Appendix A

MS/MSE Requirements

Aquatic Sciences: Research and Management (NRE)

Sustainable Systems (NRE)

Chemical Engineering (CoE)

Mechanical Engineering (CoE)

Environmental Engineering (CoE)

Master of Science Requirements
Natural Resources & Environment
Aquatic Sciences: Research and Management Field of Study

42 credit hour M.S. in NRE

1. Overview

More than two-thirds of the Earth's surface is covered with water, so it is not surprising that the planet's oceans, lakes, rivers, streams and wetlands are considered valuable natural resources and, increasingly, focal points for concerns about usage, pollution and depletion. Humans' ever-growing encroachment on aquatic ecosystems has created a strong demand for scientists trained in the sustainable management of these resources.

The Aquatic Sciences field of study provides training in basic and applied sciences relevant to the world's growing water crisis and the management of aquatic ecosystems. Faculty include professors and research scientists from a number of disciplines and departments, with interests covering a wide range of subjects, such as fisheries science, aquatic entomology and ecosystem modeling.

"International research is a possibility for interested students," explains Professor Michael J. Wiley, coordinator of the Aquatic Sciences field of study. "Current and recent projects include aquaculture studies in Thailand and China, collaboration with Indian researchers on Ganga River water quality issues and investigations of the land use change in Venezuela."

2. Program of Study

During your coursework, you will focus on a variety of related subject areas, including fisheries, watershed management, river/stream ecology, wetland science, aquatic-conservation biology and Great Lakes ecosystems. Our breadth and depth of our faculty interests offers a decidedly multidisciplinary and applied approach and creates an extensive range of opportunities for you to research and study.

You will learn the fundamental physical, chemical and biological concepts and basic techniques necessary for the study of aquatic ecosystems. In addition, you will study the physiological, behavioral and numerical responses of fish to their environment and learn how environmental factors influence energetics growth, survival, behavior and reproduction of individuals, communities and populations of fish.

In the laboratory, you will become acquainted with the field methods used in fish biology and fisheries, as well as those necessary for examining the diversity of the Michigan ichthyofauna and major groups of world fish. You will have access to a variety of aquatic research facilities on site, as well as the University of Michigan Biological Station (INSERT LINK), a research and teaching field station in Pellston, Michigan. Our partnership with local and state laboratories as well as local offices of Federal Labs provides a unique opportunity to collaborate with scientists focusing on Great Lakes Ecosystem issues.

3. Careers

This field of study prepares you for a research career focusing on specific species, ecosystems or ecological problems or for a management career requiring skills in policy and economic analysis and the application of scientific knowledge to management problems.

Graduates often pursue occupations as fishery biologists, limnologists, ecologists, aquatic-resource specialists, biometricians and natural-resource managers. They also become educators with government agencies, such as the Michigan Department of Natural Resources and the National Oceanic and Atmospheric Administration or with nonprofit organizations such as the Nature Conservancy and American Rivers.

Other graduates take positions with environmental-consulting companies, private corporations or major colleges and universities.

3. Curriculum

This Plan meets current SNRE requirements. Curriculum requirements are fulfilled through the following five elements: (a) Aquatic Sciences Core, (b) SNRE Core Requirements, (c) Opus Options, (d) Electives, and (e) Cognates. This curriculum requires a total of 42 credit hours.

a. Aquatic Science Core (9-12 hrs total)
b. SNRE Core Requirements (13 hrs total)

1) Core Courses (10 hrs)
Integrated Problem Solving [NRE 580] (3) W
Ecology: Science of Context and Interaction [NRE 509] (3) F
Environmental Governance, Choices, Institutions and Outcomes [NRE 510] (3) F
Laboratory in Social and Natural Science [NRE 507] (1) F

2) Analytics (3 hrs)
Natural Resource Data Analysis [NRE 538] (3) or equivalent graduate level analytical course

c. Opus Options (6-8 hrs total)
Students can fulfill this requirement by completing 1) or 2) below:
1) Six (6) credits of Masters Project (NRE 701) or Masters Thesis (NRE 700)
2) Additional Coursework (6-8 credits)
a. 3 credits of coursework related to AS field of study that is approved by advisor

d. Electives (8 - 14 hrs total)
Electives are plan specific but must be a graduate level course at 400-level and above

e. Cognates (minimum of 4 hrs)
Cognates can be double counted with other degree requirements but must be graduate level courses taken outside of SNRE.

f. Total Credit Hours
1) Minimum 42 credit hours total
2) Minimum 25 credit hours of SNRE

Abbreviations
ARCH = Architecture
AOSS = Atmospheric, Oceanic and Space Sciences
BE =Business Economics and Public Policy
CEE = Civil and Environmental Engineering
CSIB = Corporate Strategy and International Business
EHS = Environmental Health Sciences
FIN = Finance
LHC = Law, History, and Communication
ME = Mechanical Engineering
NRE = Natural Resources and Environment
OMS = Operations and Management Science
PUBPOL = Public Policy

Master of Science Requirements
Natural Resources & Environment
Sustainable Systems Field of Study

42 credit hour M.S. in NRE

1. Mission

To guide the development and transformation of technologies, enterprise[1], and systems[2] for meeting basic human needs in a sustainable manner. This curriculum is designed to provide interdisciplinary education and professional development for students in SNRE and those in current and future dual degree programs (e.g., Business and Engineering).

2. Careers

This curriculum addresses the nexus between technology, enterprise, and sustainability and will produce graduates prepared for careers in both the public and private sectors. Career opportunities include the following: systems analysis, management consulting, R&D labs, entrepreneurial start-ups, regulatory agencies, industrial development agencies, municipal utilities, engineering firms, design firms, product development groups, green certification organizations, the strategic planning and environmental health/safety units of manufacturing companies, and environmental NGOs. In addition, a vital and growing network of professional associations, academic journals, government programs, and opportunities for competitive research funding supports the proposed Plan.

3. Curriculum

This Plan meets current SNRE requirements. Curriculum requirements are fulfilled through the following five elements: (a) Sustainable Systems Core, (b) SNRE Core Requirements, (c) Opus Options, (d) Electives, and (e) Cognates. Two Specializations in Sustainable Systems are: Sustainable Design and Technology and Sustainable Enterprise. This curriculum requires a total of 42 credit hours.

a. Sustainable Systems Core (15 hrs total)
Requirements for headings 1, 2 and 3 below

15 credit hr breakdown:
6 credits in Systems Analysis for Sustainability (heading 1)
9 credits in Sustainable Design and Technology (heading 2) and Sustainable Enterprise (heading 3)

heading 2 and 3 distribution:
Minimum 3 credits in Sustainable Design and Technology (heading 2)
Minimum 3 credits in Sustainable Enterprise (heading 3)

1) Systems Analysis for Sustainability (6 hrs) Skills and Techniques
Systems dynamic modeling, life cycle assessment, material flow analysis, life cycle cost analysis, risk analysis, systems thinking, spatial analysis, GIS.

Courses
Industrial Ecology [NRE 557/CEE 586] (3)

[1] Enterprise encompasses public and private sector organizations including business, government and NGO's.
[2] e.g., mobility, shelter, sustenance, communication, recreation

Systems Thinking For Sustainable Development and Enterprise [NRE 550/CSIB 566] (3)
Risk-Benefit Analysis in Environmental Engineering [NRE 595/CEE 589] (3)
Microeconomics with Natural Resource Applications [NRE 570] (3)
Principles of GIS [NRE 531] (4)

2) Sustainable Design and Technology (3-6 hrs)

Skills and Techniques
Technology assessment, energy analysis and modeling, carbon emissions modeling, renewable energy systems, Design for Environment, sustainable design strategies, sustainable manufacturing strategies, landscape analysis and planning

Courses
Sustainable Energy Systems [NRE 574/ PUBPOL 519/RCNSCI 419] (3)
Principles of Ecodesign and Manufacturing [ME 589] (3)
Cases Studies in Environmental Sustainability [CEE 686/ChE 686] (2-3)
Management for Sustainable Manufacturing [ME 599] (3)
Sustainable Manufacturing [OMS 742] (1.5)
Design of Environmental Engineering Systems [CEE 460] (3)
Hydrogen Production & Storage [ChE 496] (3)
Environmental Microbiology [CEE 582] (3)
Building Ecology [Arch 575] (3)
Green Construction [NRE 677/BA741] (1)
Landscape Analysis and Planning [NRE 687] (4)
Applying Landscape Ecological Design to Brownfield Redevelopment [NRE 787] (2 or 3)

3) Sustainable Enterprise (3-6 hrs)

Skills and Techniques
Strategic planning, scenario analysis, transformational leadership, organizational change, institutional change, stakeholder engagement, conflict resolution, ethical conduct.

Courses
Strategies for Environmental Management [NRE 513/ CSIB 564* & 565**] (3)
*Competitive Environmental Strategy [CSIB 564] (1.5)
**Strategies for Sustainable Development [CSIB 565] (1.5)
Institutions for Sustainability [NRE 565] (3)
Managing Organizational Change [NRE 501] (2)
Natural Resources and Environmental Conflict Management [NRE 532] (3)
Negotiating Skills In Environmental Dispute Resolution [NRE 533] (3)
Environmental Risk Communication [NRE 515] (3)
Behavior and Environment: The Psychology of Human-Environment Interaction [NRE 560/UP 560] (3)
Ethics Corporate Management [NRE 512] (2)
Business Ethics, Science & Technology [LHC 503] (1.5)
Environmental Management Topics [CSIB 734-738] (1.5)
Sustainable Manufacturing [OMS 742] (1.5)
Social Institutions for Energy Production [NRE 527] (3)
Green Construction [NRE 677/BA741] (1)
Finance and Sustainable Enterprises [FIN 637] (1.5)
Non-Market Strategy: Shaping the Rules of the Game [BE 555] (1.5)
Environmental Economics [NRE 571/Econ 471] (3)

Intermediate Natural Resource Economics [NRE 583/Econ 472] (3)
Integrated Strategy: Corporate Social Responsibility, Sustainability, and Environment [NRE xxx/BE 556] (1.5)

b. SNRE Core Requirements (13 hrs total)

1) Core Courses (10 hrs)
Integrated Problem Solving [NRE 580] (3) W
Ecology: Science of Context and Interaction [NRE 509] (3) F
Environmental Governance, Choices, Institutions and Outcomes [NRE 510] (3) F
Laboratory in Social and Natural Science [NRE 507] (1) F

2) Analytics (3 hrs)
Statistics (3) see SNRE list; also satisfied by comparable courses in other Units.

c. Opus Options (0 - 6 hrs total)
Students can fulfill this requirement by completing 1) or 2) below:

1) Masters Project (NRE 701), Masters Thesis (NRE 700), or Practicum
2) Additional Coursework (6 credits)
a. 3 credits of Sustainable Systems Core
b. 3 credits of coursework related to your field of study that is approved by your Advisor
d. Electives (8 - 14 hrs total)
Students are encouraged to take additional Sustainable Systems core courses, policy courses listed below, and/or other courses in SNRE or in other UM departments.
Water Resources Policy [NRE 558/CEE 587] (3)
Environmental Policy [PUBPOL 563] (3)
Resource Policy and Administration [NRE 562] (3)
International Environmental Policy and Law [NRE 559] (3)

e. Cognates (minimum of 4 hrs)

1) minimum of 4 hrs outside M.S. degree program

Abbreviations
ARCH = Architecture
AOSS = Atmospheric, Oceanic and Space Sciences
BE =Business Economics and Public Policy
CEE = Civil and Environmental Engineering
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EHS = Environmental Health Sciences
FIN = Finance
LHC = Law, History, and Communication
ME = Mechanical Engineering
NRE = Natural Resources and Environment
OMS = Operations and Management Science
PUBPOL = Public Policy

Master of Science in Engineering Requirements
Chemical Engineering

BS degree in Chemical Engineering (or equivalent) ChE graduate credits: 21 or more hours

Must include:

Research Survey ChE 595
Fluid Flow ChE 527
Reactor Analysis ChE 528
Heat and Mass Transport ChE 542
Statistical Thermodynamics ChE 538

One of the following:
Math/Modeling/Thermodynamics Electives ChE 507/508/509/510/554

May Include:
Up to 6 credit hours of ChE 695 (Research) count toward requirements.

Cognate graduate credits: 4 -9 hours

Must include:

At least two relevant 2 or 3 or 4 credit-hour courses.

Total credits: 30 hours

Grade point average required: 5.00 (B or better)

Master of Science in Engineering Requirements
Mechanical Engineering

The Master of Science in Engineering (MSE) degree in Mechanical Engineering requires a Bachelor of Science (BSE) degree in Mechanical Engineering or its equivalent. There are several MSE degree program options described below. New graduate students are encouraged to discuss with their faculty advisor which option might be most suitable for their professional goals.

Program Options and Requirements

There are four separate MSE degree program options in ME: (i) coursework only, (ii) coursework with an individual study project, (iii) coursework with an M.S.E. thesis, and (iv) coursework with a practicum in industry. In the Notes section following the description of degree program options below, there is information that further describes course/program requirements. While the list is not all encompassing, the information may pertain to any one or all options. Please also refer to the audit sheet for further details. You are encouraged to go over the academic requirements with both your faculty advisor and the graduate student advisor.

Planning Your Program

In planning your program, it is strongly recommended that all incoming graduate students meet with their faculty advisor and/or the graduate student advisor as soon as possible. The MSE degree program provides the student with considerable flexibility. This flexibility also puts a lot of **responsibility on the student to know what the requirements are** and how the available programs and courses can best be utilized to meet individual educational and professional goals. Your faculty advisor and the graduate student advisor can provide considerable assistance in this regard, help minimize problems, and make sure you get the most out of your graduate studies.

The MSE program covers a broad range of topics and activities. You should identify an area of interest (e.g., fluid mechanics, biomechanics, manufacturing, etc.). Then, in consultation with your faculty advisor, plan your course selections. Consult the Time Schedule for dates, times, and location of courses. For course descriptions refer to the College of Engineering Bulletin.

Important Rules to Note:

- All options require 30 graduate level credit hours.
- For each category of the MSE Audit Sheet (A, B, C, D), only B may have credits that are not letter-graded. This category is where any research credits are placed, which most of the time have a grade of "S" (satisfactory). All other categories must have letter-graded credits.
- Cognate credits are non-ME credits. To fulfill this requirement, you may take almost any course from the College of Engineering, which may also be cross-listed with ME. Or, credits may be from the Department of Mathematics, Statistics, Chemistry, Physics, Physiology, or Biology. In some cases substitutions may be allowed in other scientific areas but require a written petition from the student and approval by the ME Graduate Program Chair.
- It is possible to satisfy the cognate requirement and the math requirement simultaneously. This distribution merely allows for more ME courses in your curriculum.
- ME 599 courses (Special Topics) must be taught by a UM faculty to satisfy a requirement. If not taught by a UM faculty, the 599 course may be used to satisfy an ME 400 level requirement if the math course is used to satisfy both a math and a cognate requirement.

Coursework only

This option is essentially an extension of the undergraduate degree and is recommended for those students who do not envision any involvement in industrial research and development or teaching. This degree can be completed in ten months by, for example, taking four courses each during Fall and Winter terms and two courses during the Spring half term.

- 12 credits ME courses at the 5xx or 6xx level
- 6 credits ME courses at the 4xx level or above
- 6 credits of non-ME courses at the 4xx level or above

- 6 credits mathematics or equivalent courses (see Acceptable Math list)

Coursework with an individual study project

This option provides an opportunity for some involvement by the student in an independent engineering design, analysis, or research project. The requirements are the same as the coursework only option, except that 3 to 6 credits of research (590) are taken in lieu of 400 level courses. This is recommended for students contemplating an engineering career in industry and who would like to gain some exposure to individual research. This requires that the student talk to faculty and find a potential faculty advisor and an individual study topic. This is typically done during the student's first term in the Master's program so that she/he can begin the individual study the second term. Typically this option may take twelve months, e.g., Fall, Winter, Spring and Summer terms.

- 12 credits ME courses at the 5xx or 6xx level
- 6 credits ME research course (590) (or 3 credits 590 and 3 credits ME courses at the 4xx level or above)
- 6 credits of non-ME courses at the 4xx level or above
- 6 credits mathematics or equivalent courses (see Acceptable Math list)

Thesis

This option requires the completion of a formal M.S.E. thesis, and is recommended for students interested in industrial research and development, teaching, or possibly continuing for the Ph. D. This option requires that the student find a faculty advisor who will supervise the thesis research. Research credits are taken under the advisor's independent study number and a formal thesis, acceptable to the thesis committee of at least two including the research advisor, is prepared. The thesis is defended before the committee in a public examination. (See the handout entitled "Thesis Option" for more information.)

- 12 credits ME courses at the 5xx or 6xx level
- 9 credits ME research courses (3 credits 595 followed by 6 credits 695) (typically 3 credits of 695 are taken per term)
- 3 credits non-ME courses at the 4xx level or above
- 6 credits mathematics or equivalent courses (see Acceptable Math list)

Coursework with an engineering practicum

This option provides an opportunity to work at companies on team projects for which they will be compensated by that company. Students interested in this option should meet with their faculty advisor and with the Interpro Program Manager (1539 DOW) during their first term to discuss possible opportunities. The Interpro Office will also advertise (mandatory) meetings regarding the procedures and possibilities for a practicum.

- 12 credits ME courses at the 5xx or 6xx level
- 3 credits ME courses at the 4xx level or above
- 3 credits team project in industry (ENG 600) - Interpro Office must register you
- 6 credits of non-ME courses at the 4xx level or above
- 6 credits mathematics or equivalent courses (see Acceptable Math list)

Master of Science in Engineering Requirements
Environmental Engineering

Environmental and Water Resources Engineering Program
Department of Civil and Environmental Engineering
College of Engineering
The University of Michigan
(Revised August 2005)

REQUIREMENTS AND PROCEDURES

These guidelines have been developed to assist graduate students working toward the M.S.E. degree in Environmental Engineering in planning a program of study to meet the requirements of that degree. Each student is responsible for planning such a study program, generally with the guidance of an advisor selected or assigned from the Environmental and Water Resources Engineering (EWRE) program faculty:

P. Adriaens
J.W. Bulkley
A. Cotel
A.H. Demond
K.F. Hayes
N.D. Katopodes
C. Lastoskie
T.M. Olson
L. Raskin
J. D. Semrau
S.J. Wright/A.M. Michalak, Graduate Program Advisors

I. REGULATIONS

The basic requirements for the M.S.E. degree are established by the Horace H. Rackham School of Graduate Studies. The faculty of the Department of Civil and Environmental Engineering has adopted certain additional requirements. These requirements as they relate to the M.S.E. in Environmental Engineering degree are described in these guidelines.

Each M.S.E. student must take personal responsibility for seeing that all requirements are met prior to the dates specified by the Graduate School. If special decisions or actions are needed, they should be initiated by the student through consultation with the graduate program advisor and the chairman of the Graduate Committee.

II. PROGRAM INFORMATION

A. Degree Offered

Master of Science in Engineering in Environmental Engineering, administered by the Environmental and Water Resources Engineering (EWRE) program in the Department of Civil and Environmental Engineering.

The purpose of the Environmental Engineering degree is to permit a higher level of specialization in Environmental Engineering than achieved in an undergraduate degree. The Environmental and Water Resources Engineering program also offers the M.S.E. degree in Civil Engineering with a specialization in Hydraulics and Hydrology. Students interested in this program should consult the separate Civil Engineering M.S.E. guidelines.

B. Admission

Completion of the Graduate Record Examination (GRE), general examination (verbal, quantitative, analytical) is required for consideration of an application.

To be granted regular admission to the M.S.E. in Environmental Engineering program, an applicant would normally hold a B.S. degree in any traditional engineering discipline (e.g., civil, chemical, etc.) and have attained an undergraduate grade point average (GPA) of at least 3.2/4.0. Students holding B.S. degrees in physical and biological science or related fields may be admitted if they have achieved the technical background required to pursue advanced work in Environmental and Water Resources Engineering. The EWRE Graduate Program Advisor reviews each application to determine whether these requirements are met. Applicants who do not meet the requirements, but who otherwise present sufficient evidence that they can meet the scholastic requirements of advanced study, may be granted either conditional admission or non candidate for degree (NCFD) admission. Students should consult the Graduate School BULLETIN for details concerning these types of admission status. In any case, students seeking a graduate degree in Environmental Engineering are expected to be proficient in both the scientific and engineering aspects of the field.

A student admitted to the M.S.E. (Environmental Engineering) program is expected to have certain background knowledge. Undergraduate core requirements for the M.S.E. degree include:

Math 216	Differential Equations
Chem 210	Structure and Reactivity
CEE 325	Fluid Mechanics
CEE 360	Environmental Process Engineering

None of the courses listed above may be used for graduate credit. Students who have not taken these courses or their equivalent are required to have taken them prior to completion of the M.S.E. degree and preferably prior to commencement of their graduate studies. It is necessary to maintain a B average in these courses.

It is also expected that a student will have breadth in the fundamentals of environmental engineering. The following list of courses must be completed to meet this requirement:

CEE 460 – Design of Environmental Engineering Systems ***or*** CEE 500 – Environmental Systems and Processes I
CEE 581 – Aquatic Chemistry
CEE 582 – Environmental Microbiology
CEE 428 – Introduction to Groundwater Hydrology ***or*** CEE 526 – Design of Hydraulic Systems
CEE 587 - Water Resource Policy ***or*** NRE 562 – Resource Policy and Administration ***or*** NRE 571 – Environmental Economics

Equivalent courses taken at other universities (even to meet undergraduate degree requirements) can be used to satisfy the breadth requirement. In the cases where a choice of two courses is allowed, an equivalent course in either topic can be used to meet the breadth requirement. Determination of equivalence of graduate or undergraduate coursework from another institution will be assessed by the Graduate Program Advisor.

C. General Requirements and Policies

1. Credit Hours and Normal Progress

A minimum of 30 credit hours of approved graduate work must be completed for the M.S.E. degrees. Nine to twelve hours of credit per term is the usual full-time graduate course load. Graduate students with research or teaching appointments generally elect no more than six to nine credit hours per term.

2. Grades

The average grade for all graduate level courses taken while enrolled in the Graduate School and for the 30 credit hours used to fulfill the credit hour requirement must be at least B (5.0/8.0). A grade below C in any course is unacceptable. A course in which a lower grade than C is obtained is not counted toward the credit hour requirement but is considered in the computation of the overall grade point average.

3. Thesis

A thesis is not required, but up to 6 hours of credit of directed study can used toward the 30 degree credit hour requirement by electing Special Problems or Research courses in hydraulics/hydrology (CEE 622 or 921) or environmental engineering (CEE 682 or 980).

4. Language

Proficiency in the English language, both spoken and written, is expected. There is no requirement for proficiency in any other language.

5. Comprehensive Examination

Comprehensive examinations are required only for those students who wish to study beyond the M.S.E. degree.

6. Residence Requirements

The Graduate School residence requirements are satisfied by full-time students enrolled for 2 or more semesters. Students pursuing the M.S.E. degree on a part-time basis should become familiar with special requirements relating to part-time enrollment (see the BULLETIN).

7. Time Limit

A student must complete all work within a period of six consecutive years after first enrollment in the Graduate School.

8. Transfer Credits

The Horace H. Rackham School of Graduate Studies guidelines permit transfer of up to half the minimum number of credit hours required for the M.S.E. degree from inter-university and intra university sources combined according to the following rules:

a. Graduate Credit

A maximum of 6 hours of graduate credit may be transferred from another institution. These must be approved graduate-level courses taken while enrolled in a degree program with a grade of B or better from a graduate school of an accredited institution approved by the Horace H. Rackham School of Graduate Studies. Graduate extension courses will be considered only from The University of Michigan, Wayne State University, Michigan State University, Western Michigan University, Central Michigan University, Eastern Michigan University, Northern Michigan University and Oakland University. Considerations of credit transfer will be made only upon written application of the student to the Graduate School through the Department of Civil and Environmental Engineering, and only after the student has established an overall graduate grade point average of B or better in resident work. Courses cannot be transferred for credit if already applied toward another degree, or if taken more than five years before beginning of graduate study at The University of Michigan.

b. Pre-graduate Credit

Credit for courses taken by the student with a B grade or better earned during the senior year in The University of Michigan's College of Engineering may be included in the student's graduate study program subject to the following regulations: (1) credit was not used to meet the bachelor's degree requirement, either as required coursework or as required credit hours, (2) credit was earned no more than two years before formal admission to the Graduate School and (3) credit was earned in courses approved for graduate credit by the Graduate School. The student may request the transfer of such credits by the Graduate School through the Department of Civil and Environmental Engineering any time after admission.

D. Study Program

A minimum of 15 hours of the total 30 hours required for the M.S.E. degree must be elected from courses offered by the Department of Civil and Environmental Engineering. Graduate level courses taken to fulfill the breadth requirements described above may be counted towards this fifteen hour requirement. In addition to the courses required to fulfill the breadth requirements, a student must complete at least three other environmental and water resources engineering related electives (9 credit hours) in the department. Up to six credits of directed study (CEE 622, 682, 921, 980) may be taken to meet this requirement. It is expected that the selection of the elective courses will provide the student with more in-depth knowledge of a particular area within environmental engineering.

The 30 hours of graduate work must include at least two cognate courses (course work related to the field of specialization) from a department other than Civil and Environmental Engineering. Courses crosslisted with the Department of Civil and Environmental Engineering cannot be accepted as cognate courses. Each cognate course must be a minimum of two credit hours. One cognate course may be used to satisfy the advanced mathematics requirement described in the following paragraph. The graduate courses from the School of Natural Resources and the Environment (NRE 562 and 571) required to fulfill the breadth requirement may also be used as one of the cognate courses.

The student must complete at least one course in mathematics, probability, statistics, or mathematical programming that is taught at a level consistent with a pre-requisite of Math 215. A list of courses that are unacceptable to satisfy this requirement is available from the graduate program advisor.

A 400 level course that is listed in the BULLETIN of the Horace H. Rackham School of Graduate Studies may be elected for graduate credit when approved by the student's advisor. Of all the 400-level courses elected, no more than a total of 12 hours, and no more than 9 hours of 400-level Civil and Environmental Engineering courses, will be accepted towards the 30 hour requirement.

Appendix B

Deans' Letters of Support

David C. Munson, Jr.
Robert J. Vlasic Dean of Engineering

Rosina M. Bierbaum
Dean of the School of Natural Resources and Environment

DAVID C. MUNSON, JR.
ROBERT J. VLASIC DEAN OF ENGINEERING
PROFESSOR OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

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February 21, 2007

Dean Janet A. Weiss
Assistant Dean Homer C. Rose
Horace H. Rackham School of Graduate Studies
University of Michigan
915 East Washington Street
Ann Arbor, Michigan 48109-1070

Dear Janet and Homer,

The College of Engineering is pleased to support the proposed dual masters degree program with the School of Natural Resources and Environment. I believe that the Engineering Sustainable Systems (ESS) program provides a new educational initiative in this increasingly important field while building upon the strengths of two highly regarded and well-ranked schools at the University of Michigan. The ESS vision of integrating a fundamental engineering curriculum with sound ecological science is a natural fit and presents future ESS graduates with a wide range of research and employment opportunities.

Interdisciplinary research is a hallmark of Michigan Engineering. This is currently best represented through ongoing collaboration between the College and the schools of Medicine, Business, and Information. In fact, Michigan is one of only two universities in the nation with top-ranked engineering, medical and business schools. I look forward to extending this theme of interdisciplinary education and research to another highly ranked school at Michigan, the School of Natural Resources and Environment.

This unique combination of top-ranked programs in the environment and engineering sets us apart from our peer institutions. The engineering and sustainability nexus, however, is a rapidly growing research and education field that is being pursued by other universities. The University of Michigan is now positioned to take the educational lead with this dual degree program. Part of our Michigan Engineering mission is to challenge students, faculty and staff to learn, to grow, to achieve and to serve the needs of society. The Engineering Sustainable Systems dual degree program fits well within that service-oriented mission.

I view this proposed program as a complement to new initiatives on both north campus and central campus including the Graham Environmental Sustainability Institute and the Michigan Memorial Phoenix Energy Institute. ESS can also leverage existing research centers within both Engineering and SNRE including the Center for Sustainable Systems (CSS), the Hydrogen Technology Laboratory, the Environmental and Sustainable Technologies Laboratory (EAST), Michigan Sea Grant, the Cooperative Institute of Limnology and Ecosystems Research (CILER), the Institute for Fisheries Research (IFR), the Automotive Research Center, and the Transportation Energy Center.

I support double-counting one quarter of graduate credit hours and view this increase of double-counted credits as critical to the success of the ESS program. As highlighted in the proposal, the common overlap between SNRE and Engineering science-based and analytics-based curricula is a strong justification for an increase in double-counted credits. Michigan Engineers, at the graduate and undergraduate levels, learn how to apply the latest developments in technological thinking to the world's major problems. I agree that allowing ESS program students to take full advantage of this unique cross-disciplinary atmosphere by double-counting one quarter of required credits increases student attraction to the program while not reducing the quality of a Michigan Engineering education.

The University of Michigan College of Engineering is considered a world leader in both engineering education and research. I feel that the proposed Engineering Sustainable Systems dual masters degree program enhances that reputation by providing graduate engineering students with the tools to *engineer* solutions to one of our greatest challenges -- global sustainability. In closing, the College of Engineering fully supports this proposal and we will be excited to see it move forward.

Sincerely,

Dave

David C. Munson, Jr.

DCM/mas

NATURAL RESOURCES
AND ENVIRONMENT
UNIVERSITY OF MICHIGAN

February 16, 2007

Janet Weiss, Dean
Homer C. Rose, Jr., Assistant Dean for Academic Programs
Horace H. Rackham School of Graduate Studies
University of Michigan
915 E. Washington St.
Ann Arbor, Michigan 48109-1070

Dear Janet and Homer:

I enthusiastically endorse the Proposal to Create a Dual Degree Program in Engineering and Natural Resources and the Environment (*The Engineering Sustainable Systems [ESS] Program)* submitted by Associate Professors Greg Keoleian and Steve Skerlos and Professors Jonathan Bulkley, Levi Thompson, Mike Wiley, and Steven Wright.

The proposed dual Master's degree has been in development for more than two years, and has been reviewed and approved by faculty in the College of Engineering's (COE) Chemical Engineering, Civil and Environmental Engineering, and Mechanical Engineering Departments, and in the School of Natural Resources and Environment (SNRE). Interim Dean of Engineering Ron Gibala, and later, Dean David Munson, and I met with the faculty involved to refine their proposal. Moreover, we have had strong indications from industry partners that they believe graduates with such a background would be highly sought after.

You'll also note that this is proposed as a 2-2½ year degree. We believe this to be key to the appeal of this program to CoE M.S. in Engineering students. Given that it is now possible to obtain an M.S. degree in Engineering in one year, this degree's viability could hinge on making it achievable in a reasonable period of time. Moreover, doing so recognizes the common overlap that already exists between CoE and SNRE science- and analytics-based courses.

As you know, The Erb Institute for Global Sustainable Enterprise has created a highly successful dual degree program between the Ross School of Business and the School of Natural Resources and Environment (SNRE) that addresses the business and sustainability nexus. This program offers the potential for similar success with an academic bridge between technology and sustainability. The engineering and sustainability nexus is a rapidly growing area of research and education that is being pursued by other universities as well. This collaboration between a top engineering school and a top environmental school would put Michigan at the leading edge.

Sincerely,
SCHOOL OF NATURAL RESOURCES AND ENVIRONMENT

Rosina M. Bierbaum
Dean and Professor of Natural Resources and Environmental Policy

Appendix C

Selected Industry Letters of Support

Center for Sustainable Systems External Advisory Board Chairs
The Dow Chemical Company
General Motors Corporation
Daimler Chrysler

Kimberly-Clark

Xerox

Steelcase

Michigan Environmental Council

The Dow Chemical Company
Midland, Michigan 48674
USA

2030 Dow Center
January 11, 2007

Associate Professor Gregory A. Keoleian
Co-Director Center for Sustainable Systems
School of Natural Resources and Environment
University of Michigan
3504 Dana Building
440 Church Street
Ann Arbor, MI 48109-1041

Dear Dr. Keoleian:

Thank you for sharing with us your proposal to the University of Michigan's Rackham Graduate School for creation of the new Engineering for Sustainable Systems (ESS) dual master's degree program between the College of Engineering and School of Natural Resources and Environment. The educational program you propose which integrates the design and engineering of new technologies with sustainability through natural and social sciences is truly unique among academic institutions. The Center for Sustainable Systems External Advisory Board (EAB) fully supports this proposed program. We expect this endeavor will lead to educational opportunities for students, and ultimately graduates of the program, who will be equipped to address sustainability challenges that we confront directly in our own organizations.

Since the Center for Sustainable System's founding as the National Pollution Prevention Center in 1991, the External Advisory Board has been very active in guiding its research, education, and outreach activities. We have seen issues related to global sustainability gain increasing attention. The Center's earlier efforts in education, including pollution prevention curriculum development and the Graduate Certificate Program in Industrial Ecology, have proven to be very successful. We are pleased to see this exciting next step take form.

The objectives for this new program align closely with sustainability goals that are indicated in our respective corporate mission statements and sustainability reports. We have made firm commitments to develop and implement new technologies designed to meet societal needs within the context of social, economic and ecological sustainability. Realizing the importance of new technologies and innovations, it is critical to train a new generation of engineers and designers with a scientific understanding of sustainable development issues in both developed and developing countries. Tools such as life cycle assessment and environmental accounting provide key metrics for measuring progress toward sustainability. As part of a larger system, adoption of sustainable technologies requires an understanding of how government policy and markets influence the potential success of these technologies.

We are confident of the significant impacts future graduates of the ESS program will have on our organizations and beyond. Innovations arising from this new generation of sustainability-cognizant engineers are much needed to address growing global sustainability concerns. Within each of our respective organizations, we are confronted daily with the challenge of finding the brightest engineers capable of solving today's complex problems. Currently, an engineering

degree from the University of Michigan is highly regarded when considering a pool of employment applicants. The rigorous analytic skills demonstrated by Michigan engineers are critical in developing today's technology. Along with this, we agree with the need for engineers to be trained in social, environmental, and economic sustainability. The highly renowned reputation of the University of Michigan School of Natural Resources and Environment provides this greater breadth and depth of understanding in sustainable design and development. We are confident these students will find employment in a variety of private, public or non-profit sector organizations such as the organizations represented on this board.

We enthusiastically support your proposed dual degree program linking the University of Michigan College of Engineering with the School of Natural Resources and Environment and look forward to its timely launching and its first cohort of graduate engineers.

On behalf of the entire Center for Sustainable Systems External Advisory Board,

The EAB Co-Chairs

Scott Noesen
Director of Sustainable Development
Dow Chemical Company
(outgoing Chair)

Terry Cullum
Director, Corporate Responsibility and Environment and Energy
General Motors Corporation
(Chair)

Ross Good
Senior Manager, Pollution Prevention
DaimlerChrysler
(Vice-Chair)

Kimberly-Clark

January 22, 2007

Associate Professor Gregory A. Keoleian
Co-Director Center for Sustainable Systems
School of Natural Resources and Environment
University of Michigan
3504 Dana Building
440 Church Street
Ann Arbor, Michigan 48109-1041

Dear Dr. Keoleian,

Kimberly-Clark was pleased to learn of the proposed dual master's degree program in Engineering for Sustainable Systems (ESS) at the November 15, 2006 CSS External Advisory Board (EAB) meeting. As a company committed to the health and well being of society, sustainable technologies are critical to the growth of our business. We believe the proposed program will provide a unique and effective approach to educating the engineers and scientists who will develop these technologies. As a member of the EAB, we support the current proposal and look forward to opportunities for further involvement with the ESS program.

Kimberly-Clark is a leading global health and hygiene company employing more than 57,000 people in 37 countries. Every day, 1.3 billion people trust Kimberly-Clark products and the solutions they provide to make their lives better. As a global company, we are committed to cultivating a fair, respectful and engaging work environment that inspires our diverse global team to thrive professionally and contribute to the communities where we operate. We also have a responsibility to attain a deeper understanding of our impact on the world. Addressing sustainability issues and incorporating solutions through all levels of Kimberly-Clark is a critical component of our business. Sustainability-minded engineers with an outstanding education from a top ranked engineering program and a prestigious environmental program would provide both the technical knowledge and leadership skills required to develop and implement next generation sustainable technologies.

I am looking forward to the opportunities to interact with students from this program.

Sincerely,

Yong Li
Director, Environmentally Sustainable Technologies

XEROX®

Patricia Calkins
Vice President
Environment, Health & Safety

January 17, 2007

Associate Professor Gregory A. Keoleian
Co-Director Center for Sustainable Systems
School of Natural Resources and Environment
University of Michigan
3504 Dana Building
440 Church Street
Ann Arbor, Michigan 48109-1041

Dear Dr. Keoleian:

Xerox Corporation is pleased to learn of your proposed dual master's degree program in Engineering Sustainable Systems (ESS). Engineers are critical players in determining whether sustainability practices will become an integral part of our culture. This newly proposed dual degree program is an important means for building sustainable design and development competency into the engineering professionals that will be responsible for future technology innovations and products. As you are likely aware, integration of sustainability-focused social/natural sciences with technology design and development is becoming increasingly important in industry, government, and society as a whole.

For your reference, Xerox is the world's largest document management company. A nearly $16 billion technology and services enterprise, Xerox develops and markets innovative technologies, products and solutions that customers can depend upon to improve business results. Xerox provides the industry's broadest portfolio of document systems and services, ranging from high-speed color presses to digital imaging archiving services.

Since the early 1990's Xerox has been on a journey to integrate sustainability practices into our business processes. This started with a broadened view of our value chain to incorporate life-cycle thinking into product design, development, and supply chain systems. We adopted the goal of manufacturing "waste-free products in waste-free factories to enable waste-free customer environments". Our first plank was to incorporate product remanufacturability into new product design. Engineers were fundamental to enabling this important initiative that in 2005 alone, prevented almost 40,000 metric tons from entering the waste stream, saving over 9 million therms of energy and associated carbon dioxide emissions, and saving Xerox

Xerox Corporation
800 Phillips Road
M/S 0105-70C
Webster, NY 14580
Telephone 585-422-2473

XEROX®

several hundred million dollars. This could not be accomplished without creative engineers that think beyond the traditional design and development concepts.

This dual degree program is the essential foundation for engineers that will enable them to bring new ideas to industry and government. They will be more effective in translating sustainability concepts into product design and development and in communicating these concepts to the technical community. This is a critical role that is sorely lacking in industry today.

Your vision of graduating a cohort of sustainability-minded engineers from both a top ranked engineering program and environmental program is truly unique within academia and represents the leading edge of the growing field of sustainable design and technology. We recognize the value future graduates of this program could represent within our company. Xerox Corporation fully supports your proposal and we are committed to building strong relationships between the ESS program, its graduates, and Xerox Corporation.

Sincerely,

Patricia A. Calkins

Patricia Calkins
Vice President
Environment, Health & Safety

Steelcase

January 10, 2007

Associate Professor Gregory A. Keoleian
Co-Director Center for Sustainable Systems
School of Natural Resources and Environment
University of Michigan
3504 Dana Building
440 Church Street
Ann Arbor, Michigan 48109-1041

Dear Greg,

I am very is pleased to learn of your proposed dual master's degree program in Engineering Sustainable Systems (ESS). I believe that this newly proposed dual degree program will provide a unique opportunity to educate engineers in the design and development of sustainable technologies. Integration of sustainability-focused social/natural sciences with technology design and development is becoming increasingly important in industry, government, and society as a whole. Realizing the important role a new breed of "sustainable design" engineers plays, I on behalf of Steelcase Inc., we would like to express our support for your proposed initiative.

From our long history of working together, I am sure you know that Steelcase believes that sustainability and environmental responsible design are key to the strategic direction of our business. As a leader in the office furniture industry, we believe it is our responsibility to continue to promote and drive the incorporation of sustainable thinking throughout our industry. I believe that engineers who are trained in a dual curriculum such as this will be better positioned for the job markets of the present and the future.

Your vision of graduating a cohort of sustainability-minded engineers from both a top ranked engineering and environmental programs represents the leading edge of the growing field of sustainable design and technology. We recognize the value future graduates of this program could represent within our company. Steelcase fully supports your proposal and we are committed to building strong relationships between the ESS program, its graduates, and Steelcase.

Sincerely,

David Rinard
Director Corporate Environmental Performance
Mail Code PS

Phone: 616.247.2996 Fax: 616.246.9191
Email: drinard@steelcase.com

January 16, 2007

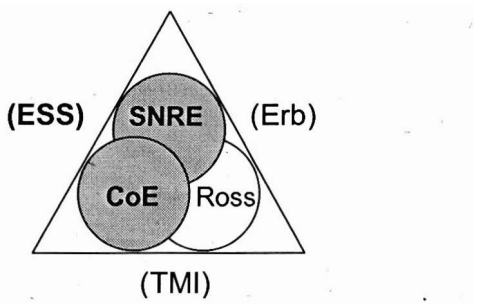
Associate Professor Gregory A. Keoleian
Co-Director Center for Sustainable Systems
School of Natural Resources and Environment
University of Michigan
3504 Dana Building, 440 Church Street
Ann Arbor, Michigan 48109-1041

Dear Dr. Keoleian,

The Michigan Environmental Council (MEC) strongly endorses the proposed dual degree program in Engineering Sustainable Systems (ESS). This formal connection between the School of Natural Resources and Environment (SNRE) and the College of Engineering (CoE) addresses a critical need for engineers who grasp ecological impact as a key design parameter.

MEC is a non-profit policy group committed to protecting human health and the environment. We often respond to harms caused or made worse by technologies aimed at meeting legitimate societal needs. Indeed the failure of well intentioned designers to anticipate negative effects of their work can bring enormous costs. ESS represents a new paradigm that can rectify this situation. Today's graduate engineers will be tomorrow's technology leaders in business, government, and academe. ESS will equip them with a systems approach to better understand complex interactions in the real world – specifically between technology and the environment. And this new program will facilitate the teaching of ecologically-inspired design, or biomimicry.

Beyond my role at MEC, personal experience gives me a unique perspective on the value of ESS. As a student in the Erb dual degree program (MBA/MS '01), I earned a certificate through the Tauber Manufacturing Institute. This gave me access to two effective synergies on campus: SNRE/Ross (Erb) and CoE/Ross (TMI). But an obvious third, SNRE/CoE, was unavailable at the time, despite the vital role for ecologically-trained engineering professionals in achieving a sustainable manufacturing sector. Now, ESS fills this educational gap as illustrated here:



Again, MEC heartily supports leveraging the University of Michigan's world-class engineering and environmental programs in this manner. ESS demonstrates the University's continued commitment to academic innovation and leadership among institutions of higher learning.

Good luck moving forward, and best regards,

David Gard
Energy Program Director

Michigan Environmental Council, A Coalition of Organizations Protecting Michigan's People and the Environment
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