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Engineering Sustainable Systems: Sustainable Water Resources Dual Degree Program

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Engineering Sustainable Systems: Sustainable Water Resources Dual Degree Program

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EXTENDED ABSTRACT

This paper describes a new graduate program established in October 2007, a new dual degree Master's Program between the School of Natural Resources and Environment and the College of Engineering at the University of Michigan. This new program enables graduate students to complete both the Master of Science degree in the School of Natural Resources and Environment as well as the Master of Science in Engineering in the Department of Civil and Environmental Engineering in the College of Engineering. The anticipated time to complete the requirements for both degrees is 2-2.5 years. The objectives of the Engineering Sustainable Systems Program will be presented. There are currently substantial opportunities and great risks for our natural water systems. The foreseeable future will see increasing demands on our natural water systems in order to provide water for increasing human consumption. A delicate balancing exists between managing our water resources for consumptive use needs and the desire to maintain a healthy environment. Opportunities arise with changes in environmental regulations such as those that attempt to improve water quality by controlling combined sewer overflows. Risks arise through pressures associated with increasing urbanization in many watersheds as well as potential stresses associated with global climate change. The resulting situation is the ability to potentially restore impaired systems while also mitigating detrimental changes to ecosystems that are still currently in a reasonably good state. Meeting these challenges will require a new type of specialist with knowledge in the combined areas of physical and biological systems. The Sustainable Water Resources dual degree program is intended to fill the need for this type of specialty.

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1. INTRODUCTION

Sustainable Systems as a field of study had been discussed and considered at the School of Natural Resources and Environment starting in the late 1990's. Limited faculty resources precluded its initiation until new faculty had been hired with joint appointments in both the School of Natural Resources and Environment and in the Ross School of Business. These new faculty combined with the existing faculty plus the strong support of Dean Rosina Bierbaum who joined the School in 2001 provided the momentum to create the new Sustainable Systems field of study. However, even with these new faculty resources and the support of the Dean, it did take four years to obtain the approvals not only within the School of Natural Resources and Environment but also from the Horace H. Rackham School of Graduate Studies representing the University of Michigan.

2. PROGRAM OVERVIEW

Global climate change, energy security, ecological degradation, environmental threats to human health and resource scarcity are critical sustainability challenges for the 21st century. Technology can be both the cause of and the solution to many of these problems. The success of sustainable technologies is based upon their ability to meet societal needs within the context of economic and ecological constraints. The design and application of new technologies - a focal point of CoE - plays a key role in addressing these complex challenges through research and education in engineering design and the applied sciences. SNRE serves to provide a comprehensive understanding of technology limitations, opportunities, and consequences, systems thinking and ecological principles, and the mechanisms which bring about social change. This is accomplished through research and education in sustainability sciences, policy, and ecology. Both elements provided by CoE and SNRE are necessary to develop technology based solutions to the complex sustainability challenges of the 21st Century.

In order to respond to these challenges, the University of Michigan College of Engineering (CoE) and the School of Natural Resources and the Environment (SNRE) have established a dual master's degree program to train graduate students who will create engineered systems that are socially, environmentally, and economically sustainable. The Engineering Sustainable Systems (ESS) Program brings curricula and faculty together from CoE and SNRE and organizes them within a structure that builds upon core educational elements of individual CoE departments (e.g., Mechanical Engineering, Chemical Engineering, Civil and Environmental Engineering, CEE) and SNRE fields of study (e.g., Sustainable Systems, Aquatic Sciences). This program combines existing degree programs in the COE and SNRE. It is expected that the typical student will have earned an undergraduate degree from an accredited engineering program. The student enrolled in the program will fulfill current requirements for both the engineering degree and the Natural Resources degree that have credit hour requirements of 30 and 42 hours, respectively. Any student enrolled in the Rackham Graduate School at the University of Michigan has the opportunity to establish a student

initiated dual degree with the ability to double count up to one-sixth of the total hours required for the combined degrees. Following this path would result in a degree requirement of 60 credit hours; this was considered to be excessive, discouraging most students from pursuing the course of study. In seeking approval from the graduate school to initiate the dual degree program, approval to use additional double counting to reduce the total number of hours to 54 was obtained. The rationale for this direction was that the specific degree paths offered under the ESS program were sufficiently focused with considerable overlap such that the reduction in total hours could be justified. For example, under the regular Aquatic Sciences program in SNRE, several CEE courses are listed as available aquatic science electives. In the initial approval, three individual programs were established, each one representing a degree option of one engineering department and one subprogram within the SNRE. The three initial programs are Sustainable Design and Manufacturing Systems (Mechanical Engineering and Sustainable Systems), Sustainable Energy Systems (Chemical Engineering and Sustainable Systems) and Sustainable Water Resources (Civil and Environmental Engineering and Aquatic Sciences). This paper focuses on the latter degree program. It is anticipated that additional subprograms will be developed as experience with the program is acquired and interest expands. It is expected that additional programs may be developed within the three engineering departments associated with the initial program (e.g. sustainable infrastructure systems with affiliated with the Civil and Environmental Engineering Department) as well as other COE departments such as Materials Science and Engineering.

The current structure of the program was developed in discussions with the External Advisory Board (EAB) of the Center for Sustainable Systems of the School of Natural Resources and Environment at the University of Michigan. The Center for Sustainable Systems evolved in 1999 from the National Pollution Prevention Center for Higher Education that had been established in 1991 at the University of Michigan through a competitive grant process with funds provided by U.S. EPA. Members of the Center's EAB whose letters of support were selected to be attached to the proposal to establish the ESS dual degree program included the Dow Chemical Company, General Motors Corporation, Chrysler, Kimberly-Clark, Xerox, Steelcase and the Michigan Environmental Council. The rationale for developing the full dual degree program rather than a certificate or concentration program (e.g. an engineering degree with a concentration in sustainability) is that anything short of the dual degree would not provide the necessary immersion in the integrated aspects of both disciplines. Prospective employers such as those represented on the External Advisory Board indicate much interest in the employment pf individuals with this type of background. It is anticipated that employment will be available through the private, public or non-profit sectors. Demand is expected in the public sector through federal agencies such as the Department of Energy, Environmental Protection Agency, national labs, and state agencies such as departments of environmental quality. Depending on the specific degree selected, private sector employment could be expected through engineering consulting firms involved with some aspect of environmental management or corporations' environmental evaluation of products or processes, corporate environmental strategic planning, or research and development of sustainable technologies. The expected enrollment in the ESS program after its first five years is 15-

20 students among 3-5 dual degree program specializations. With the program approval in late October of 2007, it was difficult to advertise the program for the admissions cycle for the fall term of 2008. In spite of this limitation, the program appears to be well on the way to exceeding initial expectations with five (5) students committed to the initial program in the fall of 2008. There are at least two additional students who did not yet apply to the Sustainable Water Resources program because they did not know about the program at the time of their application to UM but who have committed to UM and will go through the process in the fall term. It is anticipated that during the academic year 2008/2009 the enrollment in the Engineering Sustainable Systems dual degree program will reach roughly half of the 15/20 students projected for the Program during its first five years. It should be noted that the new ESS program is part of the Sustainable Systems field of study that had its inception in the School of Natural Resources and Environment in 2005. The overall enrollment in the Sustainable Systems field of study in the academic year 2007/2008 is 71 with 13 graduating by August 2008. Applications for admission to Sustainable Systems for the academic year 2008/2009 totaled 116. Of those applicants admitted to Sustainable Systems, 42 have declared that they are coming to the University this coming September. Accordingly, the expected enrollment in the overall Sustainable Systems field of study is expected to be 100 students for the coming academic year.

3. Objectives

The specific objectives of the ESS dual degree program are as follows:

- Provide graduate engineers with a comprehensive understanding of major sustainability challenges facing society in the 21st century, including global climate change, energy scarcity, ecological degradation, environmental threats to human health, and resource scarcity.
    - Students will achieve scientific literacy related to air, water, and land pollution as well as ecological systems, energy systems, and important regional/global cycles (e.g., material, nutrient, carbon, and hydrologic).
- Educate students in the engineering design approaches for products, processes, and services that facilitate the sustainable application of technology.
    - Examples of sustainable design approaches include life cycle minimization of carbon intensity, remanufacturing, use of renewable materials and dematerialization.
    - To be successful, these approaches must be compatible with market and public policy constraints while also encouraging patterns of sustainable consumption.
- Provide students with the scientific knowledge and methods required to evaluate the sustainability of engineered systems.
    - Examples of necessary scientific knowledge include formation and transport of pollutants in air, water, and on land, impact of pollutants on humans, ecosystems, and infrastructure, and the evaluation of resource scarcity.
    - Examples of evaluation methods include life cycle modeling, energy analysis, integrated assessment, ecosystem modeling, GIS, materials flows analysis, risk benefit analysis, and economic analysis.

- Provide students with successful examples of sustainable technology design and offer students opportunities to practice sustainable design.
    - Successful examples of sustainable technologies currently in practice include renewable energy technologies, bio-refineries, development of water-free and petroleum-free manufacturing facilities, advanced bio-based composites, etc.
    - Core classes in the ESS program, along with independent study and research opportunities, will offer students the opportunities to conduct and learn from sustainable design projects.

4. Sustainable Water Resources: CEE and SNRE (Aquatic Sciences)

Increasing demands are being on natural water systems to provide additional water for human consumption or other uses in the foreseeable future. At the same time, increasing pressure is applied to maintain ecological integrity in unimpaired systems and to restore it in impacted systems. Satisfying both sets of concerns will require a delicate balance with the primary challenge to meeting these demands in a sustainable way. This requires not only careful management of current resources but also restoration to mitigate historical and potential future losses. Meeting these challenges will require a new type of specialist with knowledge in the combined areas of physical and biological systems. Water quality, aquatic habitat, stream morphology and other considerations must all be considered to ensure ecosystem integrity. The Sustainable Water Resources dual degree program is intended to fill the need for this type of specialty.

As mentioned previously, the dual degree program involves simultaneously satisfying the requirements for the degree programs in Civil and Environmental Engineering and the Aquatic Sciences program in SNRE. For example all SNRE masters' degrees require 10 credits of what are referred to as core requirements, including specific courses in ecology, integrated problem solving and policy. In order to maintain the sharp focus on the ESS program objectives, additional requirements have been imposed on the general structure of the individual degree programs. Although the distribution of elective credit hours remains the same as required in the standard degree, constraints on the choices of these electives serve to maintain the ESS focus. For example, the Aquatic Science component of the Sustainable Water Resources program will require the selection of one course from a group of electives in each of three different areas; organismal biology, ecosystem ecology, and ecosystem modeling. Similarly, in Civil and Environmental Engineering, requirements for courses in hydrological modeling and fluvial system processes have been imposed to partially fulfill the more general technical elective requirements in the regular degree program. Current relevant course offerings in the CEE department are being reviewed with the objective of partial restructuring to be more responsive to the needs of the dual degree program objectives.

Because of the large credit hour requirement for the proposed degree, a requirement for a masters' thesis or directed study project has not been imposed. However, there is room within the prescribed curriculum to partially fulfill degree requirements with credits associated with a project relevant to the goals of the degree program. Preliminary discussions with consulting firms involved with habitat restoration projects, for example, have indicated a willingness to cooperate with the university in developing meaningful

experiences for students enrolled in the program. It is anticipated that the advisor for such a project could be either from CEE or SNRE faculty, or preferably, collaboration among faculty members from both programs.

Historically, efforts at restoring and preserving natural water systems have been hampered by the inability of water resource managers to appreciate the complex interactions of processes in both the physical and biological spheres, as well as in the water policy arena. Training a new generation of scientists with backgrounds in these areas will lead to a better appreciation of the complexity of the response to human-induced activities and a more careful consideration of these effects during the planning process to minimize adverse impacts.

5. EXAMPLES

This section provides more concrete examples of the types of applications that graduates of the sustainable water resources program could be expected to make contributions to the resolution of. This list is not intended to be exhaustive but represents issues that individual co-authors have been involved with in recent years.

A relevant example of an individual course that has somewhat parallel objectives to the Sustainable Water Resources degree has been developed by one of the co-authors and has been supported under the Graham Scholars Program developed by the Graham Environmental Sustainability Institute at the University of Michigan. The web link to this course is as follows:

http://www.provost.umich.edu/gesi/academics/gsp_1.html.

The objective of this course was to examine various aspects of hydropower projects that have been proposed for the Patagonia area of Chile in South America. These factors were examined in the context of sustainability related to increased energy demands within the country and the technical, social and political constraints imposed in responding to these demands. Although individual courses within the sustainable water resources program would not be as comprehensive in their focus, the overall educational objectives of the degree program would permit graduates to respond to this type of challenge.

Additional examples of applications related to sustainable water resources principles include the following:

- Ecological restoration of rivers – considerable interest exists these days for habitat restoration in impaired river systems. In order to design restoration alternatives, a clear understanding of physical and biological processes is required. Structural modifications to river corridors may trigger responses further downstream as sediment transport adjusts to the altered conditions that may be imposed. An understanding of linkages between flow modification and ecosystem function are required in order to avoid unintended consequences. An area of particular interest is dam removal which is being increasingly considered as a habitat improvement option.

- Hypoxia in the Gulf of Mexico, Chesapeake Bay – The linkages between land use practices and the long range transport of nutrients to regions where the water quality impacts are observed requires an analysis of processes at a variety of temporal and spatial scales. There is a need to be able to predict biological responses to proposed changes in land management.

- Storm water control/treatment - Increasing development or other land use changes often goes hand in hand with increases of stormwater runoff. It is necessary to understand the tradeoffs between stormwater runoff control practices and the conveyance requirements for stormwater in order to design the most effective solutions. Water quality impairments to surface water receiving stormwater runoff are also an issue that needs to be addressed. This topic could be expanded to include the issue of combined sewer overflow control that many large cities especially in the eastern and mid-western U.S. are dealing with at present. Large underground storage systems are often implemented to provide temporary retention of peak flows to reduce the duration and magnitude of environmental discharges. A comprehensive view of system function as well as receiving water quality is necessary to design the most effective alternatives.

- Invasive species – alterations in an ecosystem often result in habitat degradation for native species and also provide opportunities for non-native generalist species to dominate the altered system. One established methods for control of the invasive species may need to be developed. Understanding the response of both native and invasive specifies to habitat modification and other response alternative is critical to the design of effective control strategies.

6. Observations

- The growth in enrollment in the Sustainable Systems field of study demonstrates the strong interest of graduate students to undertake courses of study that provide the foundation for career opportunities in both the public and private sector in this professional area.

- The existing three year dual master's degree program between the School of Natural Resources and Environment and the Ross School of Business has been in place since 1994. Its student population is targeted to reach seventy-five students enrolled i.e. 25 students in each year group. Many of the students in this program elect to enroll in the Sustainable Systems field of study to complement their MBA education in the Business School. Graduates of this dual degree program work in the private sector, public agencies and non-governmental organizations.

- It is believed that the enrollment in the dual degree program between the SNRE and the College of Engineering will grow and flourish as a consequence of the complex issues facing all societies globally. Energy issues, climate change, impacts on fresh water sources, sea level rise, fossil fuel limitations, food shortages all couple with population growth to require this young generation of water resource professionals to

have in-depth education in both engineering and aquatic sciences to be productive leaders over the next 40-50 years.

- The professional education provided by the dual degree program in Sustainable Water Resources reflects the role and missions of both the Universities Council on Water Resources and the Environmental and Water Resources Institute of the American Society of Civil Engineers. Both of these organizations recognize the critical importance of broad professional training and experience for water resource professionals. This new dual degree program in Sustainable Water Resources at the University of Michigan provides a unique opportunity for graduate students with undergraduate degrees in engineering to prepare to become leaders in the critically important field of sustainable water resources.

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