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The Graduate Water Program at Texas A&M University

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The world has water woes; universities have departments. Universities have traditionally proposed solutions to societal problems through disciplinary programs. Scientists, scholars, and government officials urge that multiple disciplines must work in an integrated manner to address water woes. Some 17 years ago the National Research Council's 1991 report on "Opportunities in Hydrologic Science" called for a new educational paradigm transcending the traditional options offered under agriculture, engineering, geology or natural resources degree programs. The Report opined that hydrologic science and water management was beyond the purview of a single department, or discipline, and it called for reformulating water education based on a multidisciplinary model.[1] This Report, along with the findings of recently published Texas water plans, and a growing number of international commissions and their water reports provided the impetus to faculty and administrators at Texas A&M University to rethink their water education programs.

The Texas Water Setting

After 50 years of centralized water planning, the Texas legislature decided to change their planning model. State water plans received limited "buy-in" from major water interests resulting in their quick repose to book shelves.[2] In 1997, the legislature changed Texas water planning to a bottom up citizen consensus process.[3] The state was divided into 16 regional planning areas with citizen planning boards in charge of preparing regional water plans. Each planning group evaluated population, water demand, and supply projections to determine future water needs and then formulated a set of strategies to insure future water availability. The Texas Water Development Board then aggregated these 16 regional plans into a state water plan. As a result of this process, a stark water reality was revealed. Texas' water resources would not satisfy all future needs. It was clear that population growth and urbanization was changing the water picture as well as the economic, environmental, and political landscape of Texas.

The number of Texans will swell from some 21 million in 2000 to 42 million by 2040. Water demand is expected to dramatically increase while the existing supply is projected to decline. Demand is expected to increase from 17 million acre-feet of water today, to 22 million acre-feet by 2040. Even more shocking is the projection that existing supplies will decrease to 15 million acre-feet. This decline is primarily attributable to reservoir sedimentation and depletion of the Ogallala and other limited recharging aquifers. This reality is especially bleak for irrigated agriculture which annually consumes about 60 percent of the state's water. The most likely scenario is that population growth will require a substantial reallocation of water from agriculture to urban and industrial uses. Cities and industries will probably receive a desired amount of water, while irrigated agriculture will get less. This emerging water scenario energized a group of water faculty at Texas A&M University to address this new reality through education, research, and outreach.

Rethinking Water Education at Texas A&M University

Texas A&M University is a research-intensive flagship university with 40,000 undergraduate and 8,500 graduate students studying in over

250 degree programs in 10 colleges. A review of degree programs revealed that neither water management nor hydrology was included in this inventory of academic degrees. Water faculty and water courses are scattered throughout departments at the University. A Texas Water Resources Institute, formed in response to federal money, is located at the Agricultural Experiment Station. It dispenses the limited federal funds it receives to predominately agricultural researchers and it publishes a newsletter. The Department of Civil Engineering offers an option in water and environmental engineering as part of their undergraduate and graduate program. However, nothing resembling a water degree was offered by the University. In spite of not granting a water degree, the University offered a wide array of water, hydrologic science, and water engineering classes and had at least 50 faculty involved in some aspect of water.

A Faculty-Driven Process

Bottom-up faculty formulation with top-down administrative support guided the development of the multidisciplinary water management and hydrologic science program. Support from the President and Provost was critical in convincing Deans and Department Heads of the need for a multidisciplinary degree. Acting on their own impetus, faculty in the Colleges of Agriculture, Engineering, and Geosciences formed an *ad hoc* committee (Committee) with the ambitious goal of establishing a new water degree program. They began meeting in 2002 to explore degree options.[4] From the onset, the Committee was committed to developing a multidisciplinary degree. In addition, it faced the challenge of finding it an administrative home. The Committee considered a number of degree and program options, described below, but settled on option four.

1. *A Multidisciplinary Degree in a New Hydrology Department.* The hydrology program offered at the University of Arizona, through the Department of Hydrology and Water Resources in the College of Engineering is one of the few universities to offer this type of program. In spite of their location in the College of Engineering, faculty are drawn from a variety of disciplines beyond engineering.[5] Considered as the ideal approach in the National Research Council Report, this option was initially discussed by the Committee. However, input from senior academic administrators and faculty regarding "turf battles" convinced the Committee that a new water department was not attainable without a protracted effort.
2. *A Multidisciplinary Degree Administered through an Existing Department.* The Committee discovered that designating an existing department to house the degree was rife with conflict. It was nice to be wanted; however, competition between departments had the potential to jeopardize the entire program. This competition was heightened by the hierarchical structure at the University.[6]
3. *A Multidisciplinary Degree Administered through Multiple Departments.* Another approach was to develop a degree that could be offered in multiple departments in different colleges. The Water Resource degree program at the University of Wyoming is an example of this option where the degree is offered through nine different departments including; Agricultural Economics, Botany, Civil Engineering, Entomology, Geography, Geology, Rangeland Ecology, Soil Science, and Zoology and Physiology.[7] This approach offers some advantages over housing the degree in a single department. By involving multiple departments this arrangement can encourage faculty in diverse disciplines and departments to focus their teaching and research on water. But this approach has some limitations. One is competition for students between the disciplinary department and the multidisciplinary program. An examination of enrollments in the multidisciplinary Natural Resource Management graduate degree available through all departments in the College of Agriculture at Texas A&M revealed that few students pursue this degree. They are often encouraged to pursue the department's disciplinary degree.
4. *A Multidisciplinary Degree Administered by Participating Faculty.* This appears to be the evolving paradigm. Multidisciplinary

hydrology and water science programs are offered at the University of California-Davis, Florida, Minnesota, and Oregon.[8] Under this approach, the degree program is managed by the faculty through an interdisciplinary committee. Typically, participating faculty elect an executive committee to govern the program. The executive committee then selects a chair to handle daily administrative duties.

On its face, this seems to combine the best of all approaches and it may be preferable from a student perspective, but it is often at odds with academic departments. Multidisciplinary degree programs often compete with disciplinary departments for resources, students, and faculty loyalties (National Research Council 1991). Faculty allegiances are often stressed as tenure and resource allocation decisions are departmentally based; this can discourage participation in multidisciplinary programs.

The Committee decided to pursue this option since Texas A&M University already offered multidisciplinary graduate degrees in Agribusiness, Biotechnology, Engineering Systems Management, Food Science, Genetics, Materials Science, Molecular and Environmental Plant Sciences, Nutrition and Toxicology. An administrative framework existed for these programs. However, it was less than ideal since the University did not fund these programs with the same zeal accorded to department programs.

The Texas A&M University Water Management and Hydrologic Science Graduate Degree Program

In 2003, the Committee prepared the documentation necessary to offer three graduate degrees: a Ph.D., a Master of Science (thesis option), and a Master of Water Management (non-thesis option). This process required multiple meetings and the production of a 150 page document justifying the program. Approval by the Faculty Senate, the Provost, President, Chancellor and Board of Regents was granted in 2004. In March of 2005, the Texas Higher Education Coordinating Board gave it final approval and in September the first students were admitted to the program.

As finalized, the Water Management and Hydrologic Science program (WMHS) is designed to integrate diverse disciplines in the pursuit of water education and research. The degree's multidisciplinary character and practical orientation reflect the growing complexity of water issues. Implementing effective solutions demands an ability to communicate and work effectively with a diversity of professionals, policy-makers, and concerned citizens.

Goals

The Program's Goals are to:

1. Foster the discovery and application of knowledge about water resources to promote human well-being and sustainable development.
2. Prepare the next generation of water scientists, hydrologists, and managers for professional and academic careers at the state, national, and international levels.
3. Provide graduate students with strong technical skills in disciplines relevant to water resources including a broad understanding of hydrology and the interplay among the biophysical and social sciences in water management.
4. Provide a teaching and research base for collaborations, lectures, seminars, and workshops to improve the communication and exchange of knowledge between students, faculty, professionals and citizens.
5. Improve the availability, security, and reliability of human water supplies.

Degrees

Table 1 summarizes the course and research requirements for each degree.

Water Course Offerings

1. *Statistics and Research Methods Course Cluster.* Master of Science students are required to take one (1) research methods and one (1) statistics course. Ph.D students are required to take one (1) research methods course and two (2) statistics courses (Table 2). This requirement can be offset if a student took these courses as part of their master's degree program.
2. *Designated Water Course Clusters.* These

Table 1. Course and research requirements for each degree in the Texas A&M Water Program.

Master of Water Management (non-thesis)

This degree is intended to provide professional graduate education with an emphasis on the use of problem solving, management, and technical skills in water. The curriculum is designed to provide preparation for students who will manage public water systems and water resources. The curriculum for this degree is structured but is still flexible, enabling students, with the guidance of an advisory committee, to design courses of study that are in accord with their career objectives.

Common Body of Knowledge Water Courses (12 hours)
RENR 662 Water Law and Policy
AGEC 604 Natural Resource Economics
CVEN 664 Water Resources Engineering, Planning and Management
GEOG 626 Fluvial Geomorphology

Required Water Courses (8 hours)
WMHS 601 Applications and Problems in Hydrological Science
WMHS 602 Contemporary Issues in Water Resources
WMHS 681 Seminar—No more than 2 credit hours of seminar courses

Designated Water Electives (12 hours)
Courses from the designated list

Free Electives (4 hours)
No more than 4 credits of 400-level, or graduate courses

36 Total Hours Required for Degree

Master of Science (thesis)

The degree is designed primarily for students with technical backgrounds who wish to complement their primary discipline by obtaining scientific, technical, or managerial expertise in water. In addition, to the water courses, students are required to take one research methods class and one statistics class.

Required Water Courses (8 hours)
WMHS 601 Applications and Problems in Hydrological Science
WMHS 602 Contemporary Issues in Water Resources
WMHS 681 Seminar—No more than 2 credit hours of seminar courses

Required Research Methods and Statistics Courses (6 hours)
Courses from designated list

Designated Water Cluster (12 hours)
Courses from the designated list

Research Hours (6 hours)
Up to 6 credit hours for thesis research

32 Total Hours Required for Degree

Doctoral Degree (Ph.D)

This degree is designed to give students a thorough and comprehensive knowledge of water science and hydrology and training in methods of research. Each student must have a committee chair before they can be accepted into the program. Students will work with their chair and the advisory committee to develop a course of study satisfying the curriculum. Students who have not taken graduate courses in statistics and research methods will be required to take one research methods and two statistics courses.

Required Water Courses (9 hours)
WMHS 601 Applications and Problems in Hydrological Science
WMHS 602 Contemporary Issues in Water Resources
WMHS 681 Seminar—Up to 3 credit hours of seminar courses

Required Research Methods and Statistics Course Cluster (9 hours)
Courses from designated list

Designated Water Clusters (22-25 hours)
Courses from the designated list

Free Electives (3-6 hours)

Research Hours (21-28 hours)

64 Total Hours Required for Degree if student enters with a master's degree

courses are intended to strengthen a student's background in one or more areas. Students will take specialized courses drawn from a menu of water-related disciplinary courses (Table 3).

3. These designated electives give students the opportunity to tailor their specialized coursework in order to meet their career goals.

Program Administration

The Water Management and Hydrologic Science (WMHS) degree program is administered by an intercollegiate faculty drawn from the Colleges of Architecture, Agriculture, Engineering, and Geosciences. Participating departments include Agricultural Economics, Atmospheric Sciences, Biological and Agricultural Engineering, Civil Engineering, Geography, Geology and Geophysics, Landscape architecture and urban planning, Oceanography, Rangeland Ecology and Management, Recreation and Parks, Soil and Crop Sciences, and Wildlife and Fisheries Sciences. Some 60 faculty members participate offering expertise in the bio-physical and social sciences and in engineering.

By-laws provide for an executive committee and program chair. The program chair reports to the executive committee and to a Council of Participating Deans that has supervisory responsibility over the program. The Dean of Geosciences is the lead Dean for the program. The Geography Department in the College of Geosciences provides office space for a program coordinator and graduate students.

Table 2. Statistics and Research Methodology Courses.

Statistics Cluster
BAEN 662 Statistical Methods in Engineering
STAT 651 Statistics in Research I
STAT 652 Statistics in Research II
STAT 653 Statistics in Research III
Research Methods
AGEC 607 Research Methodology
BAEN 662 Methods in Engineering
BUSH 631 Methods in Public Management I
BUSH 632 Methods in Public Management II
CVEN 661 Research Methods for Engineers
GEOG 611 Geographical Research Design
SOCI 623 Sociological Parameters
PLAN 604 Planning Methods

Students are admitted to the degree programs through a competitive application process. Students are required to meet all the requirements for admission to graduate studies at Texas A&M University. The overall admission criteria for the University are based on the entire record of the applicant and the availability of resources.

Accomplishments to Date

1. **Program Contributions to University Credit Hours and University Earnings.** Metrics used by the state to gauge program performance are the generation of course credit hours and money receipts for the University. These metrics are used to allocate resources to the University and colleges. Table 4 reflects course credit hours and income earned from the state general fund by the WMHS program. Research hours are included and are assigned to the College in which the Chair of the student committee resides.
2. **Research and Service Activities.** Many faculty participating in the water program have diverse research programs encompassing more than water. The following section summarizes only the water related research efforts of the faculty over the last two years.
   - **Publications.** One hundred and twenty three (123) water related journal articles and technical reports were published by water faculty and they made 150 water-related presentations to academic and professional organizations.
   - **Grants.** Fifty two (52) water related grants were made to the water faculty by federal, state, local agencies and private interests. A total of $6.9 million in funding was received by the water faculty.
   - **Service.** Faculty are actively involved in providing service to academic journals and professional organizations. They serve on the editorial boards of 21 water related journals, as board members on at least 15 water related organizations and as article reviewers for at least 28 journals.
3. **Student Enrollment.** Twenty-six students are enrolled: 15 masters and 11 doctoral.

Table 3. Directed Water Course Clusters.

Water Infomatics

BAEN/FRSC 651 Geographic Information Systems
BAEN/FRSC 652 Advanced Topics in Geographic Information Systems
CVEN 658 Civil Engineering Applications of GIS
GEOG 651 Remote Sensing for Geographical Analysis
GEOG 660 Applications in GIS
GEOG 661 Digital Image Processing and Analysis
GEOG 665 GIS Spatial Analysis and Modeling
GEOG 695 Geographic Information Science
PLAN 625 GIS in a Planning
PLAN 626 Advanced GIS in Planning

Climate

ATMO 601 Fundamentals of Atmospheric Dynamics
ATMO 629 Climate Change
ATMO 631 Climate Modeling

Surface Water Hydrology & Modeling

AGRO 611 Introduction to Environmental Biophysics
BAEN 672 Small Watershed Hydrology
BAEN 673 Modeling Small Watersheds
CVEN 627 Engineering Surface Water Hydrology
CVEN 675 Stochastic Hydrology
CVEN 665 Water Resources Systems Engineering
GEOG 626 Fluvial Geomorphology
GEOL/GOEG 628 Geology of Water Resources
GEOL 631 Engineering Geomorphology
GEOL 635 Engineering Geology
RLEM 623 Ecohydrology

Coastal and Estuary Ecosystems

WFSC 611 Estuarine Ecology
OCEN 674 Ports and Harbors
OCEN 682 Coastal Sediment Processes
OCEN 683 Estuary Hydrodynamics

Groundwater Hydrology & Modeling

AGRO 605 Pedology
AGRO 617 Advanced Soil Physics
BAEN 674 Vadose Zone Hydrology
CVEN 674 Groundwater Engineering
GEOL 610 Field Methods in Hydrogeology
GEOL 620 Geology of Groundwater
GEOL 625 Applied Groundwater Modeling
GEOL 642 Chemical and Isotopic Evolution of Groundwater

Wetlands

OCNG 629 Dynamics of Aquatic Ecosystems
OCNG 650 Aquatic Ecology
RLEM 633 Wetland Plant Taxonomy
WFSC 611 Estuarine Ecology
WFSC 615 Mariculture
WFSC 628 Wetland Ecology
WFSC 629 Aquatic Ecology

Water Quality and Treatment

AGRO 615. Land Reclamation
AGRO 650 Herbicides Transport
BAEN 669 Water Quality Engineering
CVEN 604 Water Treatment Systems
CVEN 609 Oil and Hazardous Materials Spills
CVEN 682 Remediation of Contaminated Sites
GEOL 621 Contaminant Hydrology
GEOL 641 Environmental Geochemistry

Water Economics, Law and Policy

AGEC 604 Natural Resource Economics
AGEC 689 Water Resource Economics
AGEC 659 Ecological Economics
CVEN 664 Water Resources Planning
OCNG 676 Marine Environmental Policy
POLS 645 Politics, Policy and Administration
RENR 660 Environmental Impact Analysis
RENR 662 Water and Environmental Law
SOCI 616 Political Sociology

Management

Students completing ACCT 640, FINC 635, MGMT 655 and MRKT 621 will be awarded a Certificate of Business by the Lowry Mays Graduate College of Business.

ACCT 640 Accounting Concepts and Procedures
CVEN 603 Environmental Engineering Management
FINC 635 Financial Management for Non-Business
MGMT 655 Survey of Management
MGMT 639 Negotiations
MRKT 621 Survey of Marketing
RENR 664 Coastal Zone Management
RLEM 603 Range/Forest Watersheds
WFSC 604. Systems Analysis

Planning

GEOG 619 Human Impact on the Environment
PLAN 616 Risk/Hazard and Public Policy
PLAN 620 Dispute Resolution in Planning
PLAN 641 Environmental Planning
PLAN 669 Urban Infrastructure Planning

Table 4. Credit Hours and Earnings Generated by Students in the Program.

College	Student Credit Hrs	Weighted Student Credit Hrs	Formula Income
COALS	411	5,153	$304,169
ENGR	96	1,383	$81,636
GEOS	165	1,837	$108,475
OTHER	160	1,446	$85,373
WMHS	210	2,642	$155,933
Total	1,042	12,451	$735,586

Students are from Texas, India, China, Mexico, Mauritius, Nepal, South Africa, and Egypt. To date seven students have graduated and all are employed either by consulting firms or by public agencies including city water departments and county flood control districts

4. **UCOWR Award.** The Program was awarded the 2006 Education and Public Service Award from the Universities Council on Water Resources. This award recognizes exceptional individual or institutional education and public outreach contributions in water resources.

Concluding Comments

Opportunities abound and challenges await. Enrollment is projected to increase to about 50 students over the next few years. These enrollment projections are attainable if continuing University financial support is forthcoming. Presently about 20 students are funded through graduate research assistantships. University funds have been leveraged with research dollars to provide this level of support. Without this financial commitment an enrollment of 50 will be difficult to achieve.

A second issue relates to release time and a salary supplement for the program chair. Currently only one of the nine Texas A&M interdisciplinary degree programs receives a salary supplement and then it is only through the largesse of the College of Engineering. Release time from a full teaching load must be forthcoming in order to encourage faculty to chair these programs.

In spite of these challenges, the future of the WMHS program is secure. Faculty enthusiastically support the program through their teaching and research efforts and are committed to addressing water problems at the state, national, and international levels.

Endnotes

1. Hydrology, hydrologic science, and water science are used interchangeably in this article.
2. Water plans were prepared by the Texas Water Development Board and its predecessor agencies in 1968, 1984, 1990, 1992, and 1997.
3. In June 1997, Governor George W. Bush signed into law Senate Bill 1 (SB 1), comprehensive water legislation enacted by the 75th Texas Legislature. This comprehensive water legislation was an outgrowth of increased awareness of the vulnerability of Texas to drought and to the limits of existing water supplies to meet increasing demands as population grows. SB 1 allows individuals representing 11 interest groups to serve as members of Regional Water Planning Groups (RWPG) to prepare regional water plans for their respective areas. These plans will map out how to conserve water supplies, meet future water supply needs and respond to future droughts in the planning areas.
4. The Committee included: Ronald Kaiser, Co-Chair, Rick Giardino, Co-Chair, Robin Autenrieth, Bill Batchelor, Ann Chin, Bruce Herbert, Ann Kenimer, Kevin McInnes, James Mjelde Gerald North, Val Silvy, Ralph Wurbs, Brad Wilcox, Hongbin Zahn.
5. Their website indicates that the department offers programs leading to the Master of Science and the Doctor of Philosophy degrees with a major in hydrology. The department also participates in the State of Arizona Tri-University Master of Engineering (M. Eng.) degree program, a non-thesis based curriculum for working professionals. The faculty offers competence in hydrogeology, hydrogeochemistry, hydrometeorology, hydro-climatology, environmental hydrology, ground-water hydrology, surface-water hydrology, vadose zone hydrology, mathematical and statistical methods in hydrology (including numerical modeling), water resources administration, water resources systems, and water resources planning. See http://grad.arizona.edu/Prospective_Students/Program_Descriptions/Descriptions.php?majorid=79.
6. Academic departments are administered by "heads" rather than "chairs." Department heads are first and foremost administrators and rarely teach or maintain research programs while they serve in this capacity.

7. See http://uwadmnweb.uwyo.edu/UWrenewable/Renewable_Grad_Water.asp.
8. See these websites:
   Colorado: http://hydrosciences.colorado.edu/academics/index.php
   Davis: http://hydscigrad.ucdavis.edu/
   Florida: http://www.hydrology.ufl.edu/about.html,
   Minnesota: http://www.catalogs.umn.edu/grad/programs/g173.html
   Oregon State: http://oregonstate.edu/gradwater/.

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