Universities Council on Water Resources
Journal of Contemporary Water Research & Education
Issue 155, Pages 19-27, July 2015

Bringing the Elephant into the Room: Integrating Risk into Interdisciplinary Water Programs

*Laura Read[1] and Laura Kuhl[2]

[1]*Department of Civil and Environmental Engineering, Water Diplomacy IGERT Fellow, Tufts University*
[2]*Center for International Environment and Resource Policy, The Fletcher School of Law and Diplomacy, Water Diplomacy IGERT Fellow, Tufts University*
**Corresponding Author*

Abstract: Problems that require risk management are usually cross-disciplinary in nature, which makes it difficult to educate students and professionals on common language, skills, and strategies. Recognition of the interdisciplinary nature of many water challenges in terms of quality, allocation, future supply, infrastructure, damages, etc. has led to the establishment of interdisciplinary graduate water programs. Motivated by experience in an interdisciplinary water program at Tufts University, this paper argues that explicit coverage of the subject of risk is an important component of an interdisciplinary water training program, and that understanding risk should be a core competency of a water professional. The literature on water education is reviewed, particularly regarding the core competencies of an interdisciplinary water professional. Existing interdisciplinary water graduate programs are also surveyed to identify if, and how, risk features in their program descriptions or curriculums. Our analysis found that risk was not mentioned as a core competency or key issue in any of the literature on interdisciplinary water education or training, and featured in only a few program descriptions or curriculums. Based on this analysis, we conclude that there is a significant need to address risk more centrally and explicitly in interdisciplinary water programs.

Keywords: *risk, water, interdisciplinary education, IGERT*

Risk plays a central role in most water challenges, and understanding and managing risk is essential for water professionals. Addressing complex water problems requires a common language to discuss risk and the ability to view risk from technical, social, economic, and political perspectives (Haimes 2009; UNISDR 2009). Often disciplinary approaches consider and assess risk from a specific perspective; however water problems are interdisciplinary and require additional training on alternative approaches for comprehensive risk analysis. Although there is always a balance between depth and breadth in interdisciplinary research and educational programs (Howe 2008), water professionals should at least be familiar with a broad range of risks and approaches to risk management. In recent years, the importance of interdisciplinary training in water has grown significantly, with a wide range of interdisciplinary graduate water programs emerging across the world. The growth of such programs raises the important and timely question of whether these programs are preparing the next generation of water professionals to analyze and address risk.

This paper is motivated by student experiences as fellows in a National Science Foundation Interdisciplinary Graduate Education Research Traineeship (IGERT) Water Diplomacy program at Tufts University (http://waterdiplomacy.org/). Students across disciplines have different vocabularies and conceptual frameworks for analyzing risk. Without a common language to bridge disciplinary perspectives on risk, it is quite difficult for a group to productively discuss research, since risk considerations play a critical role in almost all students' research (e.g., biology, engineering, hydrology, social science, political science, food and agriculture science), an issue the

group has recognized and sought to address through dialogue on risk. Over time, students in the Water Diplomacy IGERT program have gained a greater appreciation and understanding of risk as it applies to water issues and its analysis across disciplines.

This paper highlights the importance of explicitly addressing the various (and sometimes competing) conceptions of risk across disciplines and the value of understanding risk from various perspectives when analyzing and managing water challenges. Based on the gap identified in formal education on risk management in the IGERT program at Tufts University, the authors seek to systematically examine the role of risk in other interdisciplinary water programs. The remainder of this paper is structured as follows: we begin by exploring a number of key water issues in which risk and risk management play a central role. We then review the literature on interdisciplinary education and training for water professionals, focusing on what are considered to be the core competencies of water professionals. Finally, we look at current interdisciplinary water graduate programs and analyze the role of risk in their program descriptions and core curriculums.

Centrality of Risk Across Water Issues

A wide range of water issues necessitate interdisciplinary consideration of risk and risk management, e.g., water quality, water allocation agreements, climate adaptation planning, and infrastructure investments. In this section, we provide a few specific examples of major water challenges and highlight the importance of risk in each. The selection of these four topics is based on common themes and issues found in a review of interdisciplinary water programs (discussed in a later section).

1. ***Water Quality Concerns***
   Maintaining water quality at a suitable level for consumptive and non-potable uses is a public health concern as well as a technical problem. The U.S. Environmental Protection Agency (EPA) sets standards and regulations for chemicals in drinking water based on acceptable levels of risk, often determined by a combination of societal perception, cost of treatment, and consequence of exposure. Maintaining safe drinking water sources requires engineers to design and improve treatment methods, policy makers to act on legislation, and public health scientists and communicators to educate the public (U.S. EPA 2014a). Similarly, the EPA is responsible for protecting the environment itself, and therefore establishes total maximum daily loads for surface water (U.S. EPA 2014b), and monitors state/local environmental flow requirements that each require a risk assessment. Many are handled through the federal government's National Risk Management Research Laboratory, which is directed by the EPA to investigate risk reduction and exposure control between humans, the environment and contaminants.
2. ***Water Allocation Agreements***
   Determining the appropriate mechanisms for distributing shared water resources is one of the classic challenges in the water field (Wolf 1998, 1999). Particularly when dealing with transboundary water basins, political tensions are usually high, making agreements difficult. One of the reoccurring challenges is how to incorporate risk and uncertainty into agreements, as there is a tradeoff between flexibility and enforcement (Bookmann and Thurner 2006; Drieschova et al. 2008). While mechanisms to address flow variability are widely acknowledged to be important as a means of managing risk, very few existing agreements successfully incorporate such mechanisms (Fischhendler 2004; Drieschova et al. 2008).
3. ***Climate Adaptation Planning***
   At its core, climate adaptation is about managing risk associated with increasing variability and change in climatic and hydrologic systems and their impacts on coupled human and natural systems (Blaikie et al. 1994; IPCC 2012, 2014). Understanding the impacts of climate change necessitates understanding the risks in different sectors, such as agriculture, urban environments, and health, as well as identifying approaches to managing that risk. Resilience approaches and no-regrets decision-making focus on identifying options, investments and policies

that are desirable under current conditions in addition to uncertain future conditions as a means to manage risk (Gunderson 1999; Berkes et al. 2003; Walker et al. 2006; Heltberg et al. 2009; Folke et al. 2010). Frequently, such approaches address underlying vulnerability and adaptive capacity more generally, rather than attempting to address individual hazards, and thus are often closely aligned with development priorities.

4. ***Water Infrastructure Investments***
Water infrastructure investments are another topic where risk assessment plays a central role in determining the size and design of protection (U.S.ACE 2006). In fact, since 1983 the Army Corps of Engineers has used risk-based design (Principles and Guidelines) to select dam size and other types of infrastructure by maximizing the system net benefits, calculated by considering the damages avoided as benefits and subtracting the total annualized costs (Water Resources Council 1983). While water infrastructure design for planning and managing risk and reliability is considered a classic engineering problem (Yen 1970; Lund 2002; Mays 2011), the question of how society should manage risks *due* to infrastructure is broader and requires input from experts in urban planning, political science, and economics (Loucks et al. 2005). In the latest "report card" by the American Society of Civil Engineers (ASCE), much of the large infrastructure in the U.S. received a score of D or lower (ASCE 2014). Based on this report and similar ones by the National Research Council (NRC) and ASCE, many are re-evaluating the role of infrastructure as a means for risk protection and calling for new flexible design and nonstructural management options (ASCE 2014).

Interdisciplinary Water Education and Training

To gain a broader understanding of previous work on interdisciplinary education and training for water professionals, we conducted a literature review of articles published in the UCOWR journal, as well as other prominent articles on interdisciplinary education for water. A synthesis of the findings from this review is presented here.

The importance of interdisciplinary water training is widely acknowledged, although the extent of the focus of interdisciplinarity varies, with some articles emphasizing both natural and social sciences (Kirshen et al. 2004; Bourget 2006; Fort 2008; Viessman 2008; Campkin and Neto 2013; and Pinter et al. 2013), and others addressing integration solely across natural sciences and engineering (Graney et al. 2008; Lettenmaier 2008; Stakhiv 2008). Recognizing the interdisciplinary nature of water challenges, numerous articles tackled the debate between depth versus breadth in education for water professionals. Many expressed that programs are becoming "watered-down" in an attempt to cover more perspectives (Stakhiv 2008), while others acknowledged that traditional approaches were failing to train students to deal with contemporary challenges (Lettenmaier 2008). In contrast to a common theme that the technical quality of water professionals has declined over time, Layzer (2008) argues that most water challenges are not technical "water management" issues, but rather are "people management" challenges, and thus technical skills are not the most essential characteristics for water professionals. Considering the close relationship between water management and the discipline of civil and environmental engineering, it is perhaps not surprising that the majority of articles that speak to the value of interdisciplinary education are written by faculty or professionals in engineering (an exception is Fort 2008, written by a lawyer on water education for lawyers).

A number of articles discuss the experiences of different water programs. The famous Harvard Water Program (HWP) that began in 1955 (see Reuss 2003 for a review) was one of the first examples of a formal interdisciplinary water program that brought together professors and students in engineering, economics, and public policy to address the design of water resource systems for society (Maass et al. 1962). This program has been revered by many as successful in training participants to think about water problems from a systems analysis perspective and consider multiple objectives in designing water infrastructure and policies. Some have called for a resurrection of the HWP (Reuss 2003) or one that mimics it (Kirshen et al. 2004). Kaiser (2008)

documents the process of developing a successful water resources and hydrologic sciences program at Texas A&M, discusses the institutional challenges in building a multidisciplinary graduate program, and compares the tradeoffs of various models for developing such a program, an issue also addressed by Bourget (2008). Campkin and Neto (2013) found that relying on a diverse network of experts from the UNESCO Hydrology for the Environment, Life and Policy (HELP) Programme allowed them to break through some of the traditional barriers of interdisciplinary water programs and engage in co-learning in the Erasmus Mundus Master in Ecohydrology program.

Another initiative to develop a water program to train graduate-level students was led by the Army Corps of Engineers in recognition of a lack of trained interdisciplinary water professionals available for their own needs as well as the needs of other agencies (Bourget 2006, 2008; Viessman 2008). They identified the following themes as essential to an interdisciplinary water program: philosophy of planning, institutional considerations in water resources planning, social decision-making, ecology for water resources planning, engineering for water resources planning, economics for water resources planning, hydrology/hydraulics/climatology, and quantitative methods for water resources planning (Bourget 2006; Viessman 2008). Based on the development of an interdisciplinary water program at Tufts University, Kirshen et al. (2004) proposed that the fundamental elements of an interdisciplinary water program should include: systems analysis, science and technology of water, biological aspects of water, health and nutrition, and planning and policy of water. The National Science Foundation's IGERT program also promotes interdisciplinary graduate water programs, as described in Pinter et al. (2013) for the Southern Illinois University "Watershed Science and Policy" program, as well as the Tufts University "Water Diplomacy" program in which the authors are fellows. In a similar effort to increase skill sets of students working on water and climate issues, a group of academics and professionals created an inter-institutional interdisciplinary modeling course with two objectives: expose students to a range of modeling techniques from different disciplines and train students in developing teamwork skills. The course was developed by University of Nevada Reno (UNR), the Desert Research Institute (DRI), and University of California at Davis (UCD) and was offered in various formats in 2008, 2010, and 2012 (Saito et al. 2013). McIntosh and Taylor (2013) present a "T-Shaped Water Professional" concept to articulate how training programs can balance disciplinary depth with interest in a broader range of issues and describe how this concept has been applied in post-graduate education programs run by the International Water Centre and UNESCO-IHE. These programs focused on leadership training, organizational management, and collaboration, arguing that the goal of a water professional is to stimulate change, rather than be a technician, and that students already bring to such programs a depth of disciplinary knowledge through their professional and academic background.

Interestingly, risk assessment and management did not feature in the discussion of key capacities for a water professional or as a component of a water curriculum in any of the articles reviewed. While competencies such as systems analysis, institutional and policy analysis, leadership skills, cooperation and negotiation, economics, and technical skills for water management were commonly mentioned, risk was not among them.

Risk in Current Water Graduate Programs

In addition to reviewing the literature on interdisciplinary education and training, the program descriptions and core curricula of interdisciplinary graduate water programs were systematically analyzed to determine if risk featured as a core competency or as a central program component. Table 1 provides a summary of these programs with the institution, website, and description of risk (if any). Only interdisciplinary programs that had an emphasis on water were included, which was broadly defined and included programs integrating natural and social sciences, as well as those focused on natural sciences and engineering. International and U.S. based programs were included for both degree-granting and certificate-based programs.

In our analysis, a program was considered to address risk when the concept was named in the program description, or in the course description

for any of the core (or required) courses. Based on these criteria, we identified very few programs that address risk. While it may be possible for students to take elective courses on risk, or risk may be featured in courses even when not mentioned explicitly in the descriptions (likely to be the case due to the centrality of this concept to so many aspects of water issues), if risk is not included explicitly in the core curriculum, it provides an indication of the value placed by the program on risk as a fundamental component in the program.

One program particularly stands out in contrast to this general finding: the Water Hazards, Risk and Resilience Masters (MSc) program at the University of Dundee (http://www.dundee.ac.uk/study/pg/waterhazardsriskresilience/). This MSc program is focused on natural hazard management and contextualizes its studies in the subject of water, a different approach than many others that start with an umbrella of water and pull in courses and topics from other disciplines. Additionally, the Certificate in Water Conflict Management and Transformation at Oregon State and the Integrated Water Atmosphere, Ecosystems, Education and Research IGERT program at Colorado State University are the only other programs identified that articulated risk as a central component of their program, although to a much lesser extent than the program at the University of Dundee. Considering the centrality of risk to complex water problems, it is surprising to see that risk is not a core component of more programs.

We also searched for graduate programs that *do* focus on risk to identify what subject areas discuss risk explicitly, and which could serve as models for water programs. One program could provide a particularly relevant example for water programs: the Societal Risk Management Program at the University of Illinois at Urbana-Champaign (http://cee.illinois.edu/SRM). Based on its description, the program concentrates on risk determination, risk evaluation and risk management for natural and human-made hazards, and disaster response and recovery. They state that "students in the program are exposed to content in reliability, risk and life cycle analysis; decision-making under uncertainty; performance assessment of deteriorating systems; the ethical, economic and political dimensions of risk management; the legal elements of regulatory mechanisms; risk perception and cognitive biases; risk communication; and post-disaster response and recovery." Although not focused explicitly on water, the types of challenges the program trains its students to address are very similar to the types of challenges many water programs seek to prepare their students to tackle. Apart from this specific program, most graduate programs focusing on risk come from a business or management perspective, suggesting that these fields could provide useful experiences and lessons to water graduate programs interested in incorporating risk more systematically into their curricula and activities.

Conclusion

Since many graduate programs are moving toward interdisciplinary studies as a platform for water education and problem solving, it is crucial to consider how cross-disciplinary topics such as risk management can be discussed and contextualized. Further, it is important to assess whether these programs effectively provide the resources and skill sets water professionals need to approach these interdisciplinary problems. While many programs acknowledge that interdisciplinary training is necessary to tackle complex water issues, few appear to have recognized that risk itself is an interdisciplinary topic of central importance to water challenges. This paper finds that risk is not specified as a core value of the curriculum in many interdisciplinary graduate education programs, counter to the presence of risk as a central concept in many major water challenges. Without training on risk, water professionals may miss or oversimplify important aspects of reaching solutions to water challenges and find their toolbox of resources and methods to address certain water problems to be limited. If a core competency of a water professional is to be proficient in understanding the language of risk as it relates to water, it seems fitting that interdisciplinary water programs should include risk in their courses of study. The authors urge current and future water programs to explicitly incorporate training on risk into their programs, certainly looking beyond the topic of water for examples of graduate programs in other fields that have successfully addressed risk assessment and management.

Table 1. Risk in interdisciplinary water programs.

Program Title	Institution	Website	Coverage of Risk in Curriculum
The Water Center-Interdisciplinary Watershed Sciences Minor	Colorado Mesa University	http://www.coloradomesa.edu/watercenter/index.html	None
I-WATER (Integrated Water Atmosphere, Ecosystems Education and Research)	Colorado State University	http://i-water.colostate.edu/	Yes - describes modeling as a key component to inform risk-based adaptation decisions
Graduate Certificate in Water, Environment and Development Studies	Florida International University	http://earthenvironment.fiu.edu/programs/graduate/grad-certificate-in-water-environment-and-development-studies/	None
Disaster Management PhD program	International Centre for Water Hazard and Risk Management (ICHARM and UNESCO), in coordination with National Graduate Institute for Policy Studies and Public Works Research Institute	http://www.icharm.pwri.go.jp/training/phd/phd_index.html	Yes - program description focuses on water-related risk management; unclear as to the specific courses
Integrated and Adaptive Water Resources Planning, Management, and Governance, 8-week certificate	McGill University	http://www.mcgill.ca/iwrm/online-iwrm-course	Yes - from perspective of water business risk assessment
Center for Water & Society Graduate Certificate in Sustainable Water Resources Systems	Michigan Tech University	http://www.mtcws.mtu.edu/education_gradcert.html	None
Water Science and Management	New Mexico State University	http://aces.nmsu.edu/academics/pes/water-science-and-manage.html	None
Certificate in Water Conflict Management and Transformation	Oregon State University	http://www.transboundarywaters.orst.edu/	Yes - "risk, uncertainty, and complexity" are included as a core element of the "Water and Ecosystems" component of the program
Water Resources Program (Water Resources Policy and Management and Water Resources Sciences degrees)	Oregon State University	http://oregonstate.edu/gradwater	None
Water Science and Engineering Initiative	Syracuse University	http://water.syr.edu/	None
Interdisciplinary Graduate Water Degree Program	Texas A&M University	http://takethenextstep.tamu.edu/water-degree-program-research-areas	None
Water Diplomacy Program	Tufts University	http://ase.tufts.edu/igert/waterdiplomacy/	None

Table 1 Continued.

Program Title	Institution	Website	Coverage of Risk in Curriculum
Water: Systems, Science and Society Graduate Certificate Program	Tufts University	http://www.tufts.edu/water/	None
Water Management MSc	UNESCO-IHE	http://www.unesco-ihe.org/water-management	None
IGERT in Climate Change, Water and Society	University of California Davis	http://ccwas.ucdavis.edu/	None
Water SENSE IGERT	University of California Riverside	http://watersense.ucr.edu/	None
Graduate Program in Water Science and Policy	University of Delaware	http://www.udel.edu/watersciencepolicy/index.html	None
Water Hazards, Risk & Resilience MSc	University of Dundee, Scotland	http://www.dundee.ac.uk/study/pg/waterhazardsriskresilience/	Yes - the courses focus on natural hazards and society, mapping, assessing, communicating risk
Water Institute Graduate Fellows program	University of Florida	http://waterinstitute.ufl.edu/WIGF/	None
Water Resources & Professional Science Masters (PSM) (including an IGERT program)	University of Idaho	http://www.uidaho.edu/cogs/envs-wr/academics/water-resources	None
Energy-Water-Environment Sustainability Program	University of Illinois	http://cee.illinois.edu/EWES	None
Water Resources Science Graduate Program	University of Minnesota	http://wrs.umn.edu/	None
Water Resources Program	University of New Mexico	http://www.unm.edu/~wrp/WRP_welcome.html	None
Water Resources Management Program	University of Wisconsin-Madison	http://grad.wisc.edu/catalog/degrees_waterres.htm	None
WARE (Interdisciplinary MS program in Water Resources)	University of Wyoming	http://www.uwyo.edu/ware/	None

Acknowledgements

Both authors contributed equally to this work. This research was funded through NSF research grant 0966093 IGERT: Water Diplomacy.

Author Bio and Contact Information

Laura Read is a doctoral candidate in the Civil and Environmental Engineering Department at Tufts University and a graduate fellow in the IGERT Water Diplomacy program. Her research is focused on characterizing floods in nonstationary systems and communicating the associated risks and reliabilities. She has worked on a variety of projects in Alaska on energy supply, in Peru on community water needs, and with the Army Corps of Engineers on resilience. She may be contacted at laura.read@tufts.edu or 200 College Ave, Medford, MA 02155.

Laura Kuhl is a doctoral candidate at the Fletcher School of Law and Diplomacy and a graduate fellow in the IGERT Water Diplomacy program. Her research looks at innovation, technology transfer and adoption for climate adaptation in the agricultural sector in East Africa and Central America, with case studies in Ethiopia and Honduras. She may be contacted at laura.kuhl@tufts.edu or Center for International Environment and Resource Policy, The Fletcher School, Tufts University, Cabot Intercultural Center, Suite 509, 160 Packard Ave, Medford, MA, 02155.

References

American Society of Civil Engineers (ASCE) 2014. *Flood risk management: Call for a national strategy*. Robert Traver, Ph.D., P.E. (Ed.).

Berkes F., J.J. Colding, and C. Folke (Eds.) 2003. *Navigating social-ecological systems: Building resilience for complexity and change*. Cambridge University Press, Cambridge, UK.

Blaikie P, T. Cannon, I. Davis and B. Wisner. 1994. *At risk, natural hazards, people's vulnerability, and disasters*. Routledge, London and New York.

Bookmann, B. and P.W. Thurner. 2006. Flexibility provisions in multilateral environmental treaties. *International Environmental Agreements* 6: 113-135.

Bourget, P.G. 2006. Integrated water resource management curriculum in the United States: Results of a recent survey. *Journal of Contemporary Water Research and Education* 135: 107-114.

Bourget, P.G. 2008. Key lessons from the Masters degree program in water resources planning and management. *Journal of Contemporary Water Research and Education* 139: 55-57.

Camkin, J. and S. Neto. 2013. New learning foundations for building water knowledge bridges. *Journal of Contemporary Water Research and Education* 150: 72-79.

Drieschova, A., M. Giordano and I. Fischhendler. 2008. Governance mechanisms to address flow variability in water treaties. *Global Environmental Change* 18: 285-295.

Fischhendler, I. 2004. Legal and institutional adaptation to climate uncertainty: A study of international rivers. *Water Policy* 6: 281-302.

Folke C., S.R. Carpenter, B. Walker, M. Scheffer, T. Chapin, and J. Rockström. 2010. Resilience thinking: Integrating resilience, adaptability and transformability. *Ecology and Society* 15(4): 20.

Fort, D.D. 2008. The nature of legal education and its links to water management. *Journal of Contemporary Water Research and Education* 139: 30-33.

Graney, J., K. Salvage, and W. Zhu. 2008. A watershed-based approach to environmental education integrating ecology, hydrology, and geochemistry. *Journal of Contemporary Water Research and Education* 139: 22-28.

Gunderson, L. 1999. Resilience, flexibility and adaptive management - antidotes for spurious certitude. *Conservation Ecology* 3: 7.

Haimes, Y.Y. 2009. On the complex definition of risk: A systems-based approach. *Risk Analysis* 29: 1647-1654.

Heltberg R., P.B. Siegel, and S.L. Jorgensen. 2009. Addressing human vulnerability to climate change: Toward a 'no-regrets' approach. *Global Environmental Change* 19: 89-99.

Howe, C.W. 2008. Preface to 'A creative critique of U.S. water education'. *Journal of Contemporary Water Research and Education* 139: 1-2.

IPCC, 2012. Managing the risks of extreme events and disasters to advance climate change adaptation. A special report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (Eds.). Cambridge University Press, Cambridge, UK, and New York, NY, USA.

IPCC, 2014. Climate change 2014: Impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (Eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Kaiser, R. 2008. The graduate water program at Texas A&M University. *Journal of Contemporary Water Research and Education* 139: 47-54.

Kirshen, P.H., R.M. Vogel, and B.L. Rogers. 2004. Challenges in graduate education in integrated water resources management. *Journal of Water Resources Planning and Management* 130(3): 185-186.

Layzer, J.A. 2008. Training people managers: The social and institutional dimensions of water management. *Journal of Contemporary Water Research and Education* 139: 34-36.

Lettenmaier, D.P. 2008. Have we dropped the ball on water resources research? *Journal of Water Resources Planning and Management* 134: 491-492.

Loucks, D.P. 2005. Educating future water resources managers. *Journal of Contemporary Water Research and Education* 139: 17-22.

Lund, J.R. 2002. Floodplain planning with risk-based optimization. *Journal of Water Resources Planning and Management* 128(3): 202-207.

Maass, A., M. M. Hufschmidt, R. Dorfman, H. A. Thomas Jr., S.A. Marglin and G.M. Fair. 1962. *Design of water-resource systems*. Harvard University Press, Cambridge, MA.

Mays, L.W. 2011. The role of risk analysis in water resources engineering. *Journal of Contemporary Water Research and Education* 103(1): 3.

McIntosh, B.S. and A. Taylor. 2013. Developing T-shaped water professionals: Building capacity in collaboration, learning and leadership to drive innovation. *Journal of Contemporary Water Research and Education* 150: 6-17.

Pinter, N., S. Baer, L. Chevalier, R. Kowalchuk, C. Land, and M. Whiles. 2013. An "IGERT" model for interdisciplinary doctoral education in water-related science and policy. *Journal of Contemporary Water Research and Education* 150: 53-62.

Reuss, M. 2003. Is it time to resurrect the Harvard Water Program? *Journal of Water Resources Planning and Management* 129(5): 357-360.

Saito, L., T.E. Link, A. Fernald, and L. Kohne. 2013. Lessons learned from an inter-institutional graduate course on interdisciplinary modeling for water-related issues and changing climate. *Journal of Contemporary Water Research and Education* 152(1): 4-13.

Stakhiv, E.Z. 2008. Cogitations on the education of water resources managers. *Journal of Contemporary Water Research and Education* 139: 6-11.

Thomalla F., T. Downing, E. Spanger-Siegfried, G. Han, and J. Rockström. 2006. Reducing hazard vulnerability: Towards a common approach between disaster risk reduction and climate adaptation. *Disasters* 30: 39-48.

United States Army Corps of Engineers (U.S. ACE). 2006. Risk analysis for flood damage reduction studies. Report ER 1105-2-101.

United States Environmental Protection Agency (EPA). 2014a. Drinking water risk assessments. Available at http://www.epa.gov/scipoly/sap/tools/atozindex/drinkrisk.htm. Accessed March 18, 2015.

United States Environmental Protection Agency (EPA). 2014b. TMDL Model evaluation and research needs. Available at http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/upload/600r05149.pdf. Accessed March 18, 2015.

United Nations International Strategy for Disaster Relief (UNIDSR). 2009. Terminology on disaster risk reduction. Available at: http://www.unisdr.org/we/inform/publications/7817. Accessed March 19, 2015.

Viessman, W. Jr. 2008. Water resources management and planning on-line. *Journal of Contemporary Water Research and Education* 139: 40-46.

Walker B. H., J. M. Anderies, A. P. Kinzig, and P. Ryan. 2006. Exploring resilience in social-ecological systems through comparative studies and theory development: Introduction to the special issue. *Ecology and Society* 11: 12.

Water Resources Council (US) 1983. Economic and environmental principles and guidelines for water and related land resources implementation studies. Water Resources Council.

Wolf, A.T. 1998. Conflict and cooperation along international waterways. *Water Policy* 1(2): 251-265.

Wolf, A.T. 1999. Criteria for equitable allocations: The heart of international water conflict. *Natural Resources Forum* 23(1): 3-30.

Yen, B. C. 1970. Risks in hydrologic design of engineering projects. *Journal of the Hydraulics Division* 96(4): 959-966.