MSU Water Blue-Ribbon Panel
Final Report to OVPRGS
January 3, 2011

Executive Summary

Michigan State University is uniquely positioned to become a global leader in water science and policy. Provision of a safe and sustainable supply of water for humanity is widely anticipated to be one of the driving issues of global politics and economics during this century. Water is also closely tied to many other leading sustainability issues such as energy, climate, and food security. Solutions to problems of water supply and quality will come from new science that spans traditional disciplines and innovative policy based on that science. Because of this there are enormous opportunities for a research institution such as MSU, both regionally and internationally, to garner extramural resources and to have a major impact on our global future. We have an exceptional cadre of water experts at MSU, are located in a water-rich region of the world, and are already widely seen as a center of excellence for many facets of water science. Now is the time to take our water science programs to the next level, so that we can lead the development of Michigan's "Blue Economy" and use our established international reach to become a global player in water.

Between June and November 2010, a panel of MSU water experts, spanning the natural, social and engineering sciences, was convened to assess MSU's strengths in water science and consider how best to advance a water science agenda. The panel concluded that we already have considerable disciplinary strength in all dimensions of water science, but to capitalize on the BIG opportunities in the future we need the capacity to develop truly "transdisciplinary" programs. We define transdisciplinary, following Tress et al. 2004, as research that involves academic and non-academic participants from different, unrelated disciplines and co-creates new knowledge to address problems which are insoluble from the perspective of a single discipline. We examined several current and emerging areas of focus in water science, and noted in each case that new advances are likely to be greatest when they result from meaningful integration and engagement across disciplines, often by looking outward from a disciplinary core – for example in invasion ecology or water quality engineering – to discover and exploit linkages to other disciplines – for example risk-benefit analysis or human welfare assessment. The "big plays" in water will doubtless draw upon a combination of natural (environmental) science, social science, and engineering.

The panel envisions a campus-level enterprise, which we provisionally title *The MSU Water Academy*, whose singular purpose will be to facilitate transdisciplinary water science. Strong leadership for the Academy will be vital – we should seek a leader with experience in a water-related discipline, but more importantly who can demonstrate the capacity to guide and motivate transdisciplinary work. The panel also sees great value in infrastructure that will facilitate greater interaction among water scientists from different disciplines – we believe that together with the right leadership this infrastructure will be a powerful catalyst for success. The panel also recommends the immediate establishment of a Visiting Scholar Program, wherein water experts from around the world with experience working across disciplinary boundaries are invited to MSU for an extended visit during which they would engage water scientists here through workshops and colloquia, and collaborate to develop white papers or research proposals. Finally, the panel advocates a coordinated, strategic investment in water science experts across multiple colleges, but focused in areas where the additional expertise would enhance transdisciplinary teams.

Main Report

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I. Background to the Formation of the MSU Blue-Ribbon Panel

In May 2010, the Office of the Vice-President for Research and Graduate Studies convened a Blue Ribbon Panel (Table 1) to examine MSU's strengths and opportunities for advancing a water science agenda on campus. The Panel was asked to consider the following questions:

1. What are MSU's competitive advantages in water science?
2. Are there areas where we could increase or develop a competitive research advantage if wise investments were made?
3. What are these investments, and if they were made, what would be the expected return back to MSU?
4. What would it take for MSU to become highly competitive for "big science" funding in water?
5. Is our research infrastructure for water science adequate, and if not, what is needed as a priority?
6. What should be our international goals for water science?

In his letter giving the Panel this mandate, Associate VPRGS Dr. Steve Pueppke noted that much is going on in water science at MSU already, starting with a considerable number of faculty with active research programs dealing with some aspect of water. Water is also is a major focus of several academic units on campus (e.g., Zoology, Fisheries and Wildlife, Civil and Environmental Engineering), and cross-cutting programs such as the Center for Water Science (CWS), the Institute of Water Research (IWR), and the Environmental Science and Policy Program (ESPP). CWS, IWR and ESPP have developed important mechanisms for faculty to bridge disciplines and work collectively on opportunities involving water. On the other hand, many of the MSU faculty and the Panel members feel that there are enormous opportunities to build upon MSU's existing strengths in water, and thereby to create something far more significant, enhancing the university's impact on water science, technology, education, and the development of water policy, both regionally and globally.

Table 1. Members of Water Science Blue Ribbon Panel

Name	Academic Unit	
Michael Jones	Fisheries and Wildlife	Co-chair
Fred Dyer	Zoology	Co-chair
Erin Dreelin	Fisheries and Wildlife	Panel Support
Jon Bartholic	Institute for Water Research	
Steve Hamilton	Zoology/KBS	
Syed Hashsham	Civil and Environmental Engineering	
Dan Kramer	Fisheries and Wildlife/James Madison College	
Elena Litchman	Zoology/KBS	
Frank Lupi	Fisheries and Wildlife/AFRE	
Pouyan Nejadhashemi	Biosystesm and Agricultural Engineering	
Joan Rose	Fisheries and Wildlife/Crop and Soil Science	
Jan Stevenson	Zoology	
Vlad Tarabara	Civil and Environmental Engineering	

The panel engaged in extensive discussions of strengths and opportunities in water at MSU, developed brief summaries of a representative set of potential focus areas, and advanced a common vision for the future of water science at MSU. This report summarizes the most important findings of the panel, and provides contextual information in a series of appendices. The report begins by emphasizing the great importance of water as a potential focal point for environmental research and education at MSU given the current national and international needs for water science and technology. This serves as the rationale for a University-wide, strategic investment that would position MSU to be a global leader in water science. Then the report outlines the overall conceptual framework that emerged from the panel discussions, and that the Panel believes is the key to building the broad, interdisciplinary foundation that will facilitate moving water science at MSU "to the next level". This is followed by a description of a set of research focus areas that fit within this broad framework, and that emphasize strengths in some areas and gaps that MSU needs to fill in others. The report concludes with a summary of the major opportunities that a strategic investment in water science could target, and what the panel believes is most needed to build our capacity for success.

II. Water, a Key to Global Security

It is clear that MSU will serve a pivotal role in the 21st century in helping to address societal problems related to the environment by providing new science, technology, and interdisciplinary knowledge critical to development and sustainability of crucial environmental resources. With the quantity and quality of fresh water sources being subject to increasing pressure from changes in climate and land use, a Water Initiative at MSU would fill a state, national and international niche that demands attention.

Water is essential for life. This simple statement belies the complexity of fresh water resources and the dependence of human activities on fresh water. Fresh water ecosystems, for example, provide a vast array of services including animal habitat, recreational sites, flood control, and pollutant removal. Rivers and large lakes (such as the Great Lakes) provide navigational paths for international trade. Fresh waters serve as drinking water and a driver of growth for industries, supporting urbanization and economic development. And most often ground waters serve as irrigation for a global food supply.

However, the growth in human and agricultural animal populations has led to an increased demand for and degradation of water resources. Both ecosystem health and human health have been affected, often by multiple contaminant sources and other stressors. Climate change and variability is also projected to negatively impact water quantity and quality due to increased pollutant loads and inadequate infrastructure. These changes in quantity and quality are also expected to negatively affect food availability and security (Bates et al. 2008). While the developed world will be struggling to adapt to aging infrastructure, climate change, flooding and droughts, the developing world will literally be dying. According to the United Nations, approximately 1.2 billion people, or one fifth of the global population live in areas where water is naturally scarce. An additional 1.6 billion live in areas that lack infrastructure for drinking water (UN 2007). The area of land experiencing water stress is projected to double by 2050 due to climate change (Bates et al. 2008). Ensuring high quality water for people and ecosystems will continue to be a major global challenge. As Jeff Raikes, chief executive officer of the Bill & Melinda Gates Foundation, recently stated:

> *"Water is key. It's a critical issue. In many cases, it's a critical limitation. And we come together probably in some cases with different perspectives, but I think we can all agree that it's a critical challenge, one that we must take on."*[1]

On World Water Day, (March 22, 2010) Secretary of State Hilary Rodham Clinton outlined the Obama Administration's five key actions to focus on water issues[2] 1) build capacity at the local, national, and regional levels to address water problems 2) elevate US diplomatic efforts and better coordinate them addressing transboundary issues via 24 UN agencies and other intergovernmental bodies engaged on water issues including the World Bank, and other international financial institutions; 3) mobilize financial support toward water management, addressing water security, 4) harness the power of science and technology and 5) broaden the scope of partnerships between government, industry, NGOs and others.

Global research agendas have begun to discuss needs in the following areas for science, technology, and policy: Drought and flood initiatives associated with climate variability; mitigation of water-related disasters; enhancement of water quality; interactions between water and food security; water and human settlements; groundwater sustainability; and ecohydrology. Related cross-cutting issues include building of research and technology capacity; education; governance and international relates connected with water.

III. Importance of Water to Michigan and MSU

Michigan is defined geographically by the Great Lakes, making it easily recognizable even from space. The Great Lakes contain 84% of North America's fresh surface water and 10% of the US population lives in the watershed (EPA 2008). As a water-rich state, Michigan has not faced the water supply problems of the arid Southwest or rapidly-growing Southeast. However, the quality of water for drinking,

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[1] Keynote Address. The Future of Water for Food conference. Hosted by the University of Nebraska and the Bill & Melinda Gates Foundation, University of Nebraska–Lincoln, May 3-5 2009.

[2]http://www.state.gov/secretary/rm/2010/03/138737.htm

manufacturing, and recreation has been a major concern since the 19th century, and continues to be so today. The lakes have 9,402 miles of shoreline, 2,147 miles of which are on Michigan's mainland (MDEQ, 2007). In the United States as a whole, 75 percent of all recreational activity occurs within a half mile corridor around the shorelines of beaches, rivers, and lakes (SOM, 2006), and this percentage is undoubtedly higher in Michigan. The percent of monitored beaches in Michigan that have closures and advisories due to violating water quality standards has increased from 10.2% of monitored beaches in 2003 to 19.8% in 2009 (MDNRE 2010). Beach closures due to water contamination can have severe economic impacts, particularly in Michigan, as tourism is vital to local economies by supporting a major source of revenue, job creation, and investment (Houston, 2008).

Our state now faces challenging water resource management decisions at multiple scales. Protecting water resources is not only critical for ecological and human health, it is essential for maintaining growing sectors of Michigan's economy, including our tourism, agricultural, and shipping industries. The Great Lakes provide Michigan with 823,000 jobs, which is approximately 25% of the state's payroll (MDEQ 2009). To manage our water resources, a new vision is needed that applies innovative concepts and methods for understanding the complex interactions between natural and human systems over large spatial and temporal scales.

Climate change and energy are topics currently driving a great deal of the national environment agenda, and water is a critical component of these issues. Given Michigan's place as a freshwater-rich state, we will play a critical role in the looming water crisis. Water is one of Michigan's greatest assets. Several initiatives have already begun toward positioning Michigan as a global leader in water science and technology. The Engineering Society of Detroit Institute has promoted the "Michigan's Blue Economy Initiative" and "A Clean Water Enterprise Framework." Michigan has also demonstrated its leadership in water science, water resources and aquatic systems through the impressive submissions to the recent Great Lakes Restoration Initiative project call, submitting 346 of the 1049 proposals, significantly more than any other state. MSU researchers garnered over $7 million in GLRI funds, either through direct awards or through subcontracts.

MSU is well recognized in the state of Michigan as the "go to" place for water science. Approximately 100 faculty members work on water or in water-related fields (Appendix A). The water expertise at MSU is diverse and includes faculty from the Colleges of Natural Science, Agriculture and Natural Resources, Engineering, Social Science, Veterinary Medicine, and Human Medicine. Since 2005, MSU faculty have generated over $86 million in external research grants and contracts for water-related projects (Appendix B). Clearly, MSU already has tremendous potential and capacity to advance interdisciplinary research in water science and policy. This capacity sets MSU apart from others in the region, such as the University of Wisconsin-Milwaukee, who are also trying to position themselves as regional leaders in water science.

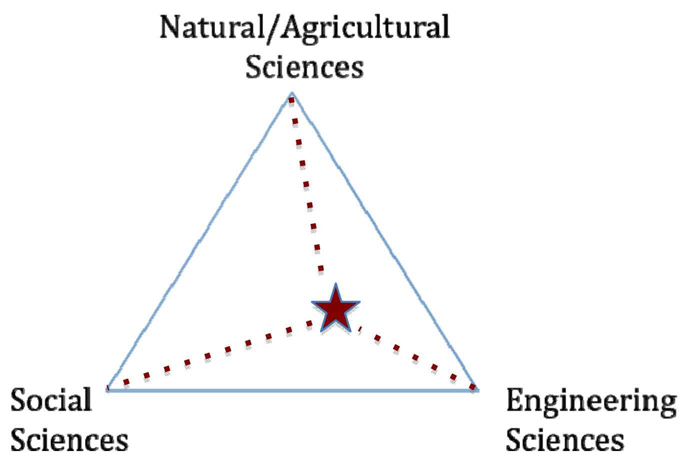
IV. A Conceptual Framework for Advancing Water Science at MSU

As noted above, MSU has tremendous capacity in scientific disciplines related to water and the environment (Appendix A), with expertise spanning many departments within the natural, social, and engineering sciences. Faculty researchers in these departments are already responsible for a large amount of research funding from a diversity of sources (Appendix B). Traditionally, much of the research has been focused within specific disciplinary settings. Research is becoming increasingly interdisciplinary, however, and the success of emerging collaborations at MSU is making it clear that continued strategic investment in interdisciplinary research will catapult MSU to national and international leadership in water research and policy development.

This growth of interdisciplinary activity is highly desirable because solving the most serious, and most challenging, problems related to water nearly always requires consideration of multiple academic disciplines. This is where the greatest opportunities exist to enhance MSU's reputation as a global leader in water science, and consequently to vastly increase extramural support.

To facilitate the thinking toward a broad initiative on water here at MSU, the Panel developed a simple conceptual framework that captures the potential for interaction among three broad disciplines: Natural and agricultural sciences (which traditionally focus natural ecosystems, food systems, pollution and environmental impacts), engineering (risk assessment, technology and solutions), and social science (assessment of the economic value of ecosystem services, evaluation of tradeoffs, and policy development).

The figure below depicts this conceptual framework. The vertices of the triangle represent the disciplinary homes described above. The triangle itself defines the space of possible interactions among disciplines, and allows for varying degrees of interaction. It is clear that most environmental problems, including those related to water, will best be addressed not by a small group of similarly-trained experts working near the vertex corresponding to their particular discipline, but in collaborations that map somewhere closer to the middle of the triangle. This framework describes interdisciplinary research activity, its real value is to aide in planning effective initiatives that will both enhance the core disciplines and increase connectivity among disciplines.



Consider the following example, discussed at more length in the next section. The development of new membrane technology for water security and efficient re-use is at its core one of the key solutions being examined by engineering scientists at MSU. However, the successful use of such technologies for water production, conservation and public safety in water-poor regions would most likely depend on (or certainly benefit from) research by economists and other social scientists to understand the incentives and impediments that may affect the widespread use of the technology. Further, water re-use, particularly for major companies that do it on a substantial scale, is quite likely to have an important environmental component, related to potential impacts on water quality and quantity. This illustrates how the impact of disciplinary research can be multiplied when disciplinary scientists "look outward" for ways to intersect with the perspectives and expertise of others. MSU, with its immense and diverse strengths in the study of the environment, and of water in particular, is exceptionally well positioned to have this impact.

While great opportunities lie in the area of interdisciplinary efforts, these efforts rely on maintaining the quality and diversity of contributing disciplines, and increasing opportunities for collaboration. The research focus areas described in the next section are intended to be *representative* of the kinds of science that MSU is well-positioned to do, that establish our leadership in the water arena, and that provide the foundation for building both disciplinary capacity and the frameworks for broader, transdisciplinary impacts. Henceforth we use the term "transdisciplinary" to represent research that involves academic and non-academic participants from different, unrelated disciplines and co-creates new knowledge to address problems which are insoluble from the perspective of a single discipline (Tress et al. 2004).

V. Research Opportunity Focus Areas

The panel identified and examined representative research areas where MSU has considerable strength and where there is opportunity to move forward at a national and international level:

- Aquatic invasive species
- Landscape hydrology
- Ecosystem approaches to water resource management
- Aquatic ecology
- Systematic freshwater conservation planning
- Water and food security
- Water, climate and energy
- Waterborne pathogens, water quality technology and health
- Water treatment technologies
- Energy-efficient water re-use

This is <u>not intended</u> to be a comprehensive or all-inclusive list of research areas where MSU has strength in water science or for water science in general. The objective in this section is to illustrate how, for each of these areas **as examples**, both disciplinary strength and opportunities for greater transdisciplinary work could establish MSU as a leader.

Aquatic Invasive Species*:* Invasive species are widely recognized as one of the primary threats to global biodiversity and the sustainable production of ecosystem services, in both terrestrial and aquatic ecosystems. Aquatic invasive species are a pre-eminent issue in the Great Lakes region: as examples, Canada and the United States have, since the mid-1950s, spent more than $500 million to combat the invasive sea lamprey, biofouling by zebra and quagga mussles is a continuing and costly problem, and the looming prospect of an Asian carp invasion of the Great Lakes has gained international attention. MSU has exceptional disciplinary strength in this area, particularly regarding the biological aspects of invasive species and their control. These strengths could provide a core from which a much broader program could be developed that considers more fully technological aspects of invasion prevention and invasive species control and socio-economic aspects of invasive species management. Species invasions are to a great extent a by-product of global commerce, and developing strategies for minimizing the risks and impacts of invasions will require a holistic perspective that confronts the trade-offs between economic benefits of increased trade and ecological/economic consequences of invasions, and seeks cost-effective solutions, pre- and post-invasion.

Landscape hydrology*:* The movement of water across landscapes and the exchange of water between groundwater and surface-water bodies determine the quality of water for consumption and the value of lakes and streams for recreation and aesthetics as well as for habitat of myriad plants and animals. Engineers and hydrologists at MSU have developed models of surface and subsurface hydrology, often motivated by practical concerns of water use and management as well as risk assessment. Aquatic ecologists have become increasingly interested in how water "in the landscape" affects water quality and biota in lakes, streams and wetlands, coining terms like "landscape limnology" and "integrated watershed assessment". The potential for greater synergisms between the physical and biological scientists in these two groups seems very large, particularly as hydrological data and models become more powerful and accessible. The human dimensions of this issue are also very important: how does demand for water use affect the distribution of water on the landscape and how might trade-offs between "up-hill" and "down-hill" water uses and values be resolved?

***Ecosystems Approach to Water Resources Management**:* It has frequently been argued that many shortcomings of past water resource management derived from a lack of consideration of the interactions among different elements of an ecosystem. The "ecosystem approach" has been coined to describe a more comprehensive and integrated approach to management. In the field of water resources, ecosystem management is a goal-directed process for achieving sustainable use of water while adequately considering environmental aspects. Such management accounts for the complex interactions between ecological structure and function, including valuable ecosystem services, and the quality, quantity, and spatiotemporal variability of water resources. Because this focus area is by definition holistic, building our capacity in this area will require scientists from a wide range of disciplinary areas to engage one another. MSU has a wealth of disciplinary experts representing all three dimensions of water science discussed above. The key to advancement in this area will be leadership: identifying (or recruiting) integrative scientists that can effectively broker productive partnerships among a group of disciplinary experts with contrasting and complementary skills.

***Aquatic ecology**:* MSU has exceptional depth and strength in the discipline of aquatic ecology – the study of how aquatic organisms interact with one another and their environment. This is a focus area that clearly lies closest to the Natural/Agricultural Sciences vertex in the conceptual framework. However, this strength in aquatic ecology, from algae to fish, provides an extremely rich starting point for the development of transdisciplinary research initiatives. Each of the focus areas listed above provides an example of this, where aquatic ecology is a key disciplinary contribution to our understanding of invasive species, landscape hydrology and aquatic ecosystem management. This strength can be exploited in many other interdisciplinary areas as well, however, including the management of harmful algal blooms and economically important fisheries. Research initiatives that bring together disciplinary expertise in aquatic ecology and social science provide a very promising opportunity to leverage existing strengths in a complementary and synergistic interaction.

***Systematic conservation planning**:* Freshwater is globally scarce and water conservation problems are numerous and great. Decision makers need sound scientific advice to prioritize freshwater conservation goals, strategies, and actions. Good planning requires a broad assessment of problems (e.g. invasive species, water quality, water quantity), solutions (e.g. protected areas, riparian buffers, water treatment, wetland mitigation), and tradeoffs: ecological, economic, and social. As with ecosystem management this requires a trans-disciplinary approach that includes human and natural systems. MSU does not have a conspicuous national profile in this area, but our connections with such efforts at the Michigan Natural Features Inventory, combined with existing expertise on conservation planning in terrestrial ecosystems (e.g., Jack Liu), create an opportunity for MSU to establish leadership in conservation planning related to water.

***Water and Food Security**:* Lack of water is a constraint to producing food for millions of people in the world today. Dramatic increases in agricultural productivity over the past 50 years have been driven by improved crop varieties, fertilizer use and the doubling of irrigated land to keep pace with population growth, but gains have slowed and experts foresee difficulty in keeping up with future demands including a doubling of food requirements by 2050.. Agriculture now consumes 75 percent of all freshwater withdrawals and 86 percent of human consumptive use, the vast majority used for irrigating crops. The prospect of dramatic increases in bioenergy crop production will further strain agricultural production systems and exacerbate impacts on water quality and quantity. Solutions to these challenges will call for holistic science that explicitly links environment, agriculture, social sciences and engineering – a "systems approach" to problem analysis. Perhaps more than any of the other focus areas discussed above, this is a largely untapped opportunity for MSU. The considerable capacity in water science that is the focus of this report needs to be connected more explicitly with the equally considerable capacity in agricultural and food sciences and our global leadership in social science related to food security. Again, there is a vital role for interdisciplinary collaborations to facilitate these connections.

Water, climate, and energy

Two issues that are receiving considerable attention at MSU and elsewhere are global climate change and renewable energy. Both of these issues have vitally important linkages to water. For example, climate change is expected to exacerbate threats to biodiversity by modifying habitats to disproportionately favor invasive species over native species adapted to historical climate patterns. Similarly, climate change is expected to significantly alter the terrestrial water balance and change precipitation and streamflow regimes, with consequences for landscape hydrology, water quality, and the ecosystem services received by people. A key area (especially for MSU) of renewable energy development concerns biofuels – expansion of biofuel crop production and land-use competition between food and fuel production also have important implications for water use, and may in some instances be driven by water supply issues. An MSU initiative in water science needs to explicitly recognize these important linkages and design programs that are cross-complementary with other initiatives in these areas. An example is the DOE-funded Great Lakes Bioenergy Research Center, whose multifaceted research program on cellulosic biofuels includes environmental and social sustainability as well as topics such as genetic engineering and ethanol production technologies.

Waterborne pathogens, water quality technology and health*:* This is an important area of existing strength at MSU. Microbial genomics, quantitative risk assessment, land use impacts on waterborne pathogens, and global health related to waterborne diseases, are all areas of active research. This research spans disciplines from molecular ecology and genetics to economics and public health, and includes engineering (development and certification of novel and new technology), environment (water quality and disease ecology) and social (risk, economics) sciences. Currently WHO, UNICEF and others are beginning to examine the considerable challenge of linking water quality to quantity for the Millennium Development Goals. This will direct resources toward much needed research on technology, tools and models in the future in which MSU is positioned to take a leadership role. This would also be tied to food safety and security as well as water treatment at the international and national levels. Here again MSU's strength in bench and field science provides a platform for building broader initiatives.

Water treatment technologies*:* More than 1.2 billion people do not have safe drinking water. The global investment needed to address water infrastructure for the next 20 years is estimated at $4.5 trillion. Although most of this investment is expected to be in infrastructure, novel treatment methods will also be an important area of investment, including residential treatment technologies (e.g., GE's ultrafiltration system for homes), and emerging technologies mainly focusing on nanotechnology-based treatment. MSU has some expertise related to water treatment technology, but existing strengths would be complemented by engineering scientists with broad expertise in novel water treatment technologies. Use of low tech solutions addressing for example storm water and wetlands would be explicitly tied to ecohydrology. Additionally, there are important human dimensions to this issue (economics, welfare, technology adoption, development) that, if integrated with the engineering science, could greatly enhance MSU's ability to be a leader in this area.

Energy-efficient water re-use*:* This focus area is related to the water treatment technologies, it is a key area of opportunity for MSU, deserving of a separate discussion. Ensuring availability of affordable and safe drinking water and the environmental sustainability of water-intensive industries is one of the great global challenges. To be sustainable, water supplies of the future must incorporate reused water in an energy-efficient way. Because of their energy efficiency and low environmental and spatial footprints, membranes promise to play a central role in treating water for reuse. The grand challenges in membrane technologies for water reuse are *ensuring water safety* and *decreasing energy costs*. MSU has important capacity in this area that we can build on. There are specialized needs within engineering science (e.g., materials expert, biofouling expert). As promising technologies begin to appear, opportunities to link this engineering research with human dimensions (economics, social welfare and risk) and ecological dimensions (opportunities for ecosystem restoration or reduced water demand) will doubtless also appear. It may be strategic to consider this broader context at the outset.

VI. The Way Forward

We have argued that understanding the role of water as a link between natural and human systems is a goal of critical importance to the state of Michigan, the U.S., and the world, and that MSU is already uniquely positioned to take a leadership role in advancing this transdisciplinary science. Building MSU's capacity in this area will not only allow MSU to contribute to the solution of major problems facing society, but will also help the university elevate the national and international profile of multiple programs across the natural, engineering, and social sciences.

This is a lofty goal, but it is a realistic one. We believe that success will depend on the establishment of a structure at MSU, provisionally called the MSU Water Academy, which ties our water science programs together and provides institutional support, particularly for strategic new hires that will be key to linking existing expertise into transdisciplinary programs. Strong, non-partisan administrative leadership will be vital to the "Academy's" success, given the wide array of disciplines and academic units that will be involved. The University should consider recruiting such a leader externally, as one of the strategic hires for this initiative.

The panel is optimistic that, with strong leadership, this goal of putting MSU at the forefront of water science is realistic because of the remarkable disciplinary strengths we already enjoy, and because there are many major funding opportunities for which we are clearly competitive. Some obvious examples of such funding opportunities are (more details can be found in Appendix D):

- Great Lakes Restoration Initiative (GLRI): This is a multimillion dollar, multi-year, federal initiative (FY 2010 budget was $475 million). MSU researchers were very successful in competing for funding in the first year ($7,692,617 in direct grants and subcontracts). MSU's involvement will continue to grow in coming years;

- NSF Science and Technology Center (STC) Program: Funding level is up to $50 million for ten years. The next pre-proposal deadline is tentatively scheduled for April 2011. We expect that a transdisciplinary proposal in water sciences could be very competitive for this next round.
- NSF Engineering Research Center (ERC) Program: Funding level is up to $18.5 million for five years. RFPs are issued in odd-numbered years, and we expect that MSU can be competitive for the 2011 round.
- NSF Climate Water and Sustainability Grants: Funding level for several programs is in the range of $3 to $5 million for five years. MSU faculty are already involved in two Category I planning grants in this areas, which positions us well for the larger funding opportunity.
- NSF-USAID new initiatives. The details of this funding has not been released as of yet, but will address new international objectives in concert with developing new science via NSF's mission. It is almost certain that water will be a major theme.

In addition to these federal government programs, MSU should be competitive for funding from both philanthropic foundations and private corporations. New, cross-cutting initiatives with clear societal relevance are particularly attractive to such funders. We need to invest more effort in developing these non-federal opportunities.

Existing MSU faculty in water sciences (Appendix A) provide a solid foundation for success of the proposed "Academy". However, new investments will be vital to providing additional leverage and complementary strengths, and thus greatly increase the probability of success. A coordinated, strategic investment in faculty lines (10-15 across several Colleges), together with targeted support for existing faculty and programs will allow us to respond to new opportunities as they arise in the short term, at the same time as building unparalleled transdisciplinary research strength in the longer term. Specific suggestions include:

- Critical faculty positions that could enhance disciplinary strengths, AND strengthen linkages across disciplinary boundaries. Examples of such critical area experts include (but are not limited to):
    i. Social scientists with interests in water technology adoption and linkages between the dynamics of water use and human economic activities, including energy, agriculture, manufacturing, and recreation;
    ii. Engineers who take a comprehensive, systems-level view of the design, manufacture, and spread of technology related to the sustainable use of water resources;
    iii. Ecosystem scientists who model both natural processes involving water and the connection of these processes to ecosystem services that affect human well-being; and
    iv. Modelers who could contribute to a systems modeling group that facilitates linkages among disciplinary experts.

Some positions should be filled as soon as possible while others should be defined as the critical needs for transdisciplinary research teams for particular opportunities are identified.

- Funds to release key faculty members from teaching duties so that they can work as part of transdisciplinary teams to prepare large-scale multi-investigator proposals. In our experience, a key ingredient of success in such programs as the GLBRC and BEACON is the commitment of an enormous amount of time by talented faculty members in pursuit of a common goal. Time is scarcer for some individuals than others, and harder to find in colleges where teaching loads are heavier, so this investment of release time should be allocated according to both need and impact.
- Travel and administrative support for developing contacts with federal agencies, philanthropic foundations, and private corporations that may be interested in funding research in water and the environment, and for developing collaborations with partners at other universities, governmental bodies, and NGOs.
- Funding for a Distinguished Visiting Scientist program that would bring experts to MSU for an extended visit with the goal of fostering transdisciplinary initiatives through symposia, workshops, and other active engagement with researchers on campus, leading to the development of problem-specific white papers and/or funding proposals. The symposia and workshops could be used to foster collaborations among researchers, and to build relationships with potential funding agencies or NGOs.
- Consolidation of infrastructure to facilitate scaled-up testing and evaluation capability. Our longer term vision for infrastructure includes a centralized facility (i.e., a "Water Science Park") that would provide a physical space to house researchers and programs drawn from multiple academic units in a common area coordinated by the Academy.

VII. Conclusions

We conclude this report by summarizing our main findings in the context of the questions the panel was directed to consider during their deliberations.

1. What are MSU's competitive advantages in water science?

Our main competitive advantage in water science stems from our considerable strength in disciplinary-based water research, especially in the environmental and engineering sciences. MSU is well recognized in the state of Michigan as a "go to" place for water science. Approximately 100 faculty members work on water or water-related fields (Appendix A). Water expertise at MSU is diverse and includes faculty from the Colleges of Natural Science, Agriculture and Natural Resources, Engineering, Social Science, Veterinary Medicine, and Human Medicine. Our competitive advantage has allowed us to be successful in bring extramural funds to MSU: Since 2005, MSU faculty have generated over $86 million in external research grants and contracts for water-related projects (Appendix B). Our strength and breadth is disciplinary water science distinguishes MSU from other universities, especially within the Great Lakes region.

2. **Are there areas where we could increase or develop a competitive research advantage if wise investments were made?**

Yes. Traditionally, water research at MSU (and elsewhere) has been focused within specific disciplinary settings. In the future we expect the big research opportunities to increasingly require transdisciplinary research teams. We believe that a strategic investment in transdisciplinary research will catapult MSU to a much more prominent national and international position in water research and policy development. Members of the panel repeatedly mentioned that although we have strong disciplinary expertise, MSU is missing the linkages among disciplines that would move water science to the next level.

3. **What are these investments, and if they were made, what would be the expected return back to MSU?**

Building MSU's capacity in transdisciplinary science will not only allow MSU to contribute to the solution of major problems facing society, but will also help the university elevate the national and international profile of multiple programs across the natural, engineering, and social sciences. To build this capacity, we recommend:

- Establishing a structure at MSU, provisionally called the MSU Water Academy, which ties our water science programs together and provides institutional and administrative support to link existing expertise into transdisciplinary programs.
- Strategic hires that would enhance disciplinary strengths AND strengthen linkages across disciplinary boundaries. We recommend several strategic hires:
    - A strong, non-partisan, visionary leader for the MSU Water Academy
    - Social scientists with interests in water technology adoption and linkages between the dynamics of water use and human economic activities, including energy, agriculture, manufacturing, and recreation;
    - Engineers who take a comprehensive, systems-level view of the design, manufacture, and spread of technology related to the sustainable use of water resources;
    - Ecosystem scientists who model both natural processes involving water and the connection of these processes to ecosystem services that affect human well-being; and
    - Modelers who could contribute to a systems modeling group that facilitates linkages among disciplinary experts.
- Funding to release key faculty members from teaching duties so that they can work as part of transdisciplinary teams to prepare large-scale multi-investigator proposals.
- Travel and administrative support for developing contacts with federal agencies, philanthropic foundations, and private corporations that may be interested in funding research in water and the environment, and for developing collaborations with partners at other universities, governmental bodies, and NGOs.
- Funding for a Distinguished Visiting Scientist program that would bring experts to MSU for an extended visit with the goal of fostering transdisciplinary initiatives through symposia, workshops, and other active engagement with researchers on campus, leading to the developing of problem-specific white papers and/or funding proposals.
- Enhancement of infrastructure to allow scaled-up testing and evaluation capability for emerging technologies, and addition of infrastructure that facilitates greater engagement of MSU water science experts across disciplines.

The panel believes that these investments would position MSU to be very competitive for large funding opportunities. Some obvious examples of such funding opportunities include (more details can be found in the report and Appendix D):

- Great Lakes Restoration Initiative (GLRI): This is a multimillion dollar, multi-year, federal initiative (FY 2010 budget was $475 million).
- NSF Science and Technology Center (STC) Program: Funding level is up to $50 million for ten years.
- NSF Engineering Research Center (ERC) Program: Funding level is up to $18.5 million for five years.
- NSF Climate Water and Sustainability Grants: Funding level for several programs is in the range of $3 to $5 million for five years.
- NSF-USAID new initiatives.

4. What would it take for MSU to become highly competitive for "big science" funding in water?

We believe the investments described above (Question 3) to create and support transdisciplinary programs are needed to position MSU to become highly competitive for "big science" funding in water. This growth of transdisciplinary activity is highly desirable because solving the most serious, and most challenging, problems related to water nearly always requires consideration of multiple academic disciplines. New interfaces among disciplines are where the greatest opportunities exist to enhance MSU's reputation as a global leader in water science, and consequently to increase extramural support. In the short term, taking steps (such as the proposed Visiting Scholar Program) to encourage transdisciplinary initiatives in water science among our existing water science experts will help us to build a clearer vision of what we need most to garner "big science" funds.

5. Is our research infrastructure for water science adequate, and if not, what is needed as a priority?

Our response to Question 3 speaks to this. MSU has lots of infrastructure to support water science. It tends to be dispersed around campus, however, in alignment with academic units with strong water science programs. If MSU is to increase its competitive edge in water, in the ways we discuss in this report, addition of some more centralized infrastructure would be very desirable. For example, our ambitions would benefit from:

- Administrative support for a systems modeling group which explicitly incorporates physical models (engineering), ecosystems models, economics models, and human behavior models – including a place where these modelers can interact and collaborate;
- Platform facilities (e.g., large BL2 confinement facility) for scale-up testing of new and emerging water technologies;
- In the longer term, a facility (Water Science Park) that would provide a physical space to house researchers and programs drawn from multiple academic units in a common area that would be, in effect, the "home" for the MSU Water Academy.

6. What should be our international goals for water science?

The panel did not explicitly discuss international goals for water science. Even though Michigan is a water-rich region, and much of the rest of the world faces serious water scarcity concerns, the panel believes we have much to contribute on the international scale, and many water scientists already work internationally. Understanding the role of water as a link between natural and human systems is a goal of critical importance to the state of Michigan, the U.S., and the world. We believe that building MSU's capacity in water science as we describe in this report will allow MSU to contribute to the solution of major problems facing society, at local, regional, national and international scales. We have the potential to be a world leader in developing water policy that is informed by world-class, transdisciplinary science that includes the environment, technology, and humanity, and recognizes that water issues reside very much within the arena of coupled human and natural systems. This should be our international goal, as well as our regional goal.

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Appendices

Appendix A. Faculty Research at Michigan State University on Water-Related Topics.

First Name	Last Name	Department/Institute	College
Vangie	Alocilja	Biosystems & Agricultural Engineering	CANR/Eng
Jeff	Andresen	Geography	Social Sciences
Mark	Axelrod	Fisheries & Wildlife, James Madison	CANR/JMC
Jon	Bartholic	CARRS, IWR	CANR
Sandra	Batie	Agricultural, Food, and Resource Economics	CANR
Jan	Beecher	Public Utilities Institute, Economics	Social Sciences
James	Bence	Fisheries & Wildlife	CANR
Janette	Boughman	Zoology	CNS
Steve	Boyd	Crop And Soil Sciences	CANR
Mary	Bremigan	Fisheries & Wildlife	CANR
Merlin	Bruening	Chemistry	CNS
Kendra	Cheruvelil	Fisheries & Wildlife, Lyman Briggs	CANR/LBC
Jongeun	Choi	Mechanical Engineering	Eng
James	Cole	Crop And Soil Sciences, Center for Microbial Ecology	CANR/
Alison	Cupples	Civil & Environmental Engineering	Eng
Tracy	Dobson	Fisheries & Wildlife	CANR
Patrick	Doran	Fisheries & Wildlife (adjunct, TNC)	CANR
Erin	Dreelin	Fisheries & Wildlife, CWS	CANR
Anne	Ferguson	Anthropology, GenCen	Social Sciences
Stephen	Gasteyer	Sociology	Social Sciences
Steve	Hamilton	Zoology, KBS	CNS
Craig	Harris	Sociology	Social Sciences
Syed	Hashsham	Civil & Environmental Engineering	Eng
Daniel	Hayes	Fisheries & Wildlife	CANR
John	Hoehn	Agricultural, Food, and Resource Economics	CANR
Richard	Hula	Political Science	Social Sciences
David	Hyndman	Geological Sciences	CNS
Dana	Infante	Fisheries & Wildlife	CANR
Michael	Jones	Fisheries & Wildlife	CANR
Andrey	Kalinichev	Chemistry	CNS
Norbert	Kaminsky	Pharmacology & Toxicology/ Ctr. Int.Toxicology	Human Medicine
Michael	Kaplowitz	CARRS	CANR
John	Kerr	CARRS	CANR
Christopher	Klausmeier	Plant Biology, KBS	CNS
Ruth	Kline-Robach	CARRS, IWR	CANR
Daniel	Kramer	Fisheries & Wildlife, James Madison	CANR/JM
Jo	Latimore	Fisheries & Wildlife	CANR
Jay	Lennon	Microbiology & Molecular Genetics, KBS	CNS
Shu-Guang	Li	Civil & Environmental Engineering	Eng

Hui	Li	Crop and Soil Sciences	CANR
Weiming	Li	Fisheries & Wildlife	CANR
Wei	Liao	Biosystems & Agricultural Engineering	CANR/Eng
Susie	Liu	Biosystems & Agricultural Engineering	CANR/Eng
Arika	Ligmann-Zielinska	Geography, ESPP	Social Sciences
Elena	Litchman	Plant Biology, KBS	CNS
David	Long	Geological Sciences	CNS
Lifeng	Luo	Geography	Social Sciences
Frank	Lupi	Fisheries & Wildlife, AFRE	CANR
David	Lusch	Geography	Social Sciences
Linda	Mansfield	Large Animal Clinical Sciences, MMG	CVM/CNS
Phani	Mantha	Civil & Environmental Engineering	Eng
Terence	Marsh	Microbiology & Molecular Genetics	CNS
Susan	Masten	Civil & Environmental Engineering	Eng
Brian	Maurer	Fisheries & Wildlife	CANR
Victoria	McGuffin	Chemistry	CNS
Rich	Merritt	Entomology	CNS
Joe	Messina	Geography	Social Sciences
Gary	Mittlebach	Zoology, KBS	CNS
Cheryl	Murphy	Fisheries & Wildlife	CANR
A. Pouyan	Nejadhashemi	Biosystems & Agricultural Engineering	CANR/Eng
Pat	Norris	CARRS	CANR
Bill	Northcott	Biosystems & Agricultural Engineering	CANR/Eng
Nathaniel	Ostrom	Zoology	CNS
Peggy	Ostrom	Zoology	CNS
Nigel	Paneth	Epidemiology	Human Medicine
Scott	Peacor	Fisheries & Wildlife	CANR
Helen	Pollard	Anthropology	Social Sciences
Nikolai	Priezjev	Mechanical Engineering	Eng
Jiaguo	Qi	Geography	Social Sciences
Gemma	Reguera	Microbiology & Molecular Genetics	CNS
Dawn	Reinhold	Biosystems & Agricultural Engineering	CANR/Eng
Joan	Rose	Fisheries & Wildlife	CANR
Brian	Roth	Fisheries & Wildlife	CANR
Steven	Safferman	Biosystems & Agricultural Engineering	CANR/Eng
Tao	Sang	Plant Biology	CNS
Orlando	Sarnelle	Fisheries & Wildlife	CANR
Kim	Scribner	Fisheries & Wildlife	CANR
Patricia	Soranno	Fisheries & Wildlife	CANR
R. Jan	Stevenson	Zoology	CNS
Greg	Swain	Chemistry	CNS
Scott	Swinton	Agricultural, Food, and Resource Economics	CANR
Xiaobo	Tan	Electrical & Computer Engineering	Eng
Volodymyr	Tarabara	Civil & Environmental Engineering	Eng
Wiliam	Taylor	Fisheries & Wildlife	CANR
Brian	Teppen	Crops & Soil Sciences	CANR

James	Tiedje	Crops & Soil Sciences	CANR
Richard	Triemer	Plant Biology	CNS
James	Trosko	Pediatrics And Human Development	Human Medicine
Brad	Upham	Pediatrics And Human Development	Human Medicine
Remke	van Dam	Geological Sciences	CNS
Gail	VanderStoep	CARRS	CANR
Thomas	Voice	Civil & Environmental Engineering	Eng
Michael	Wagner	Fisheries & Wildlife	CANR
Robert	Walker	Geography	Social Sciences
Christopher	Waters	Microbiology & Molecular Genetics	CNS
Julie	Winkler	Geography	Social Sciences
Lois	Wolfson	Fisheries & Wildlife, IWR	CANR
Irene	Xagoraraki	Civil & Environmental Engineering	Eng
Catherine	Yansa	Geography	Social Sciences
Jinhua	Zhao	Economics, AFRE, ESPP	Social Science/CANR

Appendix B. Summary of Funded Proposals, 2005-2010.

Data obtained from CGA website, using a query with search terms: (water, aquatic, fish, lake, river, bay, stream, sewage, macroinvertebrate, nonpoint, alga), spanning the dates 1/1/2005 – 9/30/2010.

Year	First/Curr Amt Requested	Award Amount	# Proposals	Notes
2005	$11,218,230	$11,892,695	111	Year based on date proposal signed by CGA
2006	$8,621,719	$10,099,428	112	
2007	$16,823,566	$17,476,243	81	
2008	$13,944,588	$13,554,785	134	
2009	$19,237,355	$20,445,760	110	
2010	$12,987,501	$13,272,530	56	Goes up to 9/30/2010
	$82,832,959	**$86,741,441**	**604**	

A couple summary of the proposals included in this query is available on request.

Appendix C. Water Entities at MSU

<u>Center for Water Sciences</u>

The mission of The Center for Water Sciences (CWS) at MSU is to advance scientific research and knowledge for understanding, protecting, and restoring water resources and their sustainable use by humans and ecosystems around the Great Lakes and the world. Our interdisciplinary scientific teams of MSU faculty and students investigate and provide solutions to current, emerging, and future environmental problems that face our local, national, and global water systems. CWS investigators are addressing a variety of research topics including antibiotics in water and development of microbial resistance, viral pathogens and waterborne disease, the complexity of natural and human influences on biodiversity and valued attributes of aquatic ecosystems within watersheds, and the effects of contaminants with global origins. The CWS is dedicated to promoting the integration of traditional fields of science to address water-related issues and research that focus on ecosystems and human health.

Institute of Water Research

The Institute of Water Research (IWR) at MSU provides timely information for addressing contemporary land and water resource issues through coordinated multidisciplinary efforts using advanced information and networking systems. The IWR endeavors to strengthen MSU's efforts in nontraditional education, outreach, and interdisciplinary studies utilizing available advanced technology, and partnerships with local, state, regional, and federal organizations and individuals. Activities include coordinating education and training programs on surface and ground water protection, land use and watershed management, and many others.

Landscape Limnology Research Group

The spatially-explicit study of lakes, streams, and wetlands as they interact with freshwater, terrestrial, and human landscapes and climatic/atmospheric effects to determine the effects of pattern on ecosystem processes across temporal and spatial scales.

Kellogg Biological Station

This field station and academic unit of MSU houses ecologists from several departments who work at scales from populations to ecosystems, in terrestrial as well as aquatic ecosystems. Five of the 12 resident faculty conduct primarily aquatic research and two contributed to this report (Hamilton, Litchman). Water-related research includes limnology, biogeochemistry, and aquatic ecology. Considerable current research examines water in agricultural ecosystems, mainly under the aegis of the LTER and GLBRC research programs.

Great Lakes Bioenergy Research Center

Research program includes evaluating the implications of biofuel crop production for water quantity and quality

Anaerobic Digestion Research and Education Center (ADREC)

ADREC provides education and conducts research on waste to resource technologies with an emphasis on anaerobic digestion.

Quantitative Fisheries Center

Quantitative fisheries research, outreach and training: stock assessment, risk assessment and management

Institute of Public Utilities

Specializes in the structure, economics, and regulation of the water utility industry, including pricing.

Other entities that include work in water:

BEACON
The study of evolution, includes aquatic organisms

Center for Microbial Ecology
Includes research on aquatic microbial ecology

Center for Microbial Pathogenesis (CMP)
This center consists of researchers under the broad heading of bacterial pathogensis research, includes work on waterborne pathogens

Center for the Study of Standards in Society
There are several areas of research that touch on water: a) the role of the standard setting in the determination level of risk and action in emerging contaminants such as nano-materials, pharmaceuticals, etc.; b) the historical emergence and interaction between governmental and non-governmental standard setting bodies in water infrastructure; c) the social dynamics and problematics of emerging water system governance standards and training.

Enterics Research Investigational Network (ERIN)
The study of enteric disease with a focus on host microbiome, includes work on waterborne diseases

Environmental Science and Policy Program (ESPP)
ESPP is an umbrella for environmental research and graduate education at MSU. ESPP was established in order to: build interdisciplinary graduate education programs, facilitate interdisciplinary environmental research, and help connect MSU's areas of excellence to national and global efforts.

Sustainable Michigan Endowed Project (SMEP)
SMEP provides a venue for ongoing scholarly reflection and critique on the sustainability of Michigan, as well as seed grants for sustainability research from a Michigan state-level perspective. SMEP also provides a venue for on-going, long-term sustainability discourse with the goal of influencing the intellectual culture within MSU, and particularly the College of Agriculture and Natural Resources.

For a complete list of environmental organizations at MSU, see the Unit Matrix page of the Sustainability Science at MSU website at http://espp.msu.edu/sustain/units.php.

Appendix D. Examples of Major Federal Funding Opportunities in Water Science

NSF Engineering Research Centers (ERC)

From the most recent RFP: $13,000,000 (approximately) is expected to be available to support at least two and up to four new Gen-3 ERCs, with approximately two in the Fall of 2010 and two in FY 2011 with year one start-up budgets each of up to $3,250,000, year two budgets of up to $3,500,000, year three budgets of up to $3,750,000, and years four and five budgets of up to $4,000,000 each, pending satisfactory annual performance and availability of funding. NSF support will be augmented by academic cost sharing and financial and in-kind support provided by member firms, and for certain topic areas, these members would include state and local government agencies. Additional support from states and other sources is desired, but not required. NSF expects to make the awards for proposals submitted under NSF 09-545 in February or March 2011. Past ERC RFPs have been issued in odd-numbered years.

Program website: http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5502

NSF Environmental Synthesis Center (ESC)

From the most recent RFP: One award with a budget up to $6,000,000 per year for up to five years is anticipated, contingent on the quality of proposals received and pending the availability of funds. Up to $30,000,000 over a five-year period. The initial term of the award is expected to be five years, with the potential for one terminal renewal for an additional five years, subject to performance and availability of funds. Note that the maximum period NSF will support the center is 10 years. We strongly encourage creative thinking about the potential range of activities that might occur at this center and their budgetary needs. The last RFP was in 2010, past RFPs have been issued every two years (even-numbered years).

Program website: http://nsf.gov/funding/pgm_summ.jsp?pims_id=503440

NSF Science and Technology Centers (STC)

The Science and Technology Centers: Integrative Partnerships Program anticipates issuing a new solicitation in late fall of 2010 with a preliminary proposal deadline in April of 2011. All new solicitations are subject to final NSF approval. Five new Science and Technology Centers (STC) were awarded in summer 2010 as a result of a recent, merit-based competition.

Program website: http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5541

NSF Water Sustainability and Climate (WSC)

From the most recent RFP: Three categories of awards are anticipated for this solicitation. Category 1 Awards: Small exploratory or incubation grants to develop teams, identify sites, hold workshops and develop plans for establishment or operation of a study site. These will be 1-2 years in duration for up to $150,000. Category 2 Awards: Place-based observational and modeling studies, up to 5 years in duration and for a maximum of $5 million for each award, Category 3 Awards: Synthesis and integration grants that will only use existing data to integrate and synthesize across sites, 3-5 years in duration and for a maximum of $1.5 million for each award.

Program website: http://nsf.gov/funding/pgm_summ.jsp?pims_id=503452

Note: MSU researchers were awarded Category 1 and Category 3 grants in 2010. Category 1 grants are expected to result in a Category 2 grant proposal.

USDA Agriculture and Food Research Initiative (AFRI)

The Coordinated Agricultural Project (CAP) is a type of Research, Education, Extension, or Integrated Project that supports large-scale, multi-million dollar projects to promote collaboration, open communication, and the exchange of information; reduce duplication of effort; and coordinate activities among individuals, institutions, States, and regions. CAP projects were solicited under multiple AFRI programs in 2010, the next RFP will be issued in 2011.

EPA Great Lakes Restoration Initiative

The President's 2010 Budget provides $475 million in EPA's budget for a new Environmental Protection Agency-led, interagency Great Lakes restoration initiative, which will target the most significant problems in the region, including invasive aquatic species, non-point source pollution, and contaminated sediment.

This initiative will use outcome-oriented performance goals and measures to target the most significant problems and track progress in addressing them. EPA and its Federal partners will coordinate State, tribal, local, and industry actions to protect, maintain, and restore the chemical, biological, and physical integrity of the Great Lakes

Program website: http://www.epa.gov/glnpo/glri/index.html

Appendix E. Major Water Resources Research Areas

(*From Confronting the Nation's Water Problems: The Role of Research (2004). Committee on Assessment of Water Resources Research, National Research Council. National Academies Press. Washington, DC. Available online at http://books.nap.edu/catalog.php?record_id=11031*)

Water Availability

1. Develop new and innovative supply enhancing technologies
2. Improve existing supply enhancing technologies such as wastewater treatment, desalting, and groundwater banking
3. Increase safety of wastewater treated for reuse as drinking water
4. Develop innovative techniques for preventing pollution
5. Understand physical, chemical, and microbial contaminant fate and transport
6. Control nonpoint source pollutants
7. Understand impact of land use changes and best management practices on pollutant loading to waters
8. Understand impact of contaminants on ecosystem services, biotic indices, and higher organisms
9. Understand assimilation capacity of the environment and time course of recovery following contamination
10. Improve integrity of drinking water distribution systems
11. Improve scientific bases for risk assessment and risk management with regard to water quality
12. Understand national hydrologic measurement needs and develop a program that will provide these measurements
13. Develop new techniques for measuring water flows and water quality, including remote sensing and in situ.
14. Develop data collection and distribution in near real time for improved forecasting and water resources operations
15. Improve forecasting the hydrological water cycle over a range of time scales and on a regional basis
16. Understand and predict the frequency and cause of severe weather (floods and droughts)
17. Understand recent increases in damages from floods and droughts
18. Understand global change and its hydrologic impacts

Water Use

19. Understand determinants of water use in the agricultural, domestic, commercial, public, and industrial sectors
20. Understand relationships between agricultural water use and climate, crop type, and water application rates
21. In all sectors, develop more efficient water use and optimize the economic return for the water used
22. Develop improved crop varieties for use in dryland agriculture
23. Understand water-related aspects of the sustainability of irrigated agriculture
24. Understand behavior of aquatic ecosystems in a broad, systematic context, including their water requirements
25. Enhance and restore of species diversity in aquatic ecosystems

26. Improve manipulation of water quality and quantity parameters to maintain and enhance aquatic habitats
27. Understand interrelationship between aquatic and terrestrial ecosystems to support watershed management

Water Institutions

28. Develop legal regimes that promote groundwater management and conjunctive use of surface water and groundwater
29. Understand issues related to the governance of water where it has common pool and public good attributes
30. Understand uncertainties attending to Native American water rights and other federal reserved rights
31. Improve equity in existing water management laws
32. Conduct comparative studies of water laws and institutions
33. Develop adaptive management
34. Develop new methods for estimating the value of nonmarketed attributes of water resources
35. Explore use of economic institutions to protect common pool and pure public good values related to water resources
36. Develop efficient markets and market-like arrangements for water
37. Understand role of prices, pricing structures, and the price elasticity of water demand
38. Understand role of the private sector in achieving efficient provision of water and wastewater services
39. Understand key factors that affect water-related risk communication and decision processes
40. Understand user-organized institutions for water distribution, such as cooperatives, special districts, and mutual companies
41. Develop different processes for obtaining stakeholder input in forming water policies and plans
42. Understand cultural and ethical factors associated with water use
43. Conduct ex post research to evaluate the strengths and weaknesses of past water policies and projects