# Table of Contents

## Overview
- **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

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## Program Management
- **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

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## 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 John Durant, Ph.D., Department of Civil and Environmental Engineering, School of Engineering
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
Antje Danielson, Program Manager Antje.Danielson@tufts.edu
Emily Geosling, Program Coordinator Emily.Geosling@tufts.edu

Participating Faculty Advisors

Department of Anthropology
Bishara Amahl

Department of Civil and Environmental Engineering, School of Engineering
Linda Abriola  Steve Chapra  Wayne Chudyk
Other Participating Water Colleagues affiliated with Tufts

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

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

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
John Foster, CEE ’52, CEO Emeritus of Malcolm Pirnie Co
Jonathan Curtis, E69, EG72, AG05, President & CEO (Retired) CDM Federal Programs Corp
Jerome DelliPriscoli, Tufts BA, Institute for Water Resources, US Army Corps of Engineers

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 and Program Coordinator Emily Geosling, who are administratively located at the Tufts Institute of the Environment in Miller Hall.

A multidisciplinary External Advisory Committee of 10 highly respected academics and practitioners, representing the range of water resources research interests in the program, meets biennially to review and advise the program.
WSSS also receives input from a Student Advisory Committee, comprising representatives from those schools and departments most active in the WSSS program. Each member of the committee represents all students and schools, but with particular emphasis on their home school. Members are self-nominated and/or nominated by their peers and selected by the steering committee each fall and serve a term of one year, after which they are eligible for re-appointment. The WSSS Steering Committee meets with this group periodically to receive feedback. 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. As Secretary of State Hillary Rodham Clinton said on March 22, 2011

…the water crisis is a health crisis, it’s a farming crisis, it’s an economic crisis, it’s a climate crisis, and increasingly, it is a political crisis. And therefore, we must have an equally comprehensive response….

Water professionals have advocated for the integration of relevant disciplines to solve water problems for nearly a half century. Planning and regulatory processes also have favored integrated multidisciplinary approaches in which specialists first work within their disciplines and then attempt to weave their results into a broader context. But these efforts have met with only mixed success. Thus, there remains a long-recognized need for professionals and researchers who are 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 nurturing interdisciplinary research. From the beginning, each participating student learns to consider problems from the viewpoints of several relevant disciplines. Since its formation in 2004, the WSSS program attracts doctoral and masters degree students from across the university -- including 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.

The international community is faced with many problems related to the supply, use and quality of water. 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 areas where the water supply already is inadequate. 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 global Millennium Development Goals target water issues.

In addition to the looming threat of climate change, 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, groundwater depletion 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 certificate program is based upon integrative graduate research and education—a model that organizes research according to the problems which need to be addressed, integrated 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 and 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 expertise.

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 that they considered applying to. 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
6. Water Diplomacy

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, which are listed at http://www.tufts.edu/home/research.

1. Water Management in a Changing Environment: Hydromorphology and Climate Change

Water supply, in-stream 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 and engineering discipline 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.
- The distinction between natural fluctuations in precipitation, and anthropogenic or external effects.
- The socio-economic impacts and adaptation strategies to deal with sea level rise and increased river flooding in the northeastern U.S.
- The management of climate change impacts 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 among watershed ecosystems, animal life, and human health, as they are affected by heavy metals in the environment and the sharing of water supplies.
- Integrative, "system-wide" studies in the developed and developing world that link precipitation, streamflow, climate, ecosystem integrity, water quality, land use, food
• 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.
• The use of improved operational management and design of water resources to help control schistosomiasis, malaria and other water-related diseases in African watersheds.
• Epidemiology and population biology of waterborne pathogens,
• Application of novel DNA sequencing methods to explore complex microbial populations include the water microbiome

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 characterization and remediation, including the study of arsenic cycling in lakes, fluorescent fingerprinting of organic contamination in water, air-water exchange of pollutants, 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 ponds and streams that can be 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 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 nutrient loads in urban watersheds, water supply and demand in stressed watersheds, and water for both human and ecological systems.
- Application of 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.
- Integration of principles of environmental justice and sustainability into DSSs.
- Examination of the importance of vernal pools and upland forests for amphibian populations.
- Restoration of urban river channels to enhance animal habitat while simultaneously improving flood carrying capacity and instream flow characteristics.
- Protection of coastal resources and coral reefs in Central America through watershed management.

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.
- Promoting health and hygiene interventions and their impact on health and social well-being of women and children.
• Examining how immigrant farmers from South Asia and Africa re-engage in farming in metro Boston.
• Conducted by the Feinstein International Center at Tufts, studying livelihoods at risk in crisis-affected and marginalized communities to understand the interplay of biophysical, socio-economic, and conflict-induced stresses, famine, and forced displacement. Water resources play a large role in these relationships.

6. Water Diplomacy

Water problems are complex because they cross physical, disciplinary and jurisdictional boundaries. Water, viewed as a fixed resource, lends itself to conflicts over its division. Origins of most water problems may be understood as intricate coupling among natural, societal, and political domains where people and problems interact to shape the framing of the problem. The search for scientific bases, without understanding the societal issues and driving values, to address water issues make these problems complex because the underlying policy issues cannot be definitively described or separated from political context. The Water Diplomacy program at Tufts University is producing interdisciplinary water professionals who think across boundaries, emphasize integration of explicit and tacit knowledge, link knowledge and action from multiple perspectives to help resolve water issues through mutual gains negotiations

Consider the following initiatives:

• With an Integrated Graduate Education and Research Traineeship (IGERT) grant from the National Science Foundation (NSF), Tufts University’s doctoral program in Water Diplomacy will educate the next generation of water professionals. Beginning in autumn 2011, 6 doctoral traineeship opportunities are available for highly motivated and creative individuals with a strong interest in pursuing interdisciplinary approaches to resolving complex water problems. The traineeship award includes a full-tuition scholarship, an annual stipend of $30,000, and a semester-long paid internship opportunity with national and international partners. See http://waterdiplomacy.tufts.edu for further information.

• Workshops guided by faculty from Tufts, Harvard and MIT will examine water diplomacy. Through these highly interactive hands-on programs, water professionals and community leaders from around the world learn to use (and teach) its theory, strategies and techniques. The first workshop was held at Tufts in June 2011. Financial assistance is available for WSSS students

• Tufts is one of six centers designated within the Food and Waterborne Disease Integrated Research Network (FWD IRN) as part of a seven-year research contract with the National Institutes of Health. The work focuses on 13 microorganisms -- including salmonella, E. coli O157H7, tularemia and the Norwalk virus – each with the capacity 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, negotiation over its allocation sometimes can have the paradoxical effect of bringing adversaries together – 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. The lesson of the many case studies examined: Cooperation over water stimulates broader cooperation.

Joining the WSSS Program

To participate in the WSSS program, 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 (download from WSSS website) to the WSSS Program Coordinator Emily Geosling no later than October 19.

To be awarded the WSSS certificate, a student must meet the requirements described below. These requirements do not normally lengthen the student’s graduate program, as many of the WSSS core courses may be used to fulfill requirements in the student’s home department. A Requirements Form, to be maintained by the student and turned in to the Program Coordinator at the same due date as AS&E degree sheets – Feb 4th for May graduation – prior to the student's graduation from Tufts. This form can be downloaded from the WSSS website. A WSSS certificate will be issued to the student upon receipt of the completed and signed Requirements Form.

Alumni network

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 educational areas; and
• Fulfill the requirements of one of two possible tracks (Track R or Track P).
• Participate in the planning and execution of the annual WSSS symposium

Each of these requirements is outlined below. The annual WSSS symposium is organized and executed under the leadership of second year WSSS students.
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 – are held in September and early October, generally on the Tufts Medford Campus. Thereafter, smaller group meetings focusing on specific interests and topics are held most weeks, with plenary meetings interspersed throughout the fall and spring semesters. The smaller group meetings take place on both the Medford and Boston campuses.

Activities and goals of the all-WSSS meetings 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; and
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 are posted on the WSSS web site (www.tufts.edu/water) and distributed via email as soon as they are available.

2. **Core Educational Areas**

The core educational areas of the WSSS program encompass the disciplines central to the integrated analysis of water issues. They support the six research areas discussed above, and in turn are deepened by our research projects. In general, 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 (fill out Exemption form which can be downloaded from WSSS website). Those enrolled in an existing interdisciplinary degree program and who feel that they would benefit from a more specialized WSSS curriculum should discuss possible alternative curricula with their advisor, and also contact one of the WSSS steering committee members.

The required core educational 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.

- **CIS 203 Water Diplomacy I, II, III, or IV: Water Science and Systems:** This course is required for all “societal domain” (policy science and diplomacy) students in the Water Diplomacy program and is open to all WSSS students. The course includes student peer-leaders from natural sciences and engineering. This course will provide an overview of “natural domain” variables (Water Quantity; Water Quality; Ecology). 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.

- **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.

- **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.

- **BIO-144 Principles of Conservation Biology.** The principles of population ecology, population genetics and community ecology and their application 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 permission of instructor. Spring 2011 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. We strongly suggest that you consider taking the course listed below in Integrated Water Resources Planning and Management, because it is a signature course for our program, reflecting a primary goal of WSSS which is to teach students how to perform integrated water resource assessments. Eligible courses include:

- **CE 294 Special Topics: Integrated Water Resources Planning and Management.** This course will introduce you to the concept of Integrated Water Resources Management.
(IWRM), “a process which promotes the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital eco-systems.” While the concept is widely applied and endorsed, it is also controversial and somewhat challenging to make operational. By the end of this course you should understand the controversies, but also the history behind the IWRM concept and why so many people find it useful. The course will focus on integrative tools for bringing together social and physical sciences, across scales and disciplines, including concepts of ecosystem services, resilience and adaptive management. We will draw upon case studies the instructors are actively engaged in, including the Jordan River, the Southwest US and the Mekong, and will involve a field trip on a boat to the Mystic River. May fulfill either the Water Resources Policy and Planning requirement or the Economics and Systems Analysis requirement. Fall

- **CIS 204 Water Diplomacy 2: Public Policy Science and Ecological Economics:** This course will be required for all “natural domain” (natural science and engineering) in the water diplomacy program. It will include student peer-leaders from social sciences and policy. This course will provide an overview of “societal domain” variables (Governance; Economics; Values).

- **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 U.S. Environmental Policy.** Analysis of the process underlying international conflict. Examines cooperation, deterrence, crises, arms races and war, using game theory, statistics, psychology, case studies. Discussion of social science methods used in investigation of war. Prerequisites: PS 61. Fall

- **DHP- P250 Elements of International Environmental Policy.** This course is designed to provide 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. It is recommended that students intending to concentrate in the environment and resource field take this course unless they have a solid environmental background. 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. The emphasis is on the development of effective policy solutions based on sound scientific and economic information that meet the often-divergent political positions of nations. Fall.

- **NUTR 233 Agricultural Science and Policy I.** First part of a two-semester sequence. May be taken without prerequisite (NUT215) with permission. 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, genetic resources, and nutrient flows, all of which are highly relevant to global climate change, as well as resource conservation policies.

- **NUTR 213 Agricultural Science and Policy II.** 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 this second semester, the topics are plant-pest interactions, livestock systems, climate change, bioenergy, and food systems. This course has NUT233 (above) as a prerequisite.

- **UEP-174 Clean Air & 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. Although the main focus is on U.S. policies, discussion topics will range from international regulatory regimes (e.g., carbon emissions trading) to highly localized efforts (e.g., watershed advocacy). Featured will be guest speakers with broad experience in the field. 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 of the work that regulatory bodies do; of the complex relations among federal, state and local governments; and of the growing opportunity for of broad policy reform. Summer.
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, economic principles, and decision theory 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 economics, safety, environment, sustainability 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.

- **CE 294 Special Topics: Integrated Water Resources Planning and Management.** This course will introduce you to the concept of Integrated Water Resources Management (IWRM), “a process which promotes the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital eco-systems.” While the concept is widely applied and endorsed, it is also controversial and somewhat challenging to make operational. By the end of this course you should understand the controversies, but also the history behind the IWRM concept and why so many people find it useful. The course will focus on integrative tools for bringing together social and physical sciences, across scales and disciplines, including concepts of ecosystem services, resilience and adaptive management. We will draw upon case studies the instructors are actively engaged in, including the Jordan River, the Southwest US and the Mekong, and will involve a field trip on a boat to the Mystic River. May fulfill either the Water Resources Policy and Planning requirement or the Economics and Systems Analysis requirement. 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.** This course will introduce students to the underlying concepts and major debates in contemporary 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 are 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 the first year in the WSSS program, a master's thesis or capstone proposal, or a preliminary dissertation proposal, as appropriate to the student's degree program;
2. During their participation in the WSSS program, a presentation at the annual WSSS symposium, or at a major national or international conference. Partial funding to support conference presentations will be provided by the WSSS program.
3. By the end of the student's participation in the WSSS program, a completed thesis, directed study or dissertation; and
4. At the same time, an article 90% ready for submission to a refereed journal, with submission following no later than the student's graduation from the WSSS program.

Most graduate degree programs at Tufts require a thesis, directed study or dissertation based on original research. The WSSS Program additionally requires that this research be interdisciplinary, meaning that the review committee must include members from at least
two departments or who represent differing disciplinary perspectives. At least one must be a participating faculty advisor in the WSSS program or an affiliated water colleague (see above list of affiliated WSSS colleagues). Students are allowed to nominate their advisors to become a WSSS affiliated faculty member.

The weekly meetings of the WSSS program will ensure that students electing Track R will learn how to prepare a research project proposal, read and critically review scholarly literature, prepare a comprehensive interdisciplinary research paper suitable for publication in a refereed journal, and 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 challenge arising in the field. 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. Typically, the Practicum team operates in the consultant-client mode, with the client being a nonprofit advocacy organization or a public or private agency facing a complex, water-related problem. The Practicum is taken as a one credit course in the spring semester, although occasional meetings in the late fall often are included. The P Track 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 also must undertake an Interdisciplinary Professional Experience (IPE), which is a problem-focused, domestic or international field experience with a public- or private-sector organization. The goal of the IPE is to provide students with a real-world experience in an area related to their academic water interest(s) and thereby to further integrate education, practice and research. 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.

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 (download IPE contract from the WSSS website). 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 send a request to the P Track coordinator, 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.

**ADD:**

Alumni relations
TIE relationship
Funding opportunities
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;
- The 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);
- International Water Management Institute (IWMI),
- Corporación Ecuatoriana de Biotecnología,
- Polytechnical University of Bobo-Dioulasso.

U. S. Federal and Local Government Agencies:
- Massachusetts Departments of Environmental Management, Environmental Protection, Public Health;
- Massachusetts Executive Office of Environmental Affairs;
- Massachusetts Water Resources Authority;
- US Agency for International Development;
- US Army Corps of Engineers;
- US Coast Guard;
- US Environmental Protection Agency;
- US Geological Survey;
- Office of Global Programs (NOAA),
• US Federal Emergency Management Agency,
• Lawrence Livermore National Laboratory.

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

**US Consulting Firms:**
• Abt Associates,
• AECOM,
• CDM,
• ICF,
• Industrial Economics,
• Louis Berger Inc.,
• Malcolm Pirnie,
• Weston and Sampson,
• Stratus Consulting,
• Geosyntec,
• Charles T. Main,
• Hydrologics,
• GKY and Associates, and others.

ADD: Forms, FY 2012-13