/11/2012</td>
<td>6/30/2014</td>
<td>$49,010.00</td>
</tr>
<tr>
<td>4-20-999-1082</td>
<td>The longevity and Evolution of Giant Magma Bodies: A textural study of supereruption deposits in the Taupo Volcanic Zone, New Zealand</td>
<td>Gualda, G.</td>
<td>5/11/2012</td>
<td>6/30/2014</td>
<td>$45,000.00</td>
</tr>
<tr>
<td>?</td>
<td>High-resolution Uranium Isotope Records from Speleothems: Calibrating a Quantitative Paleo-rainfall Proxy</td>
<td>Oster, J.</td>
<td>5/11/2014</td>
<td>6/30/2016</td>
<td>$44,000.00 (requested)</td>
</tr>
</tbody>
</table>

### Venture Fund Grants

<table>
<thead>
<tr>
<th>Grant ID</th>
<th>Project Title</th>
<th>Investigator</th>
<th>Start Date</th>
<th>End Date</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-20-999-0256</td>
<td>Geology Field Seminar</td>
<td>Savage, K.</td>
<td>1/18/2002</td>
<td>12/31/2007</td>
<td>$4,700.00</td>
</tr>
<tr>
<td>4-20-999-0528</td>
<td>Geology of National Parks</td>
<td>Bream, B.</td>
<td>1/4/2006</td>
<td>6/30/2007</td>
<td>$2,500.00</td>
</tr>
<tr>
<td>4-20-999-0531</td>
<td>Volcanoes: Impact on Earth &amp; Humans</td>
<td>Miller, C.</td>
<td>1/4/2006</td>
<td>6/30/2011</td>
<td>$5,000.00</td>
</tr>
<tr>
<td>4-20-999-0714</td>
<td>Art and Earth</td>
<td>Savage, K.</td>
<td>5/12/2008</td>
<td>12/31/2009</td>
<td>$500.00</td>
</tr>
</tbody>
</table>
**VIO Grants**

<table>
<thead>
<tr>
<th>Grant Code</th>
<th>Description</th>
<th>PI</th>
<th>Start Date</th>
<th>End Date</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-20-999-1068</td>
<td>Collaborative Research: Clarifying the effects of climate, habitat modification, and community compositions on Australian macropodid marsupials</td>
<td>DeSantis, L.</td>
<td>6/1/2012</td>
<td>5/31/2013</td>
<td>$4,500.00</td>
</tr>
<tr>
<td>4-20-999-1069</td>
<td>Evolution of Giant Magma Bodies</td>
<td>Gualda, G.</td>
<td>5/1/2012</td>
<td>4/30/2013</td>
<td>$4,500.00</td>
</tr>
<tr>
<td>?</td>
<td>Cave deposits as recorders of past seismic activity, Shillong Plateau, India</td>
<td>Oster, J.</td>
<td>11/1/2012</td>
<td>12/31/2014</td>
<td>$8,000.00</td>
</tr>
</tbody>
</table>

**Grants for courses**

<table>
<thead>
<tr>
<th>Grant Code</th>
<th>Description</th>
<th>PI</th>
<th>Start Date</th>
<th>End Date</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-49-999-9002</td>
<td>Trans-Disciplinary Initiative on Environmental Systems (TIES)</td>
<td>Miller, C.</td>
<td>2/1/2006</td>
<td>6/30/2009</td>
<td>$273,400.00</td>
</tr>
<tr>
<td>4-20-999-1040</td>
<td>American Studies AMST300</td>
<td>Ayers, J. &amp; Dana Nelson</td>
<td>7/1/2011</td>
<td>6/30/2012</td>
<td>$3,000.00</td>
</tr>
</tbody>
</table>

**TOTAL** $707,459.00
Appendix 4: EES Graduate Students During the Past 12 Years

**M.S. Students**

(Supervised by EES faculty in Earth and Environmental Sciences and Environmental Science Option of Environmental Engineering)

2001  **Mary B. Cheversia**, Documenting open system growth of feldspars by in-situ Pb isotope analysis: Aztec Wash and Mt. Perkins plutons, NV-AZ, supervising professor: C. F. Miller  
**Nicholas P. Lang**, Evolution of the Secret Pass Canyon volcanic center, Colorado River extensional corridor, northwestern Arizona, supervising professor: C. F. Miller  
**Trent McDowell**, Facies distribution of trace fossils and bioturbation in Permian and Mesozoic fluvial deposits, Colorado Plateau, supervising professor: M. F. Miller  
**Christopher Thomas**, Origins of mafic-ultramafic complexes of the eastern Blue Ridge province, southern Appalachians: Geochronological and geochemical constraints, supervising professor: C. F. Miller

2002  **Derek L. Bryant**, Geochemical, age, and isotropic constraints on the location of the Sino-Korean/Yangtze suture and evolution of the northern Dabie complex, supervising professor: J. C. Ayers  
**Alexandra Hartley**, Do reversals of the Earth's magnetic field affect life on Earth?: A biometric test of the hypothesis, using calcareous nannofossils, supervising professor: W. G. Siesser  
**Miranda Loflin**, Monazite as a tracer of fluid infiltration associated with contact metamorphism, supervising professor: J. C. Ayers  
**Russell Mapes**, Geochemistry and geochronology of mid-Paleozoic granitic plutonism in the southern Appalachian Piedmont terrane, North Carolina–South Carolina–Georgia, supervising professor: C. F. Miller

2003  **Lorrie V. Coiner**, Characterization of sheet structure in the Aztec Wash pluton, Nevada: Evidence for both cyclic deposition and vertical magma transport, supervising professor: C. F. Miller  
**Nicole L. Cates**, Perspectives on the development of an intermediate, open-system magma chamber: Aztec Wash pluton, Nevada, supervising professor: C. F. Miller  
**James R. Cook**, Faulting and fault scaling on the axial ridge walls of the Trans-Atlantic Geotraverse of the Mid-Atlantic Ridge, 26°N: A comparison of fault populations, supervising professor: M. C. Kleinrock  
**Christopher Hall**, Biostratigraphic investigation of the Oligocene in Mississippi and Alabama using calcareous nannofossils, supervising professor: W. G. Siesser  
**Laura Jacobs**, An analysis of smelter sourced Pb in stream sediment, pore water, surface water, and plants on Vashon and Maury Island, Washington, supervising professor: K. S. Savage

**Lisa Berrios**, Infaunal animals in the sand down under: An evaluation of freshwater
sediment use in Mesozoic rift basins, northeastern USA, supervising professor: M. F. Miller

Stephen Lehner, The effect of impurities on the electronic properties of pyrite crystals: Studies of synthetic pyrite (FeS$_2$) doped with As, Co, and Ni, supervising professor: K. S. Savage. Completed PhD at VU (see below).

2005

Peter Berquist, U-Pb zircon geochronology and geochemistry of southern Appalachian basement: Tectonic implications and constraints on age, extent, and origin, supervising professor: C. F. Miller

Heather Bleick, Production and redistribution of hybridized magma an a replenished, open-system magma chamber: Aztec wash pluton Eldorado Mountains, Nevada, supervising professor: C. F. Miller

Nicole Kneprath, Late Permian forests of the Buckley formation, Beardmore glacier area, Antarctica, supervising professor: M. F. Miller

George C. Koteas, Documenting the architecture of a stratified, multiply recharged intrusion, supervising professor: C. F. Miller

Lichun Zhang, Zircon solubility in alkaline aqueous solutions and trace element partitioning between zircon and fluids, supervising professor: J. C. Ayers

2006

Scott Crombie, Monazite alteration in the Searchlight Contact Metamorphic Aureole, southern Nevada, supervising professor: J. C. Ayers

Vena Jones, Land Use Contributions To Phosphorus Loading In An Impaired Stream, Mill Creek, Tennessee, supervising professor: K. S. Savage

Barry Walker, Geology and geochronology of the Spirit Mountain Batholith, southern Nevada: Implication for timescale and physical process of batholith construction, supervising professor: C. F. Miller

Lily Lowery Claiborne, Tracking magmatic processes through Zr/Hf ratios in rocks and Hf and Ti zoning in aircons: An example from the Spirit Mountain Batholith, Nevada, supervising professor: C. F. Miller. Completed PhD at VU (see below).

2007

Christopher Fisher, An exotic southern and central Appalachian basement: Pb And Nd isotopic evidence, supervising professor: C. F. Miller

Daniel Perrault, Giant country blocks within Searchlight Pluton, Southern Nevada, supervising professor: C. F. Miller

Brooke Traynham, Distributional controls and burrow characteristics of the mayfly Hexagenia in Kentucky Lake: Implications for the stratigraphic record, supervising professor: M. F. Miller

2008

Tenley Banik, Mechanisms of magma disaggregation in a cooler host: Volcanic, plutonic, and theoretical considerations, supervising professor: C. F. Miller. PhD student, Vanderbilt University.

Roberta Challener, Alteration of quartz sand-sized sediments by Mellita tenuis, supervising professor: M. F. Miller.

Elise Childs, Rainsplash as an advection-dispersion process, with implication for plant-soil interactions in arid environments, supervising professor: D. J. Furbish

Aaron Covey, Effects of earthworm burrowing on arsenic biotransformation and mobility: Implications for roxarsone-bearing poultry litter application, supervising professor: K. S. Savage. Technician and PhD student, Vanderbilt University.
Russell Pate, Multiple-proxy records of delta evolution and dispersal system behavior: Fluvial and coastal borehole evidence from the Bengal Basin, Bangladesh, supervising professor: S. L. Goodbred

Maria Takahashi, A biophysically based framework for examining phytoremediation strategies: Optimization of uptake, transport and storage of cadmium in Alpine Pennycress (Thlaspi caerulescenes), supervising professor: D. J. Furbish and J. H. Clarke

Lindy Colombini, Mid-Miocene rhyolite sequence, Highland Range, NV record of magma evolution and eruption from the Searchlight pluton magma chamber, supervising professor: C. F. Miller and G. A. R. Gualda

Danny Flanagan, Zircon from Swift Creek stage eruptions records the assembly and evolution of an intrusive magmatic complex beneath Mount St. Helens, supervising professor: C. F. Miller. PhD student, Vanderbilt University.

Sarah Krentz, Potentially tsunamigenic event layer in late Holocene Great South Bay, Long Island, New York: Constraints on origins, processes, and effects: supervising professor: S. L. Goodbred

Laura Robertson, Particulate organic matter in a stream network: A seasonal source-to-sink study, supervising professor: D. J. Furbish.


Tamara Carley, Studies of the evolution of felsic magma systems: I. Zircon in historic eruptions, Iceland; II. Modeling magma chamber evolution leading to the Peach Spring Tuff supereruption, Arizona, California and Nevada, supervising professor: C. F. Miller and G. A. R. Gualda. PhD student, Vanderbilt University.

Mohammad Ullah, Provenance analysis of Late Quaternary sediments from the Ganges-Brahmaputra delta, Bangladesh, supervising professor: S. L. Goodbred


Andrew Roberts, Rainsplash-induced mound development beneath desert shrubs: Modulation of sediment transport and storage, with implications for hillslope evolution, supervising professor: D. J. Furbish


Jennifer Murphy, Identifying land use changes and coal mining impact on water quality: A case study across time and space, supervising professor: G. M. Hornberger

Rachel Beavins, Holocene Environmental Change Recorded In Lagoonal Sediment Proxies At Huaca Prieta, North Coastal Peru, supervising professor: S. L. Goodbred


Beverly Walker, Dissolution of ophiuroid ossicles (Ophionotus victoriae) in Explorers Cove, Antarctica: implications for the Antarctic fossil record, supervising professor: M. F. Miller
2012  **Ryan Haupt**, *Dental Microwear Texture Analysis of dentin: can mammalian diets be inferred without enamel?,* supervising professor: L. DeSantis.

**Jennifer Pickering**, *Late quaternary sedimentary record of Holocene channel avulsions of the Brahmaputra River in the upper Bengal delta plain*, supervising professor: S. L. Goodbred. PhD student, Vanderbilt University.

2013  **Siobhan Fathel**, *Dynamics of desert-shrub populations in regulating soil transport based on plant-size and biomass scaling relevant to climate-change timescales*, supervising professor: D.J. Furbish. PhD student, Vanderbilt University.

**Will Frazier**, *Petrochemical constraints on generation of the Peach Spring Tuff supereruption magma Arizona, Nevada, California*, supervising professor: C. F. Miller

**Shelly Donohue**, *Using dental microwear textures to assess feeding ecology of extinct and extant bears*, supervising professor: L. DeSantis.

**Lauren Williams**, *Investigation into late Quaternary fluvial history of the Meghna valley in the tectonically active Ganges-Brahmaputra-Meghna Delta*, supervising professor: S. L. Goodbred.

**Greg George**, *Characterization of salinity sources in southwestern Bangladesh evaluated through surface water and groundwater geochemical analyses*, supervising professor: J. C. Ayers.


**Christopher Tasich**, *Modeling investigation of groundwater and surface-water interactions in shallow aquifers of coastal Bangladesh*, supervising professors: G. Hornberger and S. L. Goodbred

*Ph.D. Students*

In Environmental Science Option of Environmental Engineering, supervised by EES faculty

2006  **Simon M. Mudd**, *Reading the recorded history of soil mantled hillslopes*, supervising professor: D. J. Furbish (currently: Lecturer (equivalent to tenure-track Asst. Professor, University of Edinburgh))

2007  **Stephen W. Lehner**, *Characterization of defect energy levels due to As, Co, and Ni impurities in pyrite: A step toward understanding charge transfer kinetics at the semiconductor/electrolyte interface*, supervising professor: K. S. Savage (currently: Senior Research Scientist, Arizona State University)

2010  **Beth A. Weinman**, *The evolution of aquifers and arsenic in Asia: A study of the fluvio-deltaic processes leading to aquifer formation and arsenic cycling and heterogeneity in Bangladesh, Vietnam, and Nepal*, supervising professor: S. L. Goodbred (currently: tenure-track Assistant Professor, California State University, Fresno)

2011  **Lily Claiborne**, *Understanding upper crustal silicic magma systems using the temporal, compositional and thermal record in zircon*, supervising professor: C. F. Miller (currently Senior Lecturer, Vanderbilt University)

2012  **Timothy Peters**, *Experimental and field based investigations into the behavior of zircon in hydrothermal and deep-tectonic environments during mountain-building and crustal-evolution events*. supervising professor: J. C. Ayers (currently post-doctoral researcher with the Lunar Planetary Institute and NASA in Houston, Texas)
2013 **Kimberly Rogers**, *Spatial and temporal sediment distribution from river mouth to remote depocenters in the Ganges-Brahmaputra delta, Bangladesh*. Supervising professor: S. L. Goodbred (currently post-doctoral researcher with the Institute for Arctic and Alpine Research at University of Colorado, Boulder)

2013 **Susan Howell Taylor**, *Hydrologic and Eco-Geomorphic Response of Tidal Salt-Marsh Platforms to Sea-Level Rise and Protective Barrier Design*. Supervising professor: D. J. Furbish (currently at Abt Associates, an Environmental Services company in Washington, DC)

*Current Ph.D. Students*

In Environmental Science Option of Environmental Engineering, supervised by EES faculty

- **Tenley Banik**, supervising professor: C. F. Miller
- **Jen Bradham**, supervising professor: L. DeSantis
- **Tamara Carley**, supervising professor: C. F. Miller
- **Aaron Covey**, supervising professors: Jessica Oster and G. A. R. Gualda
- **Siobhan Fathel**, supervising professor: D.J. Furbish
- **Daniel Flanagan**, supervising professors: C. F. Miller and J. C. Ayers
- **Susanne McDowell**, supervising professors: C. F. Miller and G. A. R. Gualda
- **Trina Merrick**, supervising professor: R. Bennartz
- **Abraham Padilla**, supervising professor: C. F. Miller
- **Ayla Pamukcu**, supervising professor: G. A. R. Gualda
- **Jennifer Pickering**, supervising professor: S. L. Goodbred
- **John Roseberry**, supervising professor: D. J. Furbish
- **Ryan Sincavage**, supervising professor: S.L. Goodbred
- **Lindsey Yann**, supervising professor: L. R. G. DeSantis
Appendix 5: List of Courses

As described in Section 3.1.1, students will be expected to master a fundamental understanding of:

- materials — the physicochemical nature of solid and fluid Earth materials;
- processes — the physical, chemical and biological processes affecting the evolution of Earth materials, life, and environments;
- systems — the behavior of Earth systems wherein materials and processes are coupled over a wide range of spatial and temporal scales, and interpreting the record of this behavior.

Moreover, students will be expected to become skilled in:

- quantitative methods — defining the rates, scale, and magnitude of Earth processes and systems, plus our uncertainty in measuring them; and
- communication — effective conveyance of knowledge and outcomes in written and oral form.

Listed below are courses in EES and in other programs that fall within the three fundamental areas, where we note that: 1) courses with an asterisk are relevant to more than one area; 2) courses in EES numbered below 250 generally are taken for credit only by students with very different specializations who are seeking breadth in their studies; and 3) almost all courses in EES provide extensive experience in written and oral communications, and most employ quantitative methods — some intensively, others as an introduction to the importance of quantitative methods.

In the course catalog we have fewer 300-level than 200-level courses listed because many of our faculty offer their graduate courses as 390 Special Topics. The Special Topics courses have become a regular approach taken by faculty to allow them to adapt the content and focus of their courses to meet the needs of particular student cohorts. This has been particularly important as we have grown our Ph.D. level students and incorporated new faculty into our program. Many of these courses, though, have now been taught several times as 390 Special Topics, and so we are encouraging faculty to submit formal course descriptions to the Curriculum Committee for approval as regular 300-level courses. In academic year 2013-14 we are offering five 300-level courses, all as 390 Special Topics, but the majority of these will be transitioned to permanent, formal course offerings in the coming year.

We also maximize our course availability for graduate students by allowing students to take some upper 200-level courses for graduate credit. This is also a mechanism by which students can take upper-level courses that they did not take as undergraduates. Graduate students in 200-level courses must complete extra work to earn graduate credit.

Materials:

*EES 225 Earth Materials
*EES 226 Petrology
*EES 230 Sedimentology
*EES240 Structural geology and Rock Mechanics
*EES 260 Geochemistry
*EES275 Sustainable Systems Science  
*EES 285 Volcanic Processes  
EES 290: Microscopic Image Acquisition  
*EES310 Earth Fluids  
*EES311 Advanced Topics in Earth Materials  
EES 320 Aqueous Geochemistry  
*EES330 Isotopes and Environment  
EES 390 Structure, Composition, and Properties of Earth Materials

Examples from other departments:  
CHEM 230 Physical Chemistry  
CHEM 232 Biophysical Chemistry

Processes:  
*EES 226 Petrology  
*EES 230 Sedimentology  
*EES 240 Structural Geology and Rock Mechanics  
EES 255 Transport Processes in Earth and Environmental Sciences  
EES 257 Hydrogeology  
*EES 260 Geochemistry  
EES 261 Geomorphology  
EES 268 Paleoclimate  
*EES275 Sustainable Systems Science  
*EES 279 Problems in Sedimentology and Paleobiology Will it be offered?  
*EES 285 Volcanic Processes  
*EES 290 Physics of the Climate System  
*EES310 Earth Fluids  
*EES311 Advanced Topics in Earth Materials  
EES 322? Environmental Applications of Geochemical Modeling  
*EES330 Isotopes and Environment  
*EES 335 Magmatic Processes and Construction of Earth’s Crust  
EES362 Macroecology and Biogeography  
EES364 Topics in Macrowoolutions  
EES390 Intro to Atmospheric Physics  
EES 390 Statistical Methods in Earth and Environmental Sciences

Examples from other departments:  
ENVE 252 Physical hydrology  
ENVE 262 Hydrology  
ENVE 270 Environmental Thermodynamics, Kinetics, and Mass Transfer  
ENVE 276 Ground Water Hydrology  
CE 203 Fluid Mechanics (are these and the following courses eligible for graduate credit?)  
BSCI 205 Evolution  
BSCI 238 Ecology  
BSCI 270 Statistical Methods in Biology
Systems:
EES 201 Global Climate Change
EES 220 Life Through Time
EES 268 Paleoclimates

EES 275 Sustainable Systems Science
*EES 279 Problems in Sedimentology and Paleobiology
EES 282 Paleocological Methods
*EES 290 Physics of the Climate System
*EES 335 Magmatic Processes and Construction of Earth’s Crust
EES 338 Source to Sink
EES 362 Macroeconomy and Biogeography

Examples from other departments:
ENVE 271 Environmental Chemistry
ENVE 280 Atmospheric Pollution
ENVE 312 Pollutant Transport in the Environment

In addition, listed below are courses from other programs that students might be encouraged to
take based on the specifics of their research topics and their background preparation.

Anth 280 Intro. to GIS and Remote Sensing
BSCI 270: Statistical Methods in Biology
CE 203 Fluid Mechanics
CE 226 Introduction to Environmental Engineering
CE 227 Biological Unit Processes
CE 259 Geographic Information Systems
CE 290 Reliability and Risk Case Studies
CE 307 Finite Element Analysis
CE 310 Probabilistic Methods in Engineering Design
CE 313 Advanced Reliability Methods

ChemE 310a Applied Mathematics in Chemical Engineering I
ChemE 310b Applied Mathematics in Chemical Engineering II
ChemE 311a-311b Advanced Chemical Engineering Thermodynamics
ChemE 230 Introductory Transport Phenomena
ChemE 312a Transport Phenomena I
ChemE 312b Transport Phenomena II
ChemE 317 Physiological Transport Phenomena

ENVE 264 Environmental Assessments
ENVE 269 Radiological Aspects of Environmental Engineering
*ENVE 273 Environmental Characterization and Analysis
ENVE 275 Environmental Risk Management
ENVE 300 Water Quality Management
MATH 204 Linear Algebra
MATH 208 Ordinary Differential Equations
MATH 216 Probability and Statistics for Engineering
MATH 218 Introduction to Mathematical Statistics
MATH 218L Statistics Laboratory
MATH 219 Introduction to Applied Statistics
MATH 247 Probability
MATH 248 Mathematical Statistics
MATH 226 Introduction to Numerical Mathematics
MATH 229 Advanced Engineering Mathematics
MechE 275 Introduction to Finite Element Analysis
MechE 343 High-Performance Computing for Engineers
MechE 325a Advanced Fluid Dynamics I
MechE 325b Advanced Fluid Dynamics II
MechE 348 Convection Heat Transfer
Appendix 6: Mutual Expectations

Working and Living as a Graduate Student in the Department of Earth and Environmental Sciences, Vanderbilt University

The contributions of many people are needed to ensure a successful graduate school career. Thus, it is essential to understand what one can reasonably expect from an advisor, a teacher, a department chair and, ultimately, from oneself. This document provides a guide through the many relationships that form the structure needed to support graduate students through the long hours from entering graduate school to the dissertation defense.

Role of the Graduate Student

From the beginning of a student's graduate education, he or she is a scientist. The student should behave in a professional manner and treat his or her colleagues with respect. In their training, students must learn the necessary skills for a successful career as a scientist. These skills include searching the literature, designing experiments, constructing and applying theories, collecting and analyzing data, understanding the relationship between hypothesis and observation, and presenting results by giving talks at conferences, writing papers, and, ultimately, writing a Ph.D. thesis. Some of these skills will be learned from the thesis advisor, but many will also be learned from other students, postdocs, members of the Ph.D. committee, or from other earth scientists in the community at large. It is imperative that a student understands that he or she has the ultimate responsibility for his or her professional development and may need to seek out opportunities independently. It is equally important to understand that no advisor is perfect and thus will probably not be able to fulfill all of the educational needs of every student. Finally, the student as scientist should be aware of the ethical considerations inherent in scientific work, including issues of fraud, plagiarism, and apportioning credit for work done. This will serve to protect the student from ethical violations, guide his or her behavior, and ensure a healthy community of scientists for the future.

A graduate student must learn not only how to do science, but how to be a scientist. Science is about collaboration and working within the scientific community. In order to succeed, a student must learn the rules, mostly unwritten, by which the community of scientists functions. A student cannot learn this in isolation or from a textbook, but only by working within the community.

The role of a classroom student is probably the most familiar role for a new graduate student and will be an important one for the first few years of graduate school. A high level of effort in undergraduate classes was necessary for a student to be admitted into graduate school. An even higher level of effort is necessary and expected of students in graduate classes. Students should always attend class unless exceptional circumstances occur. Graduate classes are fast-paced and it is more difficult to make up for lost time than it is in undergraduate classes. Students are frequently encouraged to work together more collaboratively than in undergraduate classes, but are nevertheless responsible for understanding and adhering to the standards of independence required by the professor. Finally, students are responsible for knowing the academic standards required of them by the department and graduate school and for doing their best to meet these standards.
A research assistant is scientist, student, and apprentice. Having outlined the first two of these roles, the third must also be made explicit. The student should make sure that he or she understands the expectations that the advisor has for students working in his or her research group. Details to be clarified include number of hours to be worked weekly, how much time needs to be spent in the office or lab (as opposed to working at home), and which particular hours one needs to be at work. Scientific work is rarely a 9-to-5 job, and students should understand that graduate school training will entail extra effort beyond these hours. Time and effort necessary to achieve acceptable progress will vary depending on circumstances, often resulting in long, but usually rewarding, hours. While it may be acceptable to work at home, it is also important to realize the value in having peers with whom to talk and share ideas. Many important interactions can take place only in the office or laboratory setting.

At some point during graduate education, a student may hold a position as a teaching assistant (TA). As a TA, a student might be assigned as a grader for an upper-level undergraduate course or staff a “help desk” where he or she will assist students with problem-solving, but the most common assignment is to supervise laboratory sections. A TA is an apprentice teacher, with certain responsibilities to both the students and the faculty instructor in the course. For example, lab TAs are expected to be on time for meetings with their sections, to be well-prepared to assist the students in carrying out the lab, to have grading done prior to the next lab meeting, and to attend a weekly meeting with the instructor and other TAs in the lab course.

The faculty instructor of the course for which a student is a TA also has responsibilities. Faculty should set clear expectations; define roles and responsibilities in the course including what may or may not be changed (e.g., syllabi, course policies, help desk staffing times, etc.); clarify priorities; provide textbooks or other materials needed for the course; provide training as necessary in course content, teaching methods, and grading; and provide feedback on the student’s performance as a TA.

**Role of the Advisor**

Graduate students entering our Ph.D. program are strongly encouraged to become involved with research groups as early as possible. It is expected that by the summer following the first academic year, students will be actively involved in a research area with a specific professor or research group in the Department. Students may try out several areas before deciding on a dissertation research area. Soon after the student has decided on a specific research area, he or she will be choosing an advisor.

One of the first tasks of an advisor is to help a student get started in his or her chosen research field, to assist in the selection of the Ph.D. committee, and to help with the preparation for the Qualifying Exam. In this context, the advisor will make suggestions regarding the scientific literature to be surveyed by the student (textbooks, research journals, Websites, etc.), discuss experimental and/or computational methods used in the field, and answer questions. The advisor will also provide the student with instructions on how to effectively communicate technical material through both writing and presentations. A rehearsal meeting with the advisor prior to the Qualifying Exam is highly recommended.

After the student has passed the Qualifying Exam, he or she will meet with the advisor on a regular basis to discuss the research plan and to decide on a specific dissertation topic which
must be approved by the Ph.D. committee. Advisors may suggest conferences where students can present papers and/or host poster sessions. They may encourage leading discussions during group meetings or journal clubs. The advisor also serves as a role model, leading through example and suggestion to teach students how to become productive and respected scientists in their field of study. In cases where an advisor is unable to meet on a regular basis because of a research leave or extended travel, he or she should appoint a postdoc or senior student to assist the advisee. Advisors should keep their students informed of availability and travel schedule, including during the summer. Special arrangements need to be made if an advisor takes a sabbatical.

Advisors should not be expected to answer every question posed by their students, but rather should be able to assist students in finding answers and making progress in the research. Each advisor should ensure his or her students are prepared for the qualifying exam, the yearly Ph.D. committee meetings and thesis defense. If a student is unlikely to perform well during any of these exams or meetings his or her advisor should tell the student so.

In natural science departments at research universities, professors are expected to apply for and receive research grants. Most of these grants are funded by agencies of the federal government (e.g. DOE, DOD, NSF). Some areas may also receive additional funding from private companies or foundations. Principal investigators are expected to make funding decisions and guide the overall direction of any research supported by the grant.

Advisors are expected to find research funding for their students when possible, including research computers and lab equipment, as well as travel funds to attend scientific conferences. On average, experimental programs receive more funding than theoretical programs, but details vary widely between subfields. Often students do not realize how much it actually costs to support a student on a 12-month Research Assistantship, because the only benefit directly visible to the student is the stipend ($22,620 for AY 2006/07). However, the research grant also has to pay $9,111 for tuition and $2,281 for health insurance plus an additional 50% in overhead to the university, i.e. the total cost to the research grant for one RA is about $50,000 per year, much higher than the stipend would indicate!

In a situation where advisors provide funding for their students, they have a vested interest in ensuring their students are sufficiently productive and working enough hours. An advisor needs to have an honest, open and realistic discussion about current and future funding for the academic year and for the summer before taking on a student.

Role of the classroom teacher

In general, graduate students should expect that all of their course instructors provide to them at the beginning of the semester a course syllabus, a brief explanation of the course policy, and a statement of how the course grade will be assigned. Students should realize that professors have a lot of discretion in this regard: usually there are homework sets, several tests and a final exam, but in particular in high-level graduate courses most of the course grade may be assigned on the basis of active course participation and a written term paper and/or presentation. When in doubt, students should ask their professors about the grading policy during the first week of class. Students may also expect from their classroom teachers periodic updates on their progress during the semester. All course instructors have an obligation to meet their classes on time and to be
well-prepared for the lecture. Students should also expect that professors be available for questions during office hours.

At research universities, classroom teaching represents only one of many forms in which teaching and learning takes place. In addition, students learn by attending colloquia, research seminars, group meetings, and through active participation in research projects. Teaching and research are intertwined and reinforce each other. This "teaching through research" component is what sets research universities apart from teaching colleges. Students should realize that this has also important consequences for classroom teaching: it would be unrealistic to expect that professors will teach their assigned classes every single day throughout the semester. From time to time, research-related travel (e.g. offcampus experiments, research conferences) necessitate that a professor will be absent from class. In such cases, it is the course instructor’s obligation to either find a colleague to substitute for him/her or to reschedule the class at another time. In the latter case, students need to be reasonable about available times.

**Role of the Ph.D. committee**

In general, the role of the Ph.D. committee is to ensure that the student is ready to begin thesis research, is making good progress towards completion of the degree, and that the standards for a Vanderbilt Ph.D. thesis are met. The Ph.D. committee also provides additional resources for advising, recommendation letters, etc.

The Bulletin of the Graduate School states that "the purpose of the Qualifying Examination is to test the student's knowledge of the field of specialization, to assess familiarity with the published research in the field, and to determine whether the student possesses those critical and analytical skills needed for a scholarly career". This statement clarifies that the Qualifier is not meant to be a "mini-Ph.D. defense" and it does not require that students already have identified a precise thesis topic. Rather the purpose is to help the student focus, as early as possible, on a particular research area and to demonstrate that he/she is qualified to engage in Ph.D. research in a particular subfield of Earth and Environmental Sciences. After passing the Qualifying Examination, each student will meet with his or her committee typically once per year to report on progress and to receive advice from the committees members. Students should realize that these yearly meetings are for their benefit. The primary responsibility for Ph.D. research supervision rests with the Ph.D. advisor; students will meet informally with their advisor on a regular basis throughout the year.

Research is an indispensable component of the Ph.D. requirements. Good grades in courses do not guarantee the particular abilities that are required in research. Progress in research is often slow and difficult even for those who have a natural talent for it. Research requires energy and commitment as well as various talents; it may involve designing, building, using, and repairing equipment, computer programming, analysis of data, imaginative formulation and testing of hypotheses, deriving and solving equations, communication of results and the assessment of their significance. The quality of a student's research must be high enough to merit publication in a major research journal.

**Role of administrators**

The Director of Graduate Studies (DGS) has the primary responsibility for recruiting the best possible students into the graduate program in Earth and Environmental Sciences, shaping the
graduate program, including curriculum revisions and changes in departmental procedures and requirements, advising students both academically and professionally, and monitoring the progress of all students. The DGS recommends students for admission into the graduate program. The DGS approves and submits all requests to the Graduate School, including requests for transfer credit, to appoint or revise a Ph.D. committee, to schedule a Qualifying Exam, to request extensions or leaves of absence, to schedule a dissertation defense, and to approve applications for Travel Awards and Dissertation Enhancement Grants. The DGS also provides essential help to all graduate students, assisting with registration, all paperwork, including requests for transfer credit, formation of the Ph.D. committee, scheduling the qualifying exam and the dissertation defense, and general advice when you are not sure where to start.

The Department Chair oversees all aspects of the department, including the graduate program. The chair also acts as liaison between the department and the Dean of the College of Arts and Sciences. If an issue cannot first be resolved by the DGS, it may be taken to the department chair.

There are three deans whose decisions can affect graduate students in Earth and Environmental Sciences. The first of these is the Associate Dean for Graduate Studies of the College of Arts and Science (A&S). The primary role of this dean is to oversee graduate aid and admissions for students in A&S, which includes students in EES. The associate dean also is a source for new initiatives to improve graduate education within the College of Arts and Science. The second of these is the Associate Provost for Research and Graduate Education, serving in the capacity of the Dean of the Graduate School. The role of this dean is to administer the policies outlined in the Graduate School Bulletin, including academic standing and composition of Ph.D. committees. Finally, the Dean of Arts and Sciences is responsible for the entire college, including the oversight of individual departments, usually through each Department Chair, and the Graduate School.

What if something goes wrong?

Students in the Department of Earth and Environmental Sciences have several avenues available to them by which to address grievances. In general, it is suggested that students first attempt to address grievances to the offending party. If appropriate, consultation with one's advisor is the next step. Assistance may then be pursued from any one of the following bodies.

Role of the Graduate Honor Council

The Graduate Honor Council of Vanderbilt University was established to "to protect the honor of all graduate students by vindicating those falsely suspected of dishonesty and penalizing those guilty of dishonest acts." It is organized for graduate students, by graduate students. The council has a document available at [http://www.vanderbilt.edu/gradschool/current_students/pdf/GSHC.pdf](http://www.vanderbilt.edu/gradschool/current_students/pdf/GSHC.pdf) which lists the duties of the members of the honor council, along with procedures to follow when one perceives a violation of the honor code. The first step is to notify the council of a violation, after which the council will endeavor to collect information regarding the situation, hold hearings, and assess for appropriate action.
Violations that fall under the honor council's jurisdiction include:
1. falsifying or cheating on any material submitted to meet course requirements;
2. plagiarizing on any assigned material;
3. failing to report a known violation of the Code;
4. taking actions to deceive a member of the faculty, staff or fellow student regarding principles contained in the Honor Code;
5. submitting work prepared for another course without specific prior authorization of the instructors in both courses;
6. using text or papers prepared by commercial or noncommercial agents and submitting as one's own work;
7. falsifying results of study and research.

Role of the ODC

The Opportunity Development Center (ODC) was formed in 1977 to be Vanderbilt University's equal opportunity, affirmative action, and disability services office. The Center's core values include diversity, equity, accessibility, inclusiveness, and accommodation. The ODC's website at http://www.vanderbilt.edu/odc/index.htm has many resources for assistance such as university policies on affirmative action, information on how to identify sexual harassment, and instructions for filing complaints with the university.

Complaint and Grievance Procedure

Of relevance to students is the ODC's complaint procedure recommendations, which can be found online at http://www.vanderbilt.edu/odc/studcom.htm. The ODC recommends that complaints first be brought to the person or persons giving rise to the complaint, and resolution first be sought at this level. If satisfactory resolution is not reached, the grievance procedure may be followed, whereby the student may file an official complaint with the Office of the Chancellor, which may refer the grievance to the Faculty Senate Committee on Student Affairs. The committee will assess the situation and perform an investigation if deemed necessary.

Allegations of Unlawful Discrimination (from the ODC website)

If a student believes that he or she has been discriminated against on the basis of race, sex (including sexual harassment), religion, color, national or ethnic origin, age, disability, or military service, that student should report the matter to the Opportunity Development Center, which will seek to assist the student with the resolution of the complaint as described above in the Complaint Procedure.

Graduate students working in interdisciplinary laboratories

As science becomes more and more interdisciplinary, students may find opportunities for research in laboratories that span different departments or schools. In this situation, it is important to outline the course of action one must take in achieving the Ph.D. degree.

A graduate student in the Department of Earth and Environmental Sciences must complete all requirements for graduation as stated in the Graduate Student Handbook. It is the student's responsibility to maintain communication with the EES department to ensure that requirements are being met. It is the advisor's responsibility to be familiar with the requirements of the student's department, and to ensure that the standards of the department are followed in such graduate program milestones such as the qualifying exam and dissertation defense.
A last word

Graduate School in Earth and Environmental Sciences marks the real beginning of your career as a scientist. One of the main goals is to develop the knowledge and skills necessary to complete the significant independent work on which you will base your dissertation. This is done through classes and research within your advisor’s research group. Another, equally important goal is to develop your reputation as a member of the scientific community. You should consider yourself as a professional scientist and act accordingly. You and your fellow students as well as the postdocs and members of the faculty are your colleagues. As such, you should treat them with due consideration and respect. The relationships you form now can have a significant impact on your career in the future. Developing the habit of professional behavior in the department, in using departmental email lists, at conferences, while visiting other institutions, and in internet postings will help you to preserve a reputation that will enhance your work and your career.
Appendix 7: Departmental Laboratories and Analytical Facilities

The Department is housed in Vanderbilt's natural science complex and shares analytical equipment with Chemistry and Engineering. Experimental and analytical facilities are readily accessible to graduate students. They include the following:

Microscopy and Microanalysis

- ELA-ICP-MS: ThermoFisher iCAP Qc quadrupole ICP-MS with CETAC autosampler and Photon Machine Excite 193nm excimer laser ablation system
- Confocal microscope: Sensofar PLu neox 3D optical profiler has confocal and interferometry capabilities
- CM-2 microsampling system with transmitted and reflected light and epifluorescence

Transport Phenomena

- Fluid dynamics and sediment transport laboratory with stream table
- Particle settling tanks and a specialized "fluid intrusion" tank
- High-speed and lapse-rate digital cameras controlled by a high-performance work station.

Sedimentary Processes

- Sedimentology laboratory including a Geotek multi-sensor core logger featuring magnetic susceptibility, core density by gamma attenuation, and a multi-spectral digital camera
- Malvern laser-diffraction particle-size analyzer
- Two Ortec planar gamma detectors for radionuclide geochronology.

Marine Processes

- Edgetech 216s sub-bottom chirp profiler for high-resolution stratigraphic imaging in aqueous environments
- Sea-Bird salinity-temperature-depth water-column profiler with optical backscatter for suspended sediment concentrations
- Triton SB-Interpreter seismic-image processing software.

Paleoecology and Paleoenvironments

We are a member of the Hancock Biological Station consortium on Kentucky Lake, which has a full complement of field and analytical equipment for collecting and analyzing sediment and biological samples, as well as aquaria and greenhouses. Department laboratory includes
binocular microscopes, fossil collections, an X-radiography unit for burrow analysis, and a scanning confocal microscope for 3D surface analysis.

**Magmatic Processes and Crustal Evolution**

- Optical microscopy lab with Zeiss Axioskop transmitted and reflected-light petrographic microscope and Zeiss Stemi 2000 stereoscope, equipped with digital imaging system
- Petrography lab with transmitted and reflected-light optical microscopes and projection equipment
- Mineral separation facilities including Franz magnetic separator, heavy liquids, stereoscopes and glassware
- Sample preparation lab with rock saws, rock chipping and milling equipment
- Equipment for scaled tank experiments using viscous liquids

**Geochemical Processes**

- Experimental petrology lab including high-temperature furnaces, piston cylinder apparatus, hydrothermal diamond anvil cell, four cold seal pressure vessel systems, fluid inclusion heating/cooling stage
- Environmental equipment includes a portable X-Ray Fluorescence spectrometer, Teledyne ISCO automatic water sampler, and Decagon TDR device

**Other Analytical Facilities on Campus**

- Laser Ablation ICP-MS and TGA-MS
- Powder X-ray diffractometer with high-temperature furnace attachment
- Atomic absorption spectrometers (flame and graphite furnace)
- Ion and Gas chromatographs and TOC analyzer
- Eight alpha detectors for radionuclide analyses

**General Equipment**

- GPS units with integrated topographic map software
- GIS lab with large format digitizers, scanners, plotter
- Networked microcomputers and server
- Worden gravimeter

**Collaborative use of external facilities**

- SHRIMP (Sensitive High-Resolution Ion Microprobe) at Stanford University
- Ion Microprobe at UCLA
- Argonne National Laboratory
**Mission Statement:** The Department of Earth and Environmental Sciences at Vanderbilt is committed to nurturing student interests and capabilities in interpreting Earth’s dynamic history, and in understanding the behavior of modern Earth and environmental systems. The curriculum is aimed at understanding Earth processes, their global importance in the context of deep time, and their influence on humans and society. The goal is to educate students so that they gain both essential depth in their studies, and exposure to ideas and skills that facilitate communication across disciplines, such that they are poised to excel in a diversity of life opportunities in all sectors of society.

<table>
<thead>
<tr>
<th>Learning Outcomes</th>
<th>Assessment Methods and Procedures</th>
<th>Results</th>
<th>Planned Improvements Based on Assessment Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Knowledge and mastery of relevant geoscience concepts</td>
<td>Evaluation of written and oral comprehensive examination by EES faculty</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Integration of knowledge through analysis and synthesis, and applicability to the methods of research and discovery in chosen area of specialization in EES</td>
<td>Evaluation of a qualifying examination by the student’s faculty doctoral committee</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Ability to conceptualize, design, and plan independent, systematic inquiry that will result in a new contribution to knowledge in the area of specialization</td>
<td>Evaluation of a dissertation proposal by the student’s faculty doctoral committee followed by periodic assessment of progress</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Demonstrated competence in the conduct of independent inquiry; compilation of a written account of such inquiry, its outcomes, and conclusions</td>
<td>Evaluation of the student’s dissertation and performance in oral defense by the faculty doctoral committee</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Learning Outcomes Assessment Annual Report Template

Program: Earth and Environmental Sciences Ph.D.

School: College of Arts and Science

Academic Year: AY 2013-14

Person Responsible:

1. Learning Outcomes Assessed: Which learning outcomes were assessed?

2. Results Obtained: What results were obtained? Please present data including the number of students assessed and what assessment methods were used. This section should also include conclusions drawn from the data. Please attach or include the rubric, if applicable. Other attachments may also be included.

3. Use of Results for Planned Improvement(s): How will the results be used for student learning and/or program improvement(s)? What actions or modifications have been or will be made based on the results of this year’s assessment? Attachments may be included.

4. Previous Academic Year’s Planned Improvements: Describe the implementation of any improvements indicated in the program’s assessment plan from last year. If no improvements were indicated, please respond N/A.
PhD Student Progress Summary Report Template

(note: use as much space as needed to address each item below)

Date:

Name:
Primary faculty advisor(s):
Program and degree sought:
Semester and year of initiating degree program:
Anticipated degree completion (month/year):
If M.S. is sought, is this a research thesis based degree:

Research thesis or dissertation tentative title and abstract:

(title + 1 paragraph summary of research objectives and approach)

Current research status:

(bulleted summary of progress to-date)

Research milestones for next 6 months:

Source of financial support:
Status on course work and other requirements

Courses completed to date: (number and title; state the total number of credits taken; for PhD students, indicate which of Areas 1-4 the course applies to, then total the courses for each Area)

Courses remaining to be completed for degree:
(number, title and semester to be completed; state the total number of credits to be taken; for PhD students, indicate which of Areas 1-4 the course applies to, then total the courses for each Area)

For Ph.D. students only:
   Month/year for planned or completed comprehensive exam:

   Month/year for planned or completed qualifying exam (proposal defense):

   Month/year for planned completion of draft dissertation:

   Dissertation faculty committee:

Publications and Professional Presentations:
(provide full citations on completed and upcoming publications and presentations based on your research or activities while at Vanderbilt)
Appendix 9: Graduate Catalog Text

CHAIR John C. Ayers
DIRECTOR OF GRADUATE STUDIES Calvin F. Miller
PROFESSORS EMERITI Leonard P. Alberstadt, Arthur L. Reesman, William G. Siesser, Richard G. Stearns
PROFESSORS John C. Ayers, Ralf Bennartz, James H. Clarke, David J. Furbish, George M. Hornberger, Calvin F. Miller, Molly Fritz Miller
ADJOINT PROFESSORS Mark S. Ghiorso, David White
ASSOCIATE PROFESSORS Jonathan M. Gilligan, Steven L. Goodbred, Guilherme Gualda
ASSISTANT PROFESSORS Larisa R. G. DeSantis, Maria Luisa Jorge, Jessica L. Oster
RESEARCH ASSISTANT PROFESSOR Christopher P. Vanags
SENIOR LECTURERS Lily L. Claiborne, Daniel J. Morgan

DEGREES OFFERED: Master of Science, Doctor of Philosophy (option in Environmental Science offered jointly with Environmental Engineering), Doctor of Philosophy
A STUDENT earns the master’s degree in earth and environmental sciences by completing 24 hours of formal course work and submitting an approved research thesis. Specific requirements for the Ph.D. degree are defined in the Ph.D. program document that is available upon request from the Department of Earth and Environmental Sciences. Fields of study include sedimentology, geochemistry, geomorphology, transport processes, igneous and metamorphic petrology, volcanology, environmental geology, paleoclimate, and paleobiology and paleoecology. Graduate students in earth and environmental sciences must obtain permission from the department to receive credit for any course required for the undergraduate major: 220, 225, 226, 230, 240. Graduate students in other disciplines may receive credit for these courses. Six hours of graduate credit is required in another discipline or in an area of earth and environmental sciences other than that in which the student is pursuing thesis research.
Course descriptions begin on page ##.