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Educating Future Water Resources Managers

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Managing water in an integrated and sustainable manner is currently challenging water resource managers throughout the world. It requires professionals from many disciplines working together with impacted stakeholders in crafting a strategy that is economically efficient, ecologically sound, and acceptable to all who are impacted by how this resource is managed over space and time. We at universities are continually thinking about how we can better prepare our students who elect to become our future water resources planners and managers. This paper identifies some of the issues and challenges facing educators in this field, and some possible ways of addressing them.

The amount of water available and suitable for human use in the world is limited. Too many humans must live with less water than what they would like, and even need, to maintain their health let alone their overall welfare. Currently the world's water resource systems are not able to provide everyone reliable potable water at reasonable costs. Populations are increasing, as are per capita demands for water. The United Nations tells us about one person in six, on average, in this world has no access to safe drinking water, and about one in three lacks adequate sanitation. In many countries these percentages are substantially higher. One can assume that those without clean water to drink are sick. The World Health Organization (WHO) tells us more than 30 thousand children under the age of five die from either hunger or from water-borne and easily-preventable diseases. We use about 70 percent of our freshwater resources for agriculture. What we get for that varies considerably. The World Water Council believes that by 2020 we shall need 17 percent more water than is currently available if we are to feed everyone. Do all these grim statistics suggest a water crisis? Will there be a water crisis in the future? Much depends on how we manage our water and our watersheds (Rogers et al. 2006). And this in turn depends on our abilities at universities to provide the personnel with the training and capacity to manage this resource effectively.

With perhaps a few exceptions, those of us who live in North America are not dying from lack of water or sanitation. We are fortunate. We seem to have enough water, although the recent droughts in the southeast and in the west suggests we may be increasingly challenged to meet our demands for water supplies, to keep our rivers flowing and clean and our aquatic ecosystems functioning as they should. We can manage all our natural resources better, and professionals know this, but deciding what is better and implementing measures to be better involves more than just professionals. Politicians representing the public, and increasingly the public itself, are participants in this decision-making process. They define what is "better" and when and how to act. And inevitably acting requires money. Acting in ways to prevent crises is not always easy to do. There are always more pressing matters that get people's attention – and their money – until of course there really is a water crisis. This has prompted the well-known concept called the hydro-illogical cycle illustrating the lack of interest in planning for floods during periods of drought, or in planning for droughts when experiencing a flood.

Many of the issues facing water and environmental resource managers today generally stem from the following factors:

1. changing priorities of water and environmental management objectives over time – for example from economic efficiency to ecological health

and diversity that require changes in past policies and even infrastructure,

2. the way our institutions work,
3. the need for multiple disciplinary inputs and public participation,
4. uncertainties regarding future demands, supplies, and pollutant types and loads, and
5. a lack of adequate understanding of many natural and social processes affecting, and affected by, the management of water and environmental resources.

Managers and planners are challenged to develop plans and policies for serving often conflicting multiple purposes and satisfying multiple objectives expressed by multiple stakeholders representing multiple interests and backgrounds, all lacking perfect knowledge of what economic, physical, chemical, biological, ecological and social impacts will result from what ever decisions they make. We all could benefit from better science, better management tools, better training of professionals in all the applicable disciplines, and political institutions that can provide the expertise and leadership that will result in more timely, integrated, and sustainable water resources and environmental management plans and policies.

The remainder of this paper outlines some current issues related to the training of individuals who wish to accept the challenges just described and contribute to improving how we manage our water and environmental resources.

Educational Issues

Recent decades have witnessed a shift in emphasis by U.S. agencies providing funds for research and training of graduates interested in environmental and water resources management. The emphasis has been on addressing scientific uncertainties and less toward planning and management issues. This runs counter to those who claim there is a need for improved environmental and water resource management. One result of this shift away from research in planning and managerial issues has been the decline of academic programs in water management and planning. Ironically, weather- and climate-related research programs, as well as large-scale observation initiatives promoted by many in the hydrologic, ecological, environmental engineering and other communities, increasingly cite benefits for water resources, environmental, and ecological management as central to their programmatic justification. Having more scientific information and the understanding that comes from it does not automatically mean we know how best to use it.

There are many scientific, technical, political, practical, and regulatory challenges to integrating advances in hydrologic science into policies for managing environmental and water resources. There may be an unrealized potential, for instance, for using improvements in hydrologic forecasting based on new data sources and methods, such as embedded environmental sensors and data assimilation techniques. As science teaches us more about the processes taking place at the interface of hydrology and climate, and as the hydrologic, water quality, and associated ecological implications of land cover change become better understood, ways are needed to incorporate this knowledge into management plans and policies. Research is needed to figure out how best to do that, and trained professional planners and managers are needed to make it happen.

At various universities, debates are taking place over a variety of issues, some of which are listed below.

Issue #1: Educational policy – should universities turn out more well-trained engineering professionals and scientists, or more broadly trained generalists?

Many will argue that there is an overarching need for people who know there is a world beyond where they live and work and can appreciate how history and culture affects current events. There is a need for individuals who can evaluate, think, and speak and write effectively at technical and non-technical levels. In my opinion, such skills should be obtained at the undergraduate level. One way to get this background is to obtain a liberal arts education (including study in a foreign country). Expertise in specific technical disciplines can be obtained at the master's level. After all, medicine, law, and business are graduate subjects. Why not in this multidisciplinary water resource field as well? Obviously for those desiring engineering or the

sciences some basic introductory courses would be expected at the undergraduate level, just as pre-med courses are expected for admission to most medical schools. This is not to say we cannot train students to become competent technical professionals with engineering, economic, ecological, or natural resource degrees, for example, at the undergraduate level, but doing that eliminates the time needed for students to obtain the other skills that all should have who expect to become tomorrow's leaders in whatever they do. Yet in much of the world, attending universities costs money, especially at private universities and colleges. This means we need fellowships and training grants to attract the best and brightest students we can to our water resources profession.

Issue #2: Course curricula – do they need changing?

Many universities need to take a serious look at their curricula more often than they do. It seems much easier to change course contents than the overall plan. Most educators support exposing students to interdisciplinary projects at both graduate and undergraduate levels, so that students learn to participate productively in such projects and recognize the approaches and issues of fields other than their own. Engineers, economists, and ecologists especially need to appreciate each other's approaches to problem solving. Being exposed to case studies, including failed projects and those that get students out in the field is also beneficial. This gives them an appreciation of multidisciplinary team-building and dealing with multiple conflicting goals such as drought mitigation, flood management, flash flood prediction, water supply, transportation, emergency management, agriculture, and ecosystem stewardship – and conflicting opinions about how to achieve them.

Issue #3: Continuing education: How can it best be provided to all professionals?

Some have suggested that whatever the technical information students learn, it will be obsolete by the time they get their first job. The rate of increase in knowledge and changes in technology seem to be increasing over time. The half-life of the technical information we teach our students is decreasing. On-the-job training and continuing education throughout one's professional career is an absolute necessity. How can universities best meet this need? Some governmental agencies concerned with environmental and water resources management have programs for continuing education. However, a high turnover rate often makes this uneconomic. Professors themselves need continuing education as well. Their research provides some of this, but they also can learn from their consulting and what they do on their sabbatical leaves. All professionals should be provided such opportunities, not just academics.

Issue #4: Funding. Can the needed changes in education be accomplished in the absence of changes in funding "carrots and sticks"?

Difficulties in supporting students studying water and environmental resources management have led to the relative lack of students studying these subjects. University deans look for where the money is when they analyze continuing and new directions for their academic departments. The availability of fellowships, traineeships, and research grants are noticed. Industry can also provide support, and in many disciplines they do, but in the water and environmental resources arena the private sector has not been a major player. Managing water and environmental resources is primarily a public responsibility. Nevertheless industry has provided some support, for example to the American Water Works Association Research Foundation which promotes research and technology transfer. Coop programs, internships, and traineeships that expose students to the real world may be a partial solution. The USDA-CSREES coop funding program is an example for agricultural water management. The U.S. Army Corps of Engineers master's degree program in planning is another example.

Employer Needs

Employers working in the water management area often report difficulties in finding employees with the appropriate backgrounds. Because of the decrease in funding of research and training grants in the water planning and management area, few young graduate students are finding their way into the field. This leads to fewer students being trained in the areas of most interest to these employers. The report *Freshwater Ecosystems:*

Revitalizing Educational Programs in Limnology (National Research Council 1996) included a chapter on linking education and water resource management.

Water is viewed as a public good, and thus those who manage it are often associated with government agencies. At a recent meeting of the National Research Council (Logan 2006), several government agencies stated their need for articulate young people prepared for

1. working in interdisciplinary and multi-disciplinary teams, which is the nature of modern water management,
2. viewing problems in a broad systems context – water management decisions made upstream "reverberate" downstream influencing eco-systems, fisheries, and the coastal zone in general,
3. linking societal goals and objectives with performance measures and conceptual eco-logical models,
4. adaptability in general and adaptive manage-ment in particular,
5. quantifying and dealing with risk and uncertainty, and
6. conflict management and resolution in a stakeholder-driven participatory political process.

One can think of other skills needed to address some of our current and future management challenges. For example, how can managers most effectively

1. design, manage and operate infrastructure in the face of non-stationarity in water supply and demand;
2. identify and provide environmental flows in already over-allocated systems, especially in times of drought, and environmental effects of reservoir operation and dam removal;
3. alter reservoir regulation in the face of changing uses and priorities, environmental and ecological uncertainties and needs, and possibly the removal of past engineering infrastructure such as dams and canals;
4. predict and then respond to hydrologic responses to precipitation, surface water generation and transport, environmental stresses on aquatic ecosystems, the relationships between landscape changes, sediment fluxes, and subsurface transport, as well as mapping ground water recharge and discharge vulnerability;
5. respond to the environmental, economic, health and social impacts caused by floods, droughts, sedimentation, and contamination including from pharmaceuticals and other household chemicals and products;
6. provide an early warning for flooding, droughts, habitat degradation, and health hazards,
7. increase the efficiency of water use, especially in the agricultural sector;
8. address questions whose answers require knowledge of the quantitative relationships among various physical, chemical, biological, and social process occurring at disparate spatial or temporal scales. For example, how can we scale up to larger area forecasts from knowledge of smaller habitat patch scale ones? How can we estimate regional aquatic ecosystem processes over entire river basins often based on small plot experiments and observations?
9. deal with deforestation, suburbanization, road construction, agriculture, and other human land-use activities that impact economies and ecosystems (changes in land cover, climate, and land use affect water quantity and quality regimes which impact ecosystem health and other uses of water such as for drinking, irrigation, industry and recreation);
10. manage chemical and biological components of the hydrological cycle under changing land uses and habitats, and
11. control invasive species . . .

This list could continue. Suffice to say there are many subjects a competent water resource manager should be familiar with, at least to the extent that the issues are appreciated and that effective communication can take place between the manager and experts or specialists when appropriate.

Stakeholder Participation

Today's planning and management environment involves public participation, not just at the final stages of planning, but throughout the process, including decision making. Tools are being developed to help all stakeholders gain a "shared vision" of how their system works, and the physical, economic, environmental, ecological and sometimes the social impacts of various plans and management policies. Such public participation does not make the planning and management processes any easier, or more efficient, or cheaper. In fact often the opposite happens. But the end result has a far better chance of being robust to multiple interests and thus more sustainable in the long run (ASCE 1998). Future water resources managers need to know how to facilitate such participation.

Conclusion

Water resources professors cannot rest on their laurels. Planning and management issues continue to evolve as do their demands on this profession. Students today will be faced with problems and technology we can only speculate about today. But they have to be prepared to effectively address those issues and use that technology. It's the job of those of us involved in water resources planning and management programs at universities to ensure our graduates have that capability.

The increasing breadth, complexity, and rate of change of professional practice places a greater emphasis not only on continuing education but also on what a basic professional education must deliver at the undergraduate as well as graduate levels. The body of knowledge necessary to effectively manage water resources is beyond the scope of the traditional bachelor's degree, even when coupled with early-career experience. Education must meld technical excellence with the ability to lead, influence, and integrate a diverse number of disciplines and stakeholders – all required to meet societal goals in some 'best' and most sustainable way.

Ideally, graduates from university programs in water resources planning and management should be knowledgeable in their particular discipline, as well as conversant with other applicable disciplines. An engineer, for example, should not only understand how to use the theories, principles, and/or fundamentals of mathematics, physics, chemistry, engineering economics, biology, and probability and statistics underlying engineering but also be exposed to political processes, systems analysis and computer modeling, laws and regulations, history, sociology, and ethics. Most importantly, they should know how to work in interdisciplinary teams and effectively and clearly communicate orally and in writing. They must be optimistic in the face of challenges and setbacks they will surely face, and be committed to ethical behavior, both personally and professionally. After graduation they must remain curious and willing to continue learning fresh approaches, develop and use new technology or innovative applications of existing technology, and take on new endeavors that require research and ingenuity.

Managing our water resources, including our ecosystems in our natural and built environments, involves both technical and administrative expertise. It involves both the "hard" as well as the "soft" sciences. In the hard sciences, the laws of physics, biology, chemistry, and mathematics are well established. The same cannot be said of the soft social and political sciences. Thus the "hard" sciences are easy. The "soft" sciences are hard. Clearly, however, we need more people competent in both to address many of the issues water resource managers are facing today.

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