NICHOLAS SCHOOL
OF THE ENVIRONMENT
DUKE UNIVERSITY
forging a sustainable future

August 2009

WATER AND AIR RESOURCES PROGRAM

(*Master of Environmental Management*)

The program in Water and Air Resources (WAR) enables students to understand the physical, chemical, and biological processes affecting aquatic and atmospheric environments. The program concentrates on problems that span the natural divisions of the biosphere, soil, plants, lakes, watersheds, groundwater, and the atmosphere, and teaches quantitative techniques, including measurement and modeling methods used by researchers and environmental managers. Graduates of the program will acquire the skills required to practice as analysts or consultants for employers concerned with the management and protection of water and air resources. These employers include government agencies, public utilities, consulting firms, fuel and ore extraction companies, and hydrologic, atmospheric, or environmental research centers, and non-for-profit organizations.

The Water and Air Resources concentration seeks to educate students in:

1. Analysis of the physical, chemical, and biological processes affecting aquatic and atmospheric environments and the problems that span the natural divisions of the biosphere, soil, plants, lakes, watersheds, groundwater, and the atmosphere;

2. Quantitative and qualitative skills in observation, monitoring, and modeling methods that are required to understand and protect water and air resources in regional and global scales.

3. Basic principles of economics, management, law, and policy that are necessary to properly inform decision making for adequate management of water and air resources.

4. Oral and written skills needed to communicate with decision makers, conduct and understand scientific research, write cogent research reports, proposals, and policy evaluations, and giving effective public presentations.

The WAR program allows students to choose between two different tracks: 1) an integrated science- and management-oriented track, focusing on course work; and 2) a research-oriented track, focusing on research with a faculty sponsor *with a limited number of openings per faculty.*

PREREQUISITES

Prerequisites for admission to the Nicholas School of the Environment and Earth Sciences are: (1) previous training in the natural sciences or the social sciences related to the student's area of interest in natural resources; (2) at least one introductory course in calculus; (3) a statistics course that includes descriptive statistics, probability distributions, hypothesis testing, correlation analysis and linear regression; and (4) a working knowledge of microcomputers for word processing and data analysis. The WAR program requires a course in general economics and recommends, at a minimum, general courses in chemistry and physics. Deficiencies must be made up during the first year in residence; these make-up courses do not count toward degree requirements.

Integrated Science and Management Track

Course work and training in the track cover basic physical and chemical processes relevant to hydrologic and atmospheric sciences, methods of quantitative and statistical analysis, and methods of management and decision-making. Quantitative analysis techniques include mathematical and statistical methods, probabilistic and deterministic models, and optimization and simulation methods. These courses are integrated with others in water resource management, air resource management, and economic analysis.

The WAR program is offered under the Master of Environmental Management degree. Majors in the program can select an area of concentration: water quality, watershed hydrology, hydrogeology, water remediation, air quality and transport phenomena, or a combination of water and air resources. Students may use electives and additional course work to accommodate a second emphasis in another program area within the school.

CREDIT REQUIREMENTS

Students must complete 48 units of credit. These units are distributed among the major courses required for the program, minor courses, elective courses, seminars, and a master's project. Students should develop a proposed program of study (listing courses and master's project topic) in consultation with their advisors by the end of the first semester. The proposed program can be amended with the advisor's approval. Students should work closely with their advisors to ensure that all requirements are met and that elective courses are appropriate to the program.

CORE COURSES

To obtain an introduction to the basic processes for water and air resources, students are required to take at least **one course** (or equivalent) from **each of the following areas** (lists A, B, and C). Since some courses are listed in more than one category, a course cannot be counted toward more than one of these areas. Students should design their course schedule in consultation with their advisor, and note that all courses listed below may not be offered each year.

(A) Physical Sciences

ENVIRON 234L	Watershed Hydrology (4 units, fall)
CE 227	Groundwater Hydrology (3 units)

(B) Chemical Sciences

EOS 227	International Water Resources (3 units, fall)
EOS 272/BIO 272	Biogeochemistry (3 units)
EOS 123	Introduction to Hydrogeology (3 units, spring)
ENVIRON 221L	Soil Resources (3 units, fall)
ENVIRON 240	Chemical Fate of Organic Compounds (3 units, fall)
ENVIRON 242	Environmental Aquatic Chemistry (3 units, fall)
ENVIRON 279	Introduction to Atmospheric Chemistry (3 units, fall)
EOS 271	Stable and Radioactive Isotopes in Environmental Sciences (fall, 3 units)
EOS 273S	Analytic Techniques (3 units)

(C) Biological/Ecological Sciences

ENVIRON 212	Environmental Toxicology (3 units, fall)
ENVIRON 219L	Marine Ecology (6 units, summer)

BIO 272/EOS 272 Biogeochemistry (3 units)

Students also must take at least **one course** in resource/environmental economics, policy, or law. Options include:

ENVIRON 270	Resource and Environmental Economics (3 units)
ENVIRON 271	Economic Analysis of Resource and Environmental Policies (3 units)
ENVIRON 274	Environmental Politics (3 units, spring)
ENVIRON 285	Land Use Principles and Policy (3 units)
LAW 235	Environmental Law (3 units)

Three additional courses (a minimum of 9 units) must be taken in the student's area of concentration to obtain knowledge needed for modeling and management of the resource. Examples of appropriate courses follow. Additional courses are available in the Duke School of Engineering and the UNC Department of Environmental Engineering.

ENVIRON 278	Big Picture: Watershed Management in California (3 units, fall)
ENVIRON 212	Environmental Toxicology (3 units, fall)
ENVIRON 221L	Soil Resources (3 units, fall)
ENVIRON 364	Global Health (3 units, fall)
ENVIRON 235	Air Quality Management (3 units, fall)
ENVIRON 236	Water Quality Management (3 units, fall)
ENVIRON 240	Environmental Fate and Behavior of Organic Compounds (3 units, fall)
ENVIRON 279	Introduction to Atmospheric Chemistry (3 units, fall)
ENVIRON 312	Wetlands Ecology and Management (3 units)
ENVIRON 211	Energy and the Environment (3 units, fall)
EOS 211	The Climate System (3 units, fall)
EOS 240	Intro to Computer Modeling in the Earth Sciences (3 units, fall)

At Duke University's Civil Engineering

CE 247	Air Pollution Control Engineering
CE 227	Groundwater Hydrology and Contaminant Transport
CE 270	Environmental and Engineering Geophysics
CE 123L	Water Resources Engineering
CE 124L	Environmental Engineering
CE 250	Environmental Microbiology

At UNC's Department of Environmental Engineering

ENVR 767	Modeling for Environmental Risk
ENVR 685	Water and Sanitation in Less Developed Countries
ENVR 781	Water Resources Planning and Policy Analysis
ENVR 786	Environmental Quality Planning
ENVR 885	Current Applications in Environmental Management

At NC State:

SSC 562	Environmental and Applied Soil Science

QUANTITATIVE COURSES

Three courses (at least 8 units) in quantitative and analytical methods related to resource modeling and management are required. Examples of appropriate courses follow.

ENVIRON 255	Applied Regression Analysis (3 units, spring)
ENVIRON 264	Applied Differential Equations Env Sci (2 units, fall)
ENVIRON 210.001	Applied Data Analysis for Environmental Science (3 units, fall)
ENVIRON 259.001	Fundamentals of Geospatial Analysis (3 units, fall)
ENVIRON 385	Environmental Decision Analysis (3 units, spring)
COMPSCI 150	Introduction to Numerical Methods and Analysis (3 units)
COMPSCI 250	Numerical Analysis (3 units)
COMPSCI 260	Algorithms in Comp Biology (3 units)
PHYSICS 213	Nonlinear Dynamics (3 units)

ELECTIVE COURSES

Students may select courses to add depth to the water and air resources area, to develop a related area of interest in natural resources, or to strengthen quantitative skills.

SEMINARS

Students must participate in the Water and Air Resources seminar (ENVIRON 398.04, 1 unit). During their second year of residence, they present the results of their master's project in a school symposium. First year students are required to attend the presentations as well as the required skills modules. All WAR students are required to register each semester for this seminar course; the final course grade will be assigned at the end of the last semester. In addition, the *Water Forum Speaker Series Seminar* (EOS 226S, 3 units) is offered to WAR students.

MASTER'S PROJECT

A master's project for 4 to 6 units of credit is required. Final proposals (approved and signed by the advisor) are due by October 1 of the second year of enrollment. Both the proposal and the final report must be well written; most require several major revisions to meet acceptable standards. Instructions for completion of the proposal and final project are located on the Nicholas School of the Environment and Earth Science's web site located at

http://www.env.duke.edu/edprograms/advising/mpguidelines-writing.html.

Further information can be found at: http://www.env.duke.edu/programs/advising

The appendix lists key "ingredients" for a successful MP and what faculty mentors typically evaluate when reviewing MPs.

Research Track

The research track provides specialized and concentrated in-depth training in one of the WAR faculty research areas of expertise. A list of participating faculty can be found below. Moreover, this specialization provides a research-oriented approach without the commitment to a Ph.D. degree program.

Prerequisites of the Research Track. The prerequisites for admission to this track may vary with each faculty member. Thus, approval in writing by a faculty sponsor is required for admission to this track. This decision is based on: 1) an assessment of the suitability of the student's educational background and experience in the area of proposed research, 2) overall prior academic performance, and 3) identification of a research topic of mutual interest to both the student and faculty sponsor. Students are encouraged to identify and contact potential faculty sponsors for information related to possible research topics and to openings in the faculty member's research group; this should be done early on in the admissions process (preferably in the semester prior to arriving at Duke University).

Credit Requirements of the Research Track. This track requires 48 units of credit. Students should develop a proposed program of study (listing courses and research topic) in consultation with their advisors by the end of the first semester. The proposed program may be amended with the advisor's approval. Students should work closely with their advisors to ensure that all requirements are met, that courses are appropriate to the program, and that the research topic is of mutual interest to the student and faculty sponsor. The units are distributed as follows:

Core Courses. Students are required to take **at least 9 units of course work** from the following areas. The distribution of these courses should be aimed at supporting the student's area of concentration and should be worked out in consultation with the faculty sponsor.

(A) Physical Sciences

ENVIRON 234L	Watershed Hydrology (4 units, fall)
CE 227	Groundwater Hydrology (3 units)

(B) Chemical Sciences

EOS 227	International Water Resources (3 units, fall)
EOS 272/BIO 272	Biogeochemistry (3 units)
EOS 123	Introduction to Hydrogeology (3 units, spring)
ENVIRON 221L	Soil Resources (3 units, fall)
ENVIRON 240	Chemical Fate of Organic Compounds (3 units, fall)
ENVIRON 242	Environmental Aquatic Chemistry (3 units, fall)
ENVIRON 279	Introduction to Atmospheric Chemistry (3 units, fall)
EOS 271	Stable and Radioactive Isotopes in Environmental Sciences (fall, 3 units)
EOS 273S	Analytic Techniques (3 units)

(C) Biological/Ecological Sciences

ENVIRON 212	Environmental Toxicology (3 units, fall)
ENVIRON 219L	Marine Ecology (6 units, summer)
BIO 272/EOS 272	Biogeochemistry (3 units)

Students also must take at least **one course** in resource/environmental economics, policy, or law. Options include:

ENVIRON 270	Resource and Environmental Economics (3 units)
ENVIRON 271	Economic Analysis of Resource and Environmental Policies (3 units)

ENVIRON 274	Environmental Politics (3 units, spring)
ENVIRON 285	Land Use Principles and Policy (3 units)
LAW 235	Environmental Law (3 units)

Quantitative Courses. At least **6 units of quantitative classes are required**. These may include (but are not limited to) statistics, regression analysis, or differential equations. The distribution of these courses should be aimed at supporting the student's area of concentration and should be worked out in consultation with the faculty sponsor.

Elective Courses (**15 units**). These are to be determined based on the mutual research interests of the student and faculty sponsor, and on the educational needs of the student to successfully carry out the proposed research.

Independent Research Project. **An independent research project of 12 to 18 units** of credit is required and is registered for under ENVIRON 399. This research project will take the form of a high-quality research manuscript to be submitted to a peer-reviewed journal for publication. The specific format of the final project will be governed by the requirements of the peer-reviewed journal to which it will be submitted.

The research will be directly supervised by the student's faculty sponsor. Specific instructions for submittal of the proposal should be obtained from the faculty sponsor. The research must be initiated by the beginning of the second semester in residence at Duke University (e.g., by the beginning of the first spring semester for those students admitted in fall semester), and it must completed by the end of the third semester in residence at Duke (e.g., by the end of the second fall semester, for those students admitted in the fall). Research under the direction of the faculty sponsor will also be carried out on a full-time basis during the summer between the first and second years.

Note that for some research projects the student's research may contribute only a portion of the information needed for the peer-reviewed publication; however, this portion must be of publishable quality.

PARTICIPATING FACULTY MEMBERS

Resident faculty members serving as advisors in the Water and Air Resources program are listed below. Please consult the Nicholas School of the Environment home page on the World Wide Web or the *Bulletin of the Nicholas School of the Environment* for a description of their research interests.

Resident faculty	Office
John D. Albertson	Hudson Hall (CEE)
Paul Baker	301 Old Chem.
Emily S. Bernhardt	3312 French Building
David E. Hinton	A333 LSRC
Robert B. Jackson	3311 French Building
Zbigniew J. Kabala	Hudson Hall (CEE)
Prasad S. Kasibhatla	A355 LSRC
Gabriel G. Katul	A318 LSRC
Ram Oren	A319 LSRC
Lincoln Pratson	206 Old Chem
Amilcare Porporato	Hudson Hall (CEE)
Kenneth Reckhow	A317A LSRC
Curtis J. Richardson	A219A LSRC
Daniel D. Richter	A207B LSRC
Heather M. Stapleton	A220 LSRC
Avner Vengosh (Chair)	205 Old Chem

Mark Wiesner Hudson Hall (CEE)

Non-resident faculty
John J. Vandenberg

Appendix – Guidelines to MP Content

The general guidelines to formatting the MP are described in:
http://www.env.duke.edu/edprograms/advising/mpguidelines-writing.html.

Key points (and suggestions) that WAR faculty members often use to evaluate an MP in WAR are presented here.

Title Page (see http://www.env.duke.edu/edprograms/advising/mpguidelines-writing.html for format).

1. Abstract/Summary

This section should be written last – as it highlights key ideas from the introduction, methods, and conclusions.

2. Introduction

2.1 Why is this MP topic important?
2.2 What is the problem / question and what has been done. The literature search is important here.
2.3 What are the MP novelties?
2.4 What are the "criteria of success" that will be used to assess success at addressing the question/problem

3. Methods

3.1 How was the data collected or acquired?
3.2 What are the methods (modeling,/statistical) that will be used to analyze the data in the context of sections 2.3 and 2.4.

4. Results:

The results must tie back to points 2.2 and 2.4. It is necessary to explore key alternative analysis methods that are based on independent assumptions (e.g. at least 2 models - one simple, and one more refined; or two statistical methods that do not rely entirely on the same basic assumptions). Convergence of these methods strengthens the results and permits some assessment of how sensitive are the conclusions to the method adopted.

5. Discussion

Does the analysis answer the basic question/problem sought in section 2.2 -
and does it meet the success criteria set in section 2.4. The logical progression from describing the problem to how/why the data was gathered to the analysis to the results must be linear.

6. Conclusions or Products.

One has to evaluate these conclusions with respect to competing hypotheses, or at least the null hypothesis – Could these conclusions be obtained or derived without actually conducting this study.

7. Bibliography