# Table of Contents

## Overview 4

### Website 4

### Participating Schools 4

### Administrative Contacts 4

| Faculty Steering Committee | 4 |
| Program Staff              | 4 |
| Participating Faculty Advisors | 4 |
| Other Participating Water Colleagues at Tufts | 5 |

### External Advisory Committee 6

### Student Advisory Committee 6

## Program Management 6

## Program Description 7

### Background 7

### Goals 8

### Major Research Efforts 9

### Joining the WSSS Program 13

## Educational Program Requirements 13

### Weekly Meetings 14

### Core Educational Areas 14

### Tracks 19

- **Track R: Interdisciplinary Water Resources Research** 19
- **Track P: Practicum/Interdisciplinary Professional Experience** 20
  - Practicum 20
  - Interdisciplinary Professional Experience (IPE) 20

## Career Development 21

## Appendix

- List of possible IPE sites
- Enrollment Form
- Petition for Exemption
- IPE Contract
- Requirements Form
Water: Systems, Science and Society (WSSS)
Research & Graduate Education Program

Overview

Website
www.tufts.edu/water

Participating Schools
The Graduate School of Arts & Sciences
The School of Engineering
The Fletcher School of Law & Diplomacy
The School of Medicine
The Friedman School of Nutrition Science & Policy
The Cummings School of Veterinary Medicine

Administrative Contacts

Faculty Steering Committee
Professor Richard Vogel, Ph.D., Department of Civil and Environmental Engineering, School of Engineering (Director and Chair)
Professor Timothy Griffin, Ph.D., Agriculture, Food and Environment Program, Friedman School of Nutrition Science and Policy
Robert (Rusty) Russell, J.D., Lecturer, Department of Urban and Environmental Policy and Planning (UEP), School of Arts and Sciences

Program Staff
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  Scott Horsley

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Friedman School of Nutrition Science and Policy
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Cummings School of Veterinary Medicine
  Mark Pokras
  Acacia Warren

Fletcher School of Law and Diplomacy
  William Moomaw
  Astier Almedom

Department of Public Health & Family Medicine, School of Medicine
  Jeffrey Griffiths
  Elena Naumova
  Siobhan Mor

Other Participating Water Colleagues at Tufts

Consortium of Universities for the Advancement of the Hydrologic Sciences
(located at 200 Boston Avenue, Medford, MA - www.cuahsi.org)
  Richard P. Hooper

Stockholm Environment Institute, U.S. Center
(located at 11 Curtis Ave, Medford, MA - www.seib.org)
  Jack Sieber  David Purkey  Eric Kemp-Benedict
  Brian Joyce  Annette Huber

U.S. Geological Survey, Massachusetts-Rhode Island Water Science Center
  Peter Weiskel
  Stacey Archfield
  Sara Brandt

External Advisory Committee

Upmanu Lall, Ph.D., Columbia University
George Pinder, Ph.D., University of Vermont
Perry McCarty, Sc.D., Stanford University
Peter Rogers, Ph.D., Harvard University
Rita Colwell, Ph.D., University of Maryland and Johns Hopkins University
Chris Field, Ph.D., Carnegie Institution of Washington
Ray Powell, DVM, Former Land Commissioner, New Mexico
Heather MacKay, Director, FHB Consulting Services, Inc.
John Foster, CEE ’52, Former CEO of Malcolm Pirnie Co
Paul Kirshen, Ph.D., Battelle, Founder of WSSS Program

Student Advisory Committee, 2009-2010

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Program Management

All aspects of the WSSS Program are developed and overseen by the WSSS Faculty Steering Committee. The Committee consists of WSSS Director Richard Vogel from the Department of Civil and Environmental Engineering, and Steering Committee members Robert (Rusty) Russell from the Department of Urban and Environmental Policy and Planning and Professor Tim Griffin, Director of the Agriculture Food and Environment Program at the Friedman School of Nutrition Science and Policy. WSSS Program administration consists of Program Manager Antje Danielson, Program Coordinator Heather Angstrom, and Student Coordinator Georgia Kayser, all of whom are administratively located at the Tufts Institute of the Environment in Miller Hall.

A multidisciplinary External Advisory Committee of 6-12 highly respected academics and practitioners, representing the range of water resources research interests in the program, meets annually to review and provide advice on the program.
WSSS also receives input from a Student Advisory Committee with representation from those schools and departments with the most active WSSS program participation. Each member of the committee represents all students and schools, but with particular emphasis on their home school. Members are selected by their peers each spring and serve a term of one year, after which they are eligible for re-election. The WSSS Steering Committee meets with this group periodically to garner feedback and suggestions. Additional comments and suggestions are welcome at any time from any student in the program.

Program Description

Background

Complex global water issues require an interdisciplinary approach that combines engineering with the natural, physical, and social sciences. Water professionals have been promoting the integration of relevant disciplines to solve water problems since at least the 1960s. As Dr. Rita Colwell has written, “In the 21st Century, we have to develop an integrated approach across the disciplines to understand the complexity of water issues worldwide” (A Global Thirst for Safe Water: The Case of Cholera, Abel Wolman Lecture, National Academy of Sciences, January 25, 2002, p. 4). Planning and regulatory processes historically have favored “integrated multidisciplinary” approaches that begin with specialists working within their disciplines and later attempting to integrate their results. Given that these efforts have met with mixed success, there remains a long-recognized need for professionals and researchers trained from the beginning to work across disciplines.

The Tufts University graduate education and research program in Water: Systems, Science, and Society (WSSS) answers the need for an integrated approach by encouraging interdisciplinary research. From the beginning, each participating student learns to consider problems from the viewpoints of several relevant disciplines. Doctoral and masters degree students from the Friedman School of Nutrition Science and Policy, the Fletcher School of Law and Diplomacy, the Cummings School of Veterinary Medicine, and the Schools of Arts & Sciences, Engineering, and Medicine at Tufts have completed the WSSS program.

The international community is faced with many problems related to water supply, use, and quality. These issues affect political relations, public health, agriculture, development, and the environment. Among the most pressing issues are conflicts involving trans-boundary rivers (some 260 rivers cross national lines), overuse of water resources (the Yellow River in China and the Colorado River in the United States are so over-used they are dry at their mouths), lack of access to potable water (a problem for 1.1 billion people) and adequate sanitation (2.4 billion people), and increasing water needs in settings of inadequate water supply. The Intergovernmental Panel on Climate Change (IPCC) states that long-term climate change and
population growth will place further stress on water resources in many places. In recognition of the severity of these problems, many of the Millennium Development Goals target water issues.

Major problems in the United States include over-allocation of water resources, combined sewer overflows, nonpoint source pollution (particularly in agricultural and urban watersheds), conflicts over the water rights of Native Americans, and periods of extreme drought and flooding. Two-thirds of the increase in expected lifespan in the U.S. since 1900 is due to clean water, sewage management, and clean food. Yet water contaminants -- including emerging pathogens, pesticides, heavy metals, disinfection byproducts, endocrine disruptors, and industrial carcinogens -- remain threats to public health.

A 2001 National Research Council report concluded that, because “solutions cross traditional disciplinary and societal boundaries, what is needed for understanding water resources is a more holistic conceptual framework.” The World Bank, the World Commission on Dams, and the Global Water Partnership also describe the need for integrated water resources management. Clearly, there is a significant need for innovative, interdisciplinary approaches to widespread and diverse water-related problems.

The WSSS program is designed to respond to these needs. The thematic basis of the program is to take a global view of the challenge of assuring water security for the protection of the environment, public health, and human livelihoods. We believe that in order to make original contributions to the management of multi-dimensional water problems, our students must be deeply skilled in one discipline, possess a breadth of knowledge of and experience with other relevant disciplines, understand how to integrate those disciplines, and be able to work effectively in many professional environments. Instead of amalgamating results after the fact, WSSS Program graduates are expected to take a multi-disciplinary approach to water problems from the outset, and work effectively with other specialists to devise collaborative solutions. WSSS was developed not only because faculty and other water professionals recognized the need for this kind of approach, but also because current and past Tufts students requested such a program.

In short, the vision of the WSSS Program is to train a new generation of professionals and researchers who understand the causes and dynamics of water-related problems from multiple points of view, yet have significant expertise in one discipline. As educators and leaders, these individuals will be able to anticipate and respond to emerging water-related problems, and work with others to develop and implement long-term solutions.

**Goals**

The WSSS program is based upon integrative graduate research and education—a model that organizes research according to the problems that need to be addressed, integrating across disciplinary boundaries. To this end, the program has three goals:
1. To develop interdisciplinary research projects that will make significant local, national, and global contributions.
2. To educate a diverse, ethical, skilled set of professionals who are trained to work across disciplines even as they develop a disciplinary specialization.
3. To meet the growing global demand for interdisciplinary water experts.

By achieving these goals, WSSS will equip its graduates to develop integrative, interdisciplinary solutions to the complex scientific, public health, economic, engineering, environmental, behavioral, planning, and policy issues surrounding national and international water crises.

WSSS students from a variety of degree programs consistently refer to the program as unique among the graduate programs they considered in the course of their application process. Here are some of their comments:

- “WSSS is unique in that it provides a platform for people to communicate across courses rather than just teaching...specific courses.”
- “Already, I have had lengthy discussions with environmental geochemists, epidemiologists, and MDs about potential research work. I feel that I am also learning a great deal from my fellow students because they come from such diverse backgrounds. This is an exciting way to develop a thesis, in that each area of your study can be strengthened by expertise in many disciplines, not just one. It is a program for me that finally ‘gets it’ -- that water issues cannot be examined from only one angle.”

**Major Research Efforts**

WSSS research focuses on water and people. The program’s research agenda is organized around the following six areas in which Tufts has well-established research initiatives:

1. Water Management in a Changing Environment: Hydromorphology & Climate Change
2. Water & Public Health
3. Water Pollution & Remediation Science
4. Watershed Management
5. Water, Agriculture, Food & Livelihood Security

These distinct areas are interconnected, so that research projects often support the goals of two or more of the areas. Much of our research is located in watersheds throughout the world where Tufts faculty have long-term research partnerships with local organizations and researchers. We also partner with many of the other research programs and centers at Tufts listed at [http://www.tufts.edu/home/research/?p=centers](http://www.tufts.edu/home/research/?p=centers).
1. Water Management in a Changing Environment: Hydromorphology and Climate Change

Water supply, instream flows, river and coastal flood management, waste assimilation, and other uses of water are affected by long-term climate and environmental change, and by policies seeking to adapt to those changes. Some recent or current research includes:

- **Hydromorphology:** A new science devoted to managing water in the face of land use change, water use changes, and climate change.
- **The impacts of climate change on flow regimes in the United States and elsewhere, and development of indicators of the impacts of climate change.**
- **The adaptation of metropolitan water supply and other infrastructure to climate change.**
- **The impacts of uncertain population growth, climate change, and transboundary issues on water supply in the Middle East.**
- **The use of remote sensing to study the influence of socio-economic activities on the environment.**
- **Distinguishing natural fluctuations in precipitation from anthropogenic or external effects.**
- **Socio-economic impacts of sea level rise and increased river flooding in the northeastern U.S.**
- **Managing impacts of climate variability and change on socio-economic and biophysical activities in New England.**

2. Water and Public Health

Water and public health are intimately related, particularly through integrative scientific, economic and policy analyses. In fall 2004, the WSSS Program received a $1 million, five-year grant from the National Institutes of Health for the funding of Ph.D. students conducting research in the areas of water and health. Current research includes:

- **The linkage between climate variability and change, and endemic and epidemic diseases in the U.S.**
- **Relationships between watershed ecosystems, animal life, and human health through heavy metals in the environment and sharing of water supplies.**
- **Integrative “system-wide” studies in the developed and developing world which link precipitation, streamflow, climate, ecosystem integrity, water quality, land use, food security, socio-economic characteristics, and human health.**
- **The explicit incorporation of health and livelihood objectives into large-scale water resource planning in Africa and other regions.**
• Sources of arsenic in Bangladesh and the relationship between arsenic poisoning and susceptibility to other waterborne diseases there.
• Using improved operational management and design of water resources to help control schistosomiasis, malaria, and other water-related diseases in African watersheds.
• Study of enteric viruses, bacteria and protozoa by the medical and veterinary schools.

3. Watershed Pollution and Remediation Science

Due to the complexity of the interactions among biophysical factors influencing groundwater, surface water, and sediment pollution and remediation, research must include interdisciplinary scientific approaches. Examples of interdisciplinary research efforts and projects include:

• Research by the Tufts Integrated Multiphase Environmental Systems (IMPES) laboratory, which includes efficient recovery of entrapped DNAPL mass from contaminated source zones, quantification of uncertainty in field-scale contaminant mass flux estimates, microbial transport and contaminant transformation in subsurface media, and the use of permeable reactive barriers for the removal of heavy metals from ground water. The IMPES lab was created in 2004 by Professor Linda Abriola, Dean of the School of Engineering and a member of the National Academy of Engineering.

• The surface water modeling group, which conducts research to build computer models of the complex hydraulic, chemical, and biological processes that govern the fate and transport of surface water pollutants. This group is developing user-friendly software to support the management of rivers and streams that face such problems as oxygen depletion, excessive plant growth and bacterial contamination.

• Modeling and exploitation of bioemulsifier systems to promote bioremediation and to improve the overall quality of contaminated groundwater and soils.

• Urban watershed remediation, including the study of arsenic cycling in lakes, fluorescent fingerprinting of organic contamination in water, and field sampling and laboratory experiments to deepen the understanding of the mechanisms controlling contaminant fate and transport.

4. Watershed Management

Human activity creates an unavoidable impact on watersheds, including lakes and rivers that are often hidden in the urban environment. Tools for balancing the needs of human and natural systems are key to long-term sustainability of watersheds. It is no longer possible to design systems to meet a single objective in a watershed, because most watershed processes are interconnected. For example, new methods of stormwater management will also lead to recharge of groundwater, thus increasing future water supplies. Examples of current or recent research in the area of watershed management include:
• Development of new approaches for managing watershed systems in a truly integrated fashion, taking into account the complex interactions among all watershed processes.
• Creation of Decision Support Systems (DSS) for the purpose of managing watershed nutrient loads in urban watersheds, water supply and demand in stressed watersheds, and water for both human and ecological systems.
• New algorithms for the estimation and modeling of precipitation, soil and hydraulic properties, and evapotranspiration, using multi-sensor remote sensing data and novel modeling techniques.
• The integration of environmental justice and sustainable communities into DSSs.
• The importance of vernal pools and upland forests for amphibian populations.
• The restoration of urban river channels to enhance animal habitat while simultaneously improving flood carrying capacity, as well as instream flow characteristics.
• Watershed management in Central America to protect coastal resources and coral reefs.

5. Water, Agriculture, Food and Livelihood Security

Water availability, access, and use affect agricultural production, other income-generating activities, and household livelihood security. Some research efforts in this area include:

• Increasing the use of seasonal climate forecasting in different regions of the world to minimize livelihood vulnerability.
• Managing and conserving water in both rain-fed and irrigated agriculture, including implementing practices that optimize soil-water relations.
• Evaluating relationships between water insecurity, environmental stresses, livelihoods, poverty, and sustainability in developing countries.
• Health and hygiene promotion interventions and their impact on health and social well-being of women and children.
• Research on how immigrant farmers from South Asia and Africa re-engage in farming in metro Boston.
• Studies of livelihoods at risk in crisis-affected and marginalized communities conducted by the Feinstein International Center at Tufts: the interplay of biophysical, socio-economic, and conflict-induced stresses, famine, and forced displacement.

6. Water and National and International Security

Because of its importance to all human activities, water requires special protection from targeted human threats. Here WSSS has research programs in the specific areas of sensor development, basic science in human pathogens, and policy analysis. Research efforts include:
• The development of fiber optical chemical sensors to continuously measure concentration changes of various components of biological and environmental samples. This is a major area of investigation at Tufts.

• Study of ways to detect, identify, and treat diseases terrorists could use to pollute the nation’s food and water supplies. Tufts is one of six centers designated within the Food and Waterborne Disease Integrated Research Network (FWD IRN) as part of a seven-year contract with the National Institutes of Health. The research focuses on 13 microorganisms -- including salmonella, *E. coli* O157H7, tularemia, the Norwalk virus, and others -- that could be used to infect large numbers of people and animals.

• Research into water as a source of cooperation at both the local and international scales. Because water is such a vital resource necessary for survival, negotiation over its allocation can actually bring together apparent adversaries – not only to resolve water conflicts but also to cooperate on other environmental, social, economic, political and security issues. In February 2005, a workshop at Tufts initiated research into this topic. By examining many case studies, cooperation over water was found to either result from or lead to cooperation over other issues.

**Joining the WSSS Program**

In order to be eligible for WSSS program participation, students must be enrolled in a graduate program in one of the participating Tufts schools. WSSS students obtain their graduate degree from this school or department, fulfilling all requirements for that program in order to gain depth and expertise in a particular discipline. After matriculating in the first year of their graduate program, students should submit the **Enrollment Form** (see the Appendix) to the WSSS Program Manager Antje Danielson no later than October 19, 2009.

In order to obtain the WSSS certificate, students must meet the requirements described below. These requirements do not add significant time to a student’s graduate program because many of the WSSS core courses may be used to fulfill requirements in students’ home departments. A **Requirements Form**, to be maintained by the student and turned in to the Program Manager no later than two weeks prior to the students’ graduation from Tufts, is in the Appendix. A WSSS certificate will be issued to the student upon receipt of the completed and signed Requirements Form.

**Educational Program Requirements**

The WSSS program requires that participating students:

• attend weekly WSSS meetings
• take three courses selected from three out of four broad core areas, and
• fulfill the requirements of one of two possible tracks (Track R or Track P).
Each of these requirements is outlined below. In addition, all WSSS students must participate in the planning and execution of the annual WSSS symposium.

1. Weekly Meetings

To support the development of an interdisciplinary WSSS research community, all participating students are expected to attend regular weekly meetings during the first two years of their graduate work at Tufts. After that, participation is optional but strongly encouraged. The initial weekly meetings – focusing on community-building experiences – will be held in September and early October on the Tufts Medford Campus. Thereafter, weekly meetings focusing on specific interests and topics will often be held in smaller groups, with plenary meetings interspersed. Locations for smaller group meetings will be on both the Medford and Boston campuses.

Activities and goals for the weekly meetings will include (in no particular order):

1. Orientation of new WSSS students
2. Fostering participation of returning WSSS students
3. Cultivating involvement of Tufts faculty and other water colleagues
4. Planning annual WSSS symposium and practicum
5. Research presentations by WSSS students, faculty, and other water colleagues
6. Coordinating and planning individual interdisciplinary WSSS research projects
7. Building leadership, public speaking, teaching, research proposal development, project management, and budgeting skills, and promoting the ethical conduct of research.

Meeting dates, locations, and topics will be posted on the WSSS web site (www.tufts.edu/water) and distributed via email.

2. Core Educational Areas

The Core Educational Areas of the WSSS program encompass the disciplines we deem necessary for integrated analysis of water issues. Thus, they support the six research areas discussed above, and in turn are deepened by our research projects. All students are required to take at least one course in three of the four core areas described below. Prerequisites may be excused with the permission of the instructor. In addition, an exceptionally well-qualified student may obtain exemption credit in one core area if the required approvals are obtained (see Exemption form in Appendix).

The required core areas and associated courses include the following. Several are cross-listed.

A. Water Resources Science and Technology courses concentrate upon the physical aspects of water science and management. Eligible courses include:

- **CE 112 Hydrology/Water Resource**
An introduction to the science of hydrology and to the design of water resource systems. Basic hydrologic processes such as precipitation, infiltration, groundwater flow, evaporation, and streamflow are discussed. Applications of hydrology to water supply, flood control and watershed modeling are emphasized. Students develop their own hydrologic models using computer software. Fall.

- **CE 172 Fate and Transport of Environmental Contaminants**
  This course focuses on the behavior of man-made chemicals that have been released into the environment. The basic processes by which chemicals move through surface water, ground water, soil, and air are examined. Chemical transformation mechanisms and partitioning are described for different chemical classes in different environmental media. Emphasis is placed on developing and using analytical tools to predict spatial and temporal variations in chemical concentrations in water, air, and soil. Spring 2009.

- **CEE 212 Chemical Principles in Environmental and Water Resources Engineering**
  Basic principles of water chemistry related to environmental and water resources engineering. Thermodynamics, chemical equilibrium, acid-base reactions, alkalinity, complexation, precipitation, dissolution, sorption, and reduction-oxidation reactions. Quantitative problem solving. Prerequisites: undergraduate chemistry. Fall.

- **CE 213 Transport Principle in Environmental and Water Resources Engineering**
  An examination of transport phenomena in the natural or engineered environment. Topics include: momentum transport, energy transport, mass transport, interphase mass transfer, and environmental applications of ideal and non-ideal reactor models. Students will enhance their ability to apply a first principles approach for analysis of complex environmental systems. Prerequisites: Equivalent of Mathematics 38 and Engineering Science 8. Fall.

- **GEO 131 Groundwater (Cross-listed as CEE-113 and Environmental Studies 113)**
  The geology and hydrology of groundwater. Topics include: hydraulic properties of soils, sediments, and rocks; physics of groundwater flow; flow nets, modeling groundwater systems; geology of regional flow; aquifer exploration and water well construction methods; well hydraulics and aquifer testing; applications in the geosciences and in civil/ geotechnical/environmental engineering. Fall.

**B. Biological Aspects of Water, Health and Nutrition courses** cover public health, epidemiology, biology, ecology, and environmental impacts. Eligible courses include:

- **CE 241 Biology Water and Health**
  This course explores the influence of waterborne pathogens on human and environmental health. The course allows participants to become familiar with
different disciplinary approaches to addressing the assessment and control of environmental and health effects of waterborne contaminants. Fall.

- **BIO 142 Population and Community Ecology**
  Introduction to population dynamics (population structure and growth), species interactions (predator-prey, competition, mutualism), and community structure (adaptations to the physical environment, patterns and processes governing the world’s biomes). Prerequisites: Biology 13, 14, or permission of instructor. Fall 2010 and alternate years.

- **BIO 143 Evolutionary Ecology**
  Theory and evidence on mechanisms of evolutionary change in natural populations. Population genetics, speciation, biogeography, biochemical coevolution, life history strategies, sexual selection, and genetics of endangered species. Prerequisites: Biology 13, 14, 41, or equivalent. Fall 2009 and alternate years.

- **BIO 144 Principles of Conservation Biology**
  Learning and application of principles from population ecology, population genetics, and community ecology to the conservation of species and ecosystems. Focus on rare and endangered species, as well as threatened ecosystems. Includes applications from animal behavior, captive breeding, and wildlife management. Readings from current texts and primary literature. Prerequisite: Biology 14 or equivalent. Spring 2010 and alternate years.

- **BIO 181 Tropical Ecology and Conservation**
  Ecology and evolution of biodiversity in the tropics. Meets three times per week during the semester and is followed by a trip to Costa Rica. Discussions of original literature; presentations of particular ecosystems, communities, or organisms; team design of research project to be completed during two weeks of intensive fieldwork in December/January in Costa Rica. Funding may be available for those in need. Prerequisites: Biology 14L, and permission of instructor. Fall 2009 and alternate years.

C. **Water Resources Policy and Planning courses** explore the use of policy and planning to achieve desired outcomes in water resources management. Eligible courses include:

- **UEP 279 Water Resources Policy and Planning and Watershed Management**
  Presents a comprehensive approach to water resources management through the integration of environmental science and policy. Intended for students with or without technical backgrounds. Course examines groundwater, lake, riverine, wetland, and coastal management issues and relies heavily on practical case studies to illustrate successful methods. Fall.

- **PS 194 Politics of the Environment in the U.S.**
  Examines the recent history and contemporary political debates surrounding
governmental decisions affecting the environment. Environmental policy making in the general context of U.S. policy-making processes and institutions, emphasizing the roles of federal, state, and local actors in defining environmental policy. Addresses such issues as policies toward air pollution, water pollution, hazardous waste management, environmental justice, sustainability, and public opinion toward the environment. Prerequisites: PS 61. Fall.

- **DHP P250 Elements of International Environmental Policy**
  An introduction to international environmental policy development, beginning with the scientific identification of the problem, the assessment of its economic and social impact, and the political forces that shape international agreements. Following a short introduction to some of the basic scientific and economic factors that characterize most environmental problems, the course examines five case studies that illustrate the range of international problems facing diplomats and corporations. Bilateral, multilateral and commons issues are studied using examples of air, climate, hazardous waste, fisheries, and biological diversity. Fall.

- **NUTR 212 Agricultural Science and Policy I**
  First part of a two-semester sequence. May be taken independently by non-AFE students; both semesters required of AFE students. This course covers the major biological, chemical and physical components of agricultural systems. Each is discussed from the viewpoints of both the underlying natural processes and principles, and their significance for major agricultural, food safety, and environmental policy issues in the US today. In the first semester, the topics covered are soils, water, air and energy, all of which are highly relevant to global climate change, as well as resource conservation policies. Spring.

- **NUTR 213 Agricultural Science and Policy II**
  In this second semester, the topics are plant nutrients, plant-pest interactions, crop breeding, and livestock growth and reproduction. Major policy issues associated with these areas include protecting groundwater from nitrogen contamination; regulating and monitoring pesticide use; regulating agricultural biotechnology; and regulating "factory" animal production. Fall.

- **UEP 174 Clean Air & Clean Water Policy**
  This seminar course examines air and water policy from the perspective of law, regulation, economics and politics, with particular focus on – and comparison among – the primary statutory programs that promise to deliver clean air and water: the Clean Air Act, the Clean Water Act and the Safe Drinking Water Act, as well as related federal and state programs. We look at the major challenges facing the process today, particularly those crossing media boundaries – for instance, global warming and mercury contamination. Students can expect to gain a stronger substantive
understanding of air and water policy, and a clearer sense of how citizen activists shape that policy – as well as a deeper appreciation for the work of regulatory bodies. Summer.

- **UEP 294 Planning for Low Impact Development (LID)**
  Designed for students in the field of planning, engineering, and environmental policy. Provides a land use planning approach and specific site planning skills. Low impact development (LID) is a land use planning and a site planning approach that integrates conservation design principles and specific best management practices to minimize or eliminate the environmental impacts associated with development. Course will present planning approaches using actual case studies. A field trip to visit LID projects will be scheduled.

D. **Economics and Systems Analysis courses** provide tools to analyze and evaluate complex, multifaceted problems. In most cases, students are also taking statistic courses as part of departmental requirements. Eligible courses include:

- **CE 214 Environmental and Water Resources Systems**
  Mathematical models of water resource and environmental systems are presented in combination with optimization procedures, decision theory, and environmental applied statistics to generate an integrated approach to the planning, design, and management of complex water resources systems. Water resources systems applications are formulated as decision problems where an optimal solution is sought, yet cost, safety, environment, and technology appear as competing constraints. Applications include regional water quality management; siting treatment plants; reservoir system operations; and design, irrigation, flood control, and watershed planning. Spring.

- **ECON 105 Mathematics for Economists**
  Introduction to mathematical economics. Core topics: calculus, linear algebra, unconstrained and constrained optimization, difference and/or differential equations, and dynamic optimization with emphasis on the use of these techniques in economics. Prerequisites: Economics 11 and Mathematics 11 and 12, or consent. Fall.

- **ES 152 Engineering Systems: Stochastic Models**
  An introduction to network models in the study/design of engineering, economic, environmental, and social systems with an emphasis on systems exhibiting probabilistic behavior. Topics include network models, Markov chains, queuing theory, reliability analysis, and genetic algorithms (GAs). Practical treatment is stressed; applications and projects are chosen from several areas, including civil and environmental engineering. Prerequisites: permission of instructor.
• **ECON 130 Topics in Environmental Economics**
  Research seminar for students who wish to pursue environmental economics beyond the level of Economics 30. Topics may include the design and administration of environmental excise taxes, the theory and practice of benefit-cost analysis, the economics of renewable and exhaustible resources, and the sustainability of economic growth. Prerequisites: Economics 11 and 30, or consent. Fall.

• **Fletcher EIB E246 Natural Resource and Environmental Economics**
  Building on basic concepts from microeconomics, this course emphasizes how environmental degradation takes place in market economies and how incentives can be designed to protect the environment. Topics covered will include resource consumption, innovation, international trade and the environment, global climate change and environmental regulation. Special attention will be paid to how such issues play out in Mexico and Latin America. Students will engage in empirical data analysis to test relevant environmental economics hypotheses. Open to students who have completed E201 or equivalent. Background in basic statistics and working knowledge of Excel is encouraged. Spring.

3. **Tracks**

WSSS students are required to choose and fulfill the requirements of either Track R or Track P.

**Track R: Interdisciplinary Water Resources Research**

Each student in this track undertakes a significant interdisciplinary water resources research project, culminating in the following:

1. By the end of their first year in the WSSS program, an Masters thesis or capstone proposal, or a preliminary dissertation proposal, as appropriate to the students' degree program,
2. By the end of their participation in the WSSS program, a completed thesis, directed study or dissertation,
3. By the end of their participation in the WSSS program, a refereed journal article 90% ready for submission by graduation from the WSSS program, and
4. During their participation in the WSSS program, a presentation at the annual WSSS symposium and/or a major national or international conference. Partial funding in support of such a conference presentation will be provided by the WSSS program.

Most graduate degree programs at Tufts require a thesis, directed study or dissertation based upon an original research effort for graduation. The WSSS Program additionally requires that this thesis/dissertation research be interdisciplinary, meaning that the review committee must have members either from at least two departments or who represent...
differing disciplinary perspectives. At least one faculty advisor must be a participating faculty member in the WSSS program.

The weekly meetings of the WSSS program will ensure that students electing this option will learn how to prepare a research project proposal, to read and critically review scholarly literature, to prepare a comprehensive interdisciplinary research paper suitable for publication in a refereed journal, and to present their findings at a suitable national or international conference.

**Track P: Practicum/Interdisciplinary Professional Experience**

Each student in this track is required to participate in the WSSS Practicum and complete an Interdisciplinary Professional Experience (IPE), described below.

**Practicum**

The Practicum will enable WSSS students to work in a small group on the integrated assessment of a water resources case study. The goal of the Practicum is to expose students at an early point in their graduate academic careers to the techniques and thought processes of integrated assessment in order to train them as researchers and professionals. The Practicum is headed by Rusty Russell of the Urban & Environmental Policy & Planning Department in the School of Arts & Sciences, with input from other participating WSSS faculty.

**Interdisciplinary Profession Experience (IPE)**

To foster individual student development, Track P students undertake a problem-focused, domestic or international field experience with a public- or private-sector organization—the Interdisciplinary Profession Experience (IPE). The goal of the IPE is for students to work in an area related to their academic water interest(s) and thereby to further integrate education, practice, and research. Students and their faculty mentors, however, may select other IPE placements tailored to the student’s interests. Students may secure their own IPE or seek the advice of WSSS faculty with similar interests. WSSS faculty members have access to an impressive array of potential opportunities in a wide range of international and domestic organizations. A partial list is included in the Appendix. Limited funding is sometimes available to support IPEs.

IPE requirements include:

- A minimum of 150 hours, logged at one time or spread over the period in which the student is participating in WSSS.
• An agreement between the student and the sponsoring organization specifying the purpose and location of the internship, duration, number of hours expected, and intern mentor/manager (see the IPE contract in the Appendix). After completion, the student must submit the contract to confirm completion of the IPE.

Some students may satisfy this requirement through prior experience. In addition, some existing internship programs required by students’ home programs (e.g., at the Department of Urban & Environmental Policy & Planning and in the AFE program at the Friedman School of Nutrition Science and Policy) may satisfy the IPE requirement, provided that they meet the objectives of the IPE noted above. Students who feel they are eligible for exemption from the IPE requirement should petition to the WSSS Internship Director, Rusty Russell.

**Career Development**

Students are treated as colleagues from the moment they enroll in the WSSS Program. Thus, career development begins immediately. WSSS faculty and staff provide a rich support network to help students find jobs in both academic and non-academic settings. Students can also seek employment advice and opportunities from a broad range of outside partners, while enhancing their career opportunities through research and internships.
Appendix

Possible Interdisciplinary Professional Experience (IPE) Sites

**International:** AGRHYMET (a regional agro-meteorology organization in the Sahel-Sudan); Agricultural Research Institute of Burkina Faso; Center for Development Studies, Bonn, Germany; Environmental Change and Security Project, Woodrow Wilson Center for Scholars; Ghana Water Resources Commission; Global Water Partnership; International Federation of Red Cross and Red Crescent Societies; Mekong River Commission; Pacific Institute for Studies in Development, Environment, and Security; several United Nations agencies (e.g., World Food Program, UNEP, UNDP, FAO); International Food Policy Research Institute; World Bank; World Health Organization; World Meteorological Organization; World Wildlife Fund; World Watch Institute; World Business Council for Sustainable Development, Assessments of Impacts and Adaptations to Climate Change (AIACC, START Secretariat), IWMI, Corporación Ecuatoriana de Biotecnología, Polytechnical University of Bobo-Dioulasso.


**US Nongovernmental organizations:** Howard University, Salish Kootenai College, Alternatives for Community and Environment; American Water Works Association; Boston Green Space Alliance; Clean Water Action; Eagle Eye Institute; Environmental Partnerships, Inc.; Mass Bays Program; Mystic River Watershed Association; National Resources Defense Council; National Rural Water Association; Save the Harbor/Save the Bay; Neighborhood Association of Affordable Housing; The Nature Conservancy; Trust for Public Land; Union of Concerned Scientists; Urban Ecology Institute, Pacific Institute.

Tufts University
Water: Systems, Science and Society Program
Enrollment Form
This form declares the student’s participation in the WSSS program and confirms his/her commitment to complete the requirements for the WSSS certificate.

Please print.
Name ______________________________________________    Student ID # ____________________
School/Department/Program ___________________________________________________________
Degree _______________________________   Expected Graduation Date (Month/Year) ____________

Intended Track (circle one):  TRACK R (research)    TRACK P (practicum/IPE)

Area(s) of research interest (check one or more):

☐  Water Management in a Changing Environment: Hydromorphology and Climate Change
☐  Water and Public Health
☐  Water Pollution and Remediation Science
☐  Watershed Management
☐  Water, Agriculture, Food and Livelihood Security
☐  Water and National and International Security

Required Signatures
Student ______________________________________________________________  Date  ________________
Academic Advisor _____________________________________________________  Date  ________________
School/Department/Program __________________________________________________________________
WSSS Director ________________________________________________________  Date  ________________

Prof. Richard Vogel of Civil & Environmental Engineering, 208E Anderson Hall, Medford

Return completed form to the WSSS Program Office c/o Antje Danielson, Program Manager
Tufts Institute of the Environment, Miller Hall, Medford, MA 02155
Phone: 617-627-5521 – Fax: 617-627-6645 – Email: antje.danielson@tufts.edu
Petition for Exemption from Required Course or Other Requirement

This form is to be submitted by student requesting exemption from one or more requirements of the WSSS program prior to program completion.

Please print.

Name ______________________________________________    Student ID # ____________________

School/Department/Program    ___________________________________________________________

Degree  _______________________________   Expected Graduation Date (Month/Year)  ___________

Requesting exemption from:
☐ required course (list number and title) _________________________________________________
☐ other degree requirement (specify) ___________________________________________________

Based upon:
☐ Equivalent course
   Attach official course description, course syllabus, official transcript (may be unofficial if taken at Tufts) including grade and number of credits received in course.
   Course Number and Title ______________________________________________________________
   School/Department ______________________________________ Semester Taken  __________

☐ Examination
   Exemption may be based on a formal exam or on an informal assessment by an expert faculty member.

☐ Professional competence
   Attach description or other evidence of professional competence for evaluation.

Signatures

Academic Advisor (indicates approval) _______________________________ Date _________________

Expert Faculty Signature ____________________________________________  Date _______________

Expert Faculty Name/Dept. (print) ________________________________________________________

WSSS Director _______________________________________________________     Date _________________
(To be signed by Prof. Richard Vogel of Civil & Environmental Engineering, 208E Anderson Hall, Medford campus)

Return completed form to the WSSS Program Office c/o Antje Danielson, Program Manager
Tufts Institute of the Environment, Miller Hall, Medford, MA 02155
Phone: 617-627-5521 – Fax: 617-627-6645 – Email: antje.danielson@tufts.edu
Tufts University
Water: Systems, Science and Society Program
Interdisciplinary Professional Experience (IPE) Contract
This form is required for students completing Track P (practicum/IPE) of the WSSS Program.

Please print.

Name ___________________________________________   Student ID # ____________________
School/Department/Program _____________________________________________________________
Degree ___________________________   Expected Graduation Date (Month/Year)  ___________
Internship Organization _________________________________________________________________
Internship Site Location _________________________________________________________________
Internship Site Supervisor _______________________________________________________________
Supervisor Email ______________________________________________________________________
Start Date __________   End Date __________   No. of Hours _______   No. of Weeks _______
Description of work ___________________________________________________________________
_____________________________________________________________________________________
Learning objectives ___________________________________________________________________
_____________________________________________________________________________________

Signatures Prior to Internship to Bind Contract:
WSSS Internship Director ___________________________   Date ________________
(To be signed by Rusty Russell, Dept of Urban & Environmental Policy & Planning, Medford campus)
Internship Site Supervisor ___________________________________________   Date ________________

Signatures to Confirm Completion of IPE
Student ___________________________________________   Date ________________
Internship Site Supervisor ___________________________________________   Date ________________
WSSS Program Manager ___________________________   Date ________________
(To be signed by Antje Danielson, Tufts Institute of the Environment, Miller Hall, Medford campus)

Return completed form to the WSSS Program Office c/o Antje Danielson, Program Manager
Tufts Institute of the Environment, Miller Hall, Medford, MA 02155
Phone: 617-627-5521 – Fax: 617-627-6645 – Email: antje.danielson@tufts.edu
Tufts University
Water: Systems, Science and Society Program
Requirements Form
This form declares the student’s completion of the WSSS program requirements. The form must be submitted prior to graduation from Tufts to receive WSSS certificate.

Please print.

Name ______________________________________________    Student ID # ____________________

School/Department/Program    ___________________________________________________________

Degree  _______________________________    Expected Graduation Date (Month/Year)  ___________

Primary Academic Advisor Name __________________________________________________

School/Department/Program    _____________________________________________________

Secondary Academic Advisor Name ________________________________________________

School/Department/Program    _____________________________________________________

Program Requirements

☐ Attendance at weekly meetings / participation in symposium planning
  (To be checked off by WSSS Steering Committee Member – see website for contact information)

Courses (Students must complete courses in 3 of the 4 core areas)
Attach official or unofficial Tufts transcript.

☐ Water Resources Science and Technology Core Area
Course Number and Title ________________________________________________________

☐ Biological Aspects of Water, Health and Nutrition Core Area
Course Number and Title _________________________________________________________

☐ Water Resources Policy and Planning Core Area
Course Number and Title _________________________________________________________

☐ Economics and Systems Analysis Core Area
Course Number and Title _________________________________________________________

(continued on next page)
Tufts University
Water: Systems, Science and Society Program
Requirements Form
This form declares the student’s completion of the WSSS program requirements. The form must be submitted prior to graduation from Tufts to receive WSSS certificate.

Track R (research track) Requirements

Thesis Title______________________________________________________________
________________________________________________________________________
________________________________________________________________________
Conference Presentation Title _____________________________________________
________________________________________________________________________
________________________________________________________________________
Signature of Thesis/Research Advisor ___________________________ Date ________

Track P (practicum/IPE track) Requirements

Practicum Location _______________________________________________________
Semester Completed ______________________________________________________
IPE Site/Location _________________________________________________________
Dates Completed _________________________________________________________
Signature of Track P Coordinator ____________________________________ Date ______
(To be signed by Rusty Russell, Dept of Urban & Environmental Policy & Planning, Medford campus)

Signatures

WSSS Director ______________________________________ Date ____________
(To be signed by Prof. Richard Vogel of Civil & Environmental Engineering, 208E Anderson Hall, Medford campus)

WSSS Program Manager ___________________________ Date ____________
(To be signed by Antje Danielson, Tufts Institute of the Environment, Miller Hall, Medford campus)

** Attach official or unofficial Tufts transcript (and exemption form(s), if applicable). **

Return completed form to the WSSS Program Office c/o Antje Danielson, Program Manager
Tufts Institute of the Environment, Miller Hall, Medford, MA 02155
Phone: 617-627-5521 – Fax: 617-627-6645 – Email: antje.danielson@tufts.edu