# **GLOBAL INSTITUTE FOR WATER SECURITY**

PROGRESS REPORT 2011-13

(Founding Report)









Global Institute for Water Security

# **GLOBAL INSTITUTE FOR WATER SECURITY**

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#### **OUR VISION**

To undertake world-class research that enables and enhances water security – "sustainable use and protection of water resources, the safeguarding of access to water functions and services for humans and the environment, and protection against water-related hazards (flood and drought)."

#### **OUR MISSION**

- Create a focus and platform for interdisciplinary collaboration that recognizes the societal dimensions of water security, human impacts on the environment, and the linkages and feedbacks between atmosphere, land and water systems. This requires new integration of the relevant spectrum of natural, health and social sciences, public policy and engineering;
- Develop the knowledge, science and technologies needed to support integrated water quantity and quality management in the face of uncertain climate and water resource futures, and address local, regional and global water security agendas;
- Develop partnerships with key stakeholders to translate science into policy and management support to meet water security challenges, including interactions among water, food, energy and ecosystem services (i.e., benefits to human welfare), climate change adaptation and mitigation challenges, and the human health agenda;
- Provide tools, technologies, and computer models for application to key globally significant water security issues, with international application; and,
- Create a unique opportunity for governments, industry and universities to invest in and collaborate on one of our most pressing global issues.

#### **DIRECTOR'S MESSAGE**

Welcome to the University of Saskatchewan's Global Institute for Water Security (GIWS). The institute was created in 2011 with support from the Canada Excellence Research Chair in Water Security to foster research collaboration across the university and with key Federal and

Provincial partners. Together, we are addressing regional and global challenges of Water Security. Key research themes include Climate Change and Water Security, Land-Water Management and Environmental Change, Sustainable Development of Natural Resources and Sociohydrology.

Fresh water is essential for human life and well-being, for economic development and for entire global ecosystems. While water can be a major threat through floods and droughts, water resources are also under pressure worldwide, from population growth and movement, economic development, climate and land use changes, and pollution. Tensions are rising over scarce water resources, with potential for population migration in the face of water stress and growing awareness of the role of "embedded water" in food, goods and services. Effective water management is thus a social imperative and water security is increasingly recognized as a strategic national and international priority. Further, effective water management is becoming increasingly complex, requiring understanding of aquatic and terrestrial environments, their vulnerabilities to environmental change and water management and protection challenges.



Canada is not immune from these global issues. Water contributes \$23 billion annually to our economy, yet recent floods and droughts have caused loss of life and major economic damage, and our water resources face serious pressures on water quantity and quality. A 2009 World Wildlife Fund (WWF) report points to significant concerns for the environmental sustainability of Canada's major river systems, concerns exacerbated by climate change.

New interdisciplinary science and technological innovation is urgently required to inform water management and policy and to develop new solutions to critical problems facing global and domestic water security. It is now imperative to address these issues using the spectrum of relevant disciplines and to translate this integrated science into technologies and useful information for decision-making, working with stakeholders and state-of-the-art informatics tools. These global needs are addressed through our institute, which is already viewed as an

internationally-leading institution for interdisciplinary water science. GIWS takes advantage of the capacity, investments, sense of place and 45-year history of water-related research here at the University of Saskatchewan (U of S). We address issues of national and international priority, contribute to innovation and promote broad and inclusive research collaboration.

GIWS strategically positions Canada to deal with water security challenges nationally and internationally, including water use, policy, management and reclamation, while training national and international students to ensure the world's water security.

GIWS has come a long way since its foundation in 2011, and we are proud of our achievements thus far. However, none of this would have been possible without the far-sighted support of our major sponsors, the Canadian Government, through the Canada Excellence Research Chair program, the Province of Saskatchewan, and the U of S. I would like to record my personal thanks to these sponsors for their recognition of the strategic importance of water security and their vision and confidence in the U of S and myself to deliver on this important and unique opportunity.

Finally, we hope you will enjoy reading about our research achievements and plans, and our outstanding team of students and researchers. And as my close colleague and Associate Director, Jeff McDonnell notes, we very much welcome interest in our work and have many opportunities for collaboration.

Professor Howard Wheater, FREng

Canada Excellence Research Chair in Water Security

Director, Global Institute for Water Security

#### ASSOCIATE DIRECTOR'S MESSAGE

It is a pleasure to welcome you to the University of Saskatchewan's Global Institute for Water Security. We actively encourage your collaboration with our research staff and partners across campus. Beyond our work nationally, our program is growing internationally through formal research and graduate exchanges and partnerships with the Imperial College London (England), University of Aberdeen (Scotland), Lippmann Institute (Luxembourg), Nanjing Hydraulic Research Institute (China), Universidade Federal do Rio de Janeiro (Brazil), Universidad Austral de Chile (Chile), University of Georgia and Oregon State University (USA). Together with our research staff and our many international partners, we are tackling some of the world's biggest water security challenges. We host visiting scientists, sabbatical leaves and student internships. We invite you to come and be a part of our team!



Jeffrey J. McDonnell Professor of Hydrology

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Associate Director, Global Institute for Water Security

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#### **EXECUTIVE SUMMARY**

At the University of Saskatchewan's (U of S) Global Institute for Water Security (GIWS), sustainable use of the world's water resources and protection against natural hazards such as flood and drought are key priorities. Officially launched in March 2011, the institute builds upon leading expertise and capacity in water research at the U of S. This initiative is funded by the Canada Excellence Research Chair (CERC) in Water Security - a federal-provincial-university partnership with a base funding of \$30 million over seven years. GIWS integrates expertise from 14 academic units across the U of S and builds on strong partnerships with Federal and Provincial agencies, in particular Environment Canada and the Saskatchewan Water Security Agency. This research report summarizes GIWS activities from March 22, 2011 to December 31, 2013.

Our work focuses on four research themes: Climate Change and Water Security; Land-Water Management and Environmental Change; Sustainable Development of Natural Resources; and Socio-hydrology. As we move into 2014, we are building on our existing expertise to develop new areas of focus in Water and Health, and Water and Wastewater Treatment Technologies.

Our team is steadily growing and GIWS now enjoys the privilege of a critical research mass of seven core researchers and a total membership of 168, which includes 64 members, 14 associate members, three affiliates and 87 student members. The institute combines expertise in natural, health and social sciences, public policy and engineering, recognizing that people and their activities are of critical importance for water science and management.

While our vision is global, a key focus for new interdisciplinary research is on the Saskatchewan River Basin, which is located in one of the most extreme and variable climates of the world. The basin spans over 336,000 km² and is a critically-important water resource for the Prairie Provinces of Canada, embodying many of the management challenges faced world-wide and including regionally and globally-important biomes. The institute has developed the river basin as a large-scale observatory, now recognized as a Regional Hydro-climate Project of the World Climate Research Program's Global Energy and Water Exchanges project, one of ten in the world and the only one of its kind in North America. Our research in the basin builds on world-class field and laboratory facilities to develop new hydro-ecological science and modelling tools and address issues including climate change, water resources and water quality management. We are proud to recognize important contributions from a wide range of stakeholder partners, including First Nations communities, other local residents and non-governmental organizations, and our provincial and federal partners.

Our institute is rapidly building international links and networks. GIWS members have leadership roles in various international initiatives, and hold visiting appointments in many international universities. They have also provided advice to national and provincial/state governments and international agencies, including membership of an International Court of Arbitration in a dispute between Pakistan and India concerning the Indus Waters Treaty. Current collaborative research includes projects in Asia, Australia, Europe, North America and South America. Also, efforts are underway to initiate significant research collaboration with the

agriculture, energy (hydro, oil sands, petroleum and nuclear) and mining (potash and uranium) industries.

#### GIWS by the numbers:

Since 2011, GIWS has financially supported a total of 157 personnel, including seven faculty members, eight administrative staff, 20 research technicians, four research associates/scientists, 21 postdoctoral fellows, 17 doctoral students, 31 masters' students, 49 undergraduate and graduate student assistants, and 25 visiting scholars. Over the same period, our 64 members have supported an additional 96 graduate students (41 PhD, 55 MSc), 16 postdoctoral fellows, five research associates, two research scientists, 20 technicians and three visiting scholars related to water security research.

While GIWS has the benefit of base funding for seven years, we have been working to develop added value for this investment from external funding. The seven core faculty hired through the CERC program have secured an additional \$10.7 million during the reporting period, mostly from federal resources, while GIWS members as a whole have secured a total of \$25.2 million to support water security research. New projects include grants from the Social Science and Humanities Research Council (SSHRC), the National Science and Engineering Research Council (NSERC) and the Canadian Water Network. For example, since 2013 we are leading the \$5 million Changing Cold Regions Network, funded under NSERC's Climate Change and Atmospheric Research program, which brings together 37 Canadian and 15 international researchers to study environmental change in the Mackenzie, as well as the Saskatchewan, river basins – the interior of western Canada, from the US border to the Arctic Ocean.

While the first report of GIWS inevitably focuses on achievements in initiating new research, it recognizes significant research outputs. GIWS members have published a total of 295 journal articles, participated in 180 conference proceedings and presentations and delivered more than 100 invited, key-note and plenary lectures to share research outcomes and enlighten our stakeholders and scientific community. It is also a pleasure to note the international recognition of GIWS members, ranging from senior faculty to junior graduate students, through multiple prizes, awards, and various national and international honours.

GIWS and its members have been engaged in various local, regional, national and international outreach activities, communicating science to a wide range of stakeholders and engaging them in our research. This helps ensure that institute research is useful and applicable to governments, organizations and individuals working in the broad world of water security.

#### 1. INTRODUCTION

Water Security is widely recognized as a global priority for the 21<sup>st</sup> Century, and in 2010 the University of Saskatchewan (U of S) identified "Water Security: Stewardship of the World's Freshwater Resources" as one of its six *signature areas* of research excellence and focus, in recognition of the university's capacity, investments, history and potential in this area. In the same year, Dr. Howard Wheater was awarded a Canada Excellence Research Chair (CERC) in Water Security, with \$30 million support from the Federal and Provincial governments and the U of S for a seven year research program.

The U of S Global Institute for Water Security (GIWS) was created in 2011 to provide an organizational structure through which the CERC in Water Security could realize its specific

goals and also address a broader water security research agenda, creating a focus for the university's signature area. GIWS aims to draw together relevant expertise across the full range of university academic units (including natural science, engineering, social science, public policy, and human health) as well as colocated Federal and Provincial partners.



The challenges of water security are complex and multi-faceted. Not only is there a need for new knowledge, but also for new interdisciplinary science and technological innovation, to inform water resource management and policy, and to develop new solutions to critical problems facing global and domestic water security. Hence, as defined in its mission statement, the key ambitions of GIWS are to:

- Create a focus and platform for interdisciplinary collaboration that recognizes the societal dimensions of water security, the human impacts on the environment and the linkages and feedbacks between atmosphere, land and water systems. This requires new integration of the relevant spectrum of natural, health and social sciences, public policy and engineering;
- Develop the new knowledge, science and technologies needed to support integrated water quantity and quality management in the face of uncertain climate and water resource futures, and address local, regional and global water security agendas;
- Develop partnerships with key stakeholders to translate the science into policy and management support to meet water security challenges, including interactions among water, food, energy and ecosystem services (i.e., benefits to human welfare), climate change adaptation and mitigation challenges, and the human health agenda;
- Provide tools, technologies and computer models for application to key globally significant water security issues, with international application; and,
- Create a unique opportunity for governments, industry and universities to invest in and collaborate on one of our most pressing global issues.

Through this transformative initiative, it is envisioned that a new research paradigm will be generated, creating new interdisciplinary and inter-sectoral research, collaboration and technological innovation. Capitalizing, integrating and building upon the world-class facilities, the extensive breadth of expertise and the existing partnerships at the U of S (including Environment Canada (EC), Agriculture and Agri-Food Canada (AAFC) and other key partners), new interdisciplinary science will be used to: i) understand changing water/land/climate interactions, changing flood and drought risk, and the role of society in land and water management, ii) improve water use and assessment, including the management of extremes, and iii) develop improved risk assessment, management and remediation options applicable to all types of natural resource development. GIWS strategically positions Canada to address urgent water security challenges and inform changes in water use, policy, management and reclamation, while training national and international students to help ensure the world's water security. The U of S has a proven track record of conducting research that influences public policy and environmental regulation. A goal of the institute is to build upon this reputation in the support of policy which addresses local, regional and global threats to water security.

The GIWS is closely aligned with the institutional priorities of the U of S. The strategic directions articulated in Renewing the Dream (2002) and the Third Integrated Plan *Promise and potential* (2012-2016), are each closely linked to GIWS's goals:

- Attract and retain outstanding faculty;
- Increase campus-wide commitment to research, scholarly and artistic work;
- Establish the U of S as a major presence in graduate education; and,
- Recruit and retain a diverse and academically promising body of students, and prepare them for success in the knowledge age.

#### 2. MEMBERSHIP AND SUPPORT STAFF, PARTNERSHIPS AND GOVERNANCE

Our membership and support staff are the heart of GIWS. We have four membership categories:

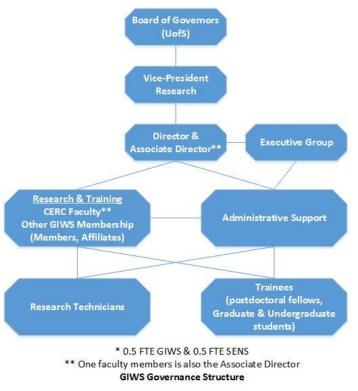
- Members: Individuals working at a level of responsibility which includes initiating and leading water research activities;
- Associate Members: Individuals who are making a significant contribution to water research or who are providing support for water research activities;
- Affiliates: Distinguished individuals who have demonstrated a commitment towards the ambitions of GIWS; and,
- Student Members: Students registered at a postsecondary institution who are under the supervision or co-supervision of GIWS members, or any graduate or undergraduate student registered at the U of S.

Currently, GIWS has a total membership of 168, which includes 64 Members, 14 Associate Members, three Affiliates and 87 Student Members. Our support staff include an Assistant

Director, Executive Assistant, Financial Officer, Communications Officer (0.5 FTE), Data Manager, Clerical Assistant and 20 Research Technicians. Appendix 1 lists GIWS membership and support staff as of December 31, 2013 (also see GIWS Governance Structure figure below).

GIWS benefits from and greatly values various strong partnerships that have been developed with Federal and Provincial agencies. In particular, during the reporting period Memorandums of Understanding have been signed with EC and Saskatchewan's Water Security Agency (SWSA). EC researchers are closely involved both in the institute's core themes and projects and in several major new grants. This is facilitated by the co-location of GIWS in EC's National Hydrology Research Centre (NHRC). Similarly, staff of the SWSA are closely involved in a range of GIWS research projects. Several major projects are jointly funded and co-supervised, and GIWS greatly benefits from the advice of SWSA's senior management, including insights into the province's operational and management needs. Regular liaison is also maintained with Saskatchewan's Ministries of Agriculture and of Environment. We were honoured by a visit in 2013 from Minister Cheveldayoff, Minister of the Environment for the Province of Saskatchewan. GIWS also benefits from the contributions of its members from AAFC and the Saskatchewan Research Council (SRC), as well as advice and software provided by Alberta's Ministry of Environment and Sustainable Resource Development, and advice and data from Alberta's Ministry of Agriculture.

Dr. Howard Wheater, CERC in Water Security, is the director for GIWS and reports directly to the U of S Vice-President Research, and in turn to the Board of Governors. The governance and management structure of the institute is designed to foster a collaborative environment where all members work in partnership toward a set of common goals. An Executive Group, comprising of senior academics from key units and EC, has provided strategic guidance through the early phases of GIWS development. Open to a broad range of perspectives and disciplines, the institute facilitates and encourages broad collaboration. Development of the core GIWS research



program has been achieved by multi-disciplinary working groups focused on key research themes. These working groups developed detailed work plans and proposals for GIWS support, and provide appropriate project management, and reporting to the GIWS Director. Appendix 2 contains a list of funded projects.

Funding is targeted towards the development of the institute's goals by providing new resources to support growth of faculty research agendas without drawing upon college and unit resources. GIWS also provides administrative support, both technical and financial, to assist in the development of research proposals and the management of research. In this way, the GIWS takes responsibility for developing and managing an integrated research program, but credit for that program is circulated back to the academic units. An important strategic aim is to ensure that the management and governance of the institute enhances, rather than impedes, a college or department's ability to deliver its academic programs.

#### 3. RESEARCH

#### 3.1 Research Themes and Objectives

While the CERC program funding is primarily for science and engineering research, it nevertheless recognizes the broader disciplinary dimensions of water security. GIWS provides a vehicle to develop additional areas of focus and to address these broader perspectives. To date, GIWS has developed four strongly inter-dependent research themes, and is working towards the development of two new themes.

#### **Research Themes**

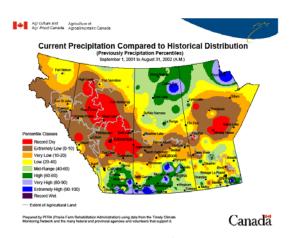
- A. Climate change and water security
- B. Land-water management and environmental change
- C. Sustainable development of natural resources
- D. Socio-hydrology
- E. Water and Health (under development)
- F. Water and Wastewater Treatment Technologies (under development)

#### Theme A: Climate change and water security

One of the greatest environmental and societal challenges associated with climate change is prediction and management of its impact on water security. There is an urgent need to improve the science upon which prediction of water resources for climate futures is based, particularly for high latitudes and cold regions. This need is particularly pressing for Western Canada, where the cold region, semi-arid climate creates a hydrological system that is extremely vulnerable to climate change and can be profoundly affected by either changes in temperature or precipitation. The region is subject to both recurrent severe droughts and periods of intense flooding events, which are expected to increase in severity and frequency under climate change. There is a need for development of sophisticated understanding and modelling of current and future effects of climate change on hydrology, ecology and water resource systems, and the associated land-atmosphere feedbacks. In addition, given the high levels of uncertainty associated with climate futures, particularly for extreme events, there is a need for new adaptive approaches to governance, policy and management.

## Research Objectives:

- Improve understanding of interactions between terrestrial ecosystems and atmospheric processes, and of the impacts of climate variability on water-related ecosystem function;
- Improve the quality of global and regional climatic models and enable better downscaling for water-related climate change impacts assessment;
- Improve assessment of variability in water supply and quality, including climate change impacts; and,
- Develop new decision support tools for water security analysis to enable policy development.





Prairie Drought of 1994-2004

Flooding in Manitoba, 2009

#### Theme B: Land-water management and environmental change

Intensification of land-water management, due to agriculture, forestry, and urban and periurban development, is a global phenomenon, raising concerns for changes to hydrology, including flood and drought risk, and water quality in North America, Europe and the world's developing economies. In particular, nutrient pollution has been defined as one of the 'Grand Challenges' of the 21st century by the US Academy of Engineering. Scientists at GIWS are exploring the effects of agricultural and urban land and water management on water quality and water movement through a watershed, as well as the potential for agricultural beneficial management practices (BMPs) to mitigate adverse effects.

#### **Research Objectives:**

- Improve agricultural land-water management through understanding of multiple stressor effects and water quantity and quality impacts at watershed scales;
- Inform development of water quality modelling tools through better understanding of hydrology, water quality and aquatic ecology interactions; and,
- Develop new decision support tools for management and remediation of diffuse pollution, including impacts on aquatic ecosystem health.





Algal Bloom September 2011 – Lake Diefenbaker, SK

**Kenaston Soil Moisture Site, SK** 

# Theme C: Sustainable development of natural resources

Canada is at the forefront of natural resource development, including the energy sector (oil and gas, biofuels, hydropower, nuclear), mining (including potash, uranium, gold and base metals)

and forestry. This area presents a unique opportunity for the development of new science and management practices that could significantly change the way water is used, how land and water are reclaimed, and how environmental risks are assessed and managed in natural resources development.



#### **Research Objectives:**

- Better understand pollutant toxicity on ecological and human health by integrating assessments across terrestrial and aquatic ecosystems;
- Develop integrated decision-support tools for risk assessment and remediation of contaminated land and water, including biodegradation and sequestration of pollutants; and,
- Support new assessment and remediation technologies through better understanding of interactions among hydrology, ecotoxicology, water quality and wetland ecology, including potential for bioremediation in the subsurface (both soil and groundwater) and in wetlands.

## Theme D: Socio-hydrology

Social scientists bring an interest in human values, markets, social organizations and political institutions to the traditional focus of water science on climate and hydrology, while hydrologists are increasingly aware of the need to understand the effects of human activities on

land and water management. Socio-hydrology integrates these different communities and highlights the importance of the complex and dynamic interactions between humans and the environment. The socio-hydrology program encompasses both the human drivers of hydrological change and the social processes through which hydrological science is translated and communicated to relevant decision-makers.



#### Research Objectives:

- Better understand societal attitudes and values with respect to water security;
- Better understand impacts of land and water management, governance and policy on hydrological and water resource systems, including water quality;
- Include effects of land and water management in large-scale hydrological and water quality models;
- Develop improved methods for analysis of vulnerability to environmental change, and decision-making under uncertainty, including improved models for scenario-based analysis of water futures;
- Better understand the social processes of science translation and communication; and,
- Facilitate the development and communication of science through active stakeholder engagement in experimental, modelling and decision-support research.

#### Theme E: Water and Health (under development)

Access to clean drinking water and sanitation is a basic requirement for human health. This remains a global priority, and is also an issue for rural and First Nations communities in Canada. However, water and health have multiple connections. GIWS is looking at issues that are critical to society, such as drinking water quality, water hygiene and sanitation, transmission of waterborne and water-related diseases in an ecosystem, aquatic pollution and effects on the food chain, wastewater re-use, extreme events such as flooding and drought, and health-based water quality standards. Our current research addresses four strategic priority areas:

- Water supply for rural and First Nations communities, with a strong Northern focus;
- Drinking water quality in developing countries, including issues of arsenic and salinity in Bangladesh;
- Public water supply issues addressing questions such as: How safe is our water? What are the public perceptions of that safety?; and,
- Health impacts of the legacy of resource development activities (i.e., minerals, oil sands).

# Theme F: Water and Wastewater Treatment Technologies (under development)

With increasing pressures on water quality due to human activities, there is a worldwide need to improve efficiency and effectiveness of water and wastewater treatment technologies, and to assess impacts of contaminants on environmental and human health. Treatment challenges include appropriate technology for rural communities, development of advanced water treatment technologies to tackle emerging contaminants in our water systems, improved technologies for the treatment of industrial wastes, including those generated by natural resource extraction, and improved technologies for remediation of pollution. Five major areas of application of particular relevance to the U of S, the Province of Saskatchewan and Western Canada will be addressed by this theme, namely the needs of the oil and gas sector, the food and beverage industry, natural resources (particularly mining) industry, municipalities, and rural water supply and sanitation.

#### 3.2 Research Facilities

The U of S is home to an outstanding set of facilities for water-related research, with some of the world's most advanced equipment, laboratories and expertise for hydrology, chemical and biological water quality, and geochemical and toxicological analysis. These include the \$298 million Canadian Light Source (the country's only synchrotron facility, with several beamlines that provide exceptional opportunities for water research), specialist centers including the Toxicology Centre, Centre for Hydrology, R.J.F. Smith Centre for Aquatic Ecology, Saskatchewan Structural Science Centre, and departmental facilities that provide excellent and unique infrastructure and instrumentation, including advanced facilities for stable isotope analysis and research into water and wastewater treatment, efficacy of constructed wetlands, mine reclamation, site remediation, water balance modelling and hydrogeochemistry. GIWS draws extensively on these facilities, but in addition has sought to complement them through development of world-leading field-based research facilities. Hence, a key research facility and focus for interdisciplinary integration has been created, based on the Saskatchewan River Basin (SaskRB). The basin spans over 336,000 km<sup>2</sup>, is a critically-important water resource for the Prairie Provinces of Canada and includes regionally and globally-important biomes. The SaskRB experiences one of the most extreme and variable climates in the world and is home to 80% of Canada's agriculture, important natural resources and the rapidly developing economies of the three Prairie Provinces. It experiences many, if not most, of the world's water issues resources are fully allocated in southern Alberta, with irrigation dominating water consumption, nutrient pollution is a significant threat to water quality, rapid environmental change is taking place and the history of flood and drought includes Canada's most expensive natural disasters (the 1999-2001 drought and recent Alberta flooding, in June 2013, with several deaths and evacuation of 100,000 Calgary residents). These pressures are set against a backdrop of fragmented governance, with multiple jurisdictions and sometimes conflicting

Federal and Provincial responsibilities. The basin presents interdisciplinary research challenges of local, regional and global relevance.

With CERC funding and grants from the Canada Foundation for Innovation (CFI), to Drs. Howard Wheater, John Pomeroy (Canada Research Chair in Water Resources and Climate Change) and John Giesy (Canada Research Chair in Environmental Toxicology), the institute has developed



the SaskRB as a large-scale observatory, now recognized as a Regional Hydroclimate Project (RHP) of the World Climate Research Program's (WCRP) Global Energy and Water Exchanges (GEWEX) project, one of ten in the world and the only one of its kind in North America. This includes state-of-the-art instrumented sites in the biomes of the Rocky Mountains, Boreal Forest and Prairies and new biogeochemical research facilities to support water quality research, with a focus on Lake Diefenbaker, a major source of water for the province of Saskatchewan. The SaskRB is a focus for collaborative, interdisciplinary research, including integration of Themes A, B, C and D.



**Rocky Mountain Research Site** 



**Prairie Research Site** 



**Boreal Forest Research Site** 

In partnership with EC and the US National Aeronautics and Space Administration (NASA), the observatory provides data to support the development of improved weather and climate models and to test new remote sensing products. In addition, it supports a key goal for GIWS, to improve the ability to predict river flows, and understand how water quality and river basin ecosystems respond to climate change and the effects of land and water management. Outreach and engagement with a wide range of stakeholders includes participation in monitoring design and the translation of research into useful information for managing local and regional issues. New models and tools for water resource decision-making are being developed for the basin to allow users to explore water futures and extremes (flood and drought). In addition, Socio-hydrology research is integrating people, their activities and their values into water science and decision-making. A major study of the Saskatchewan River Delta, undertaken in collaboration with First Nations communities, addresses changing river flows, effects on aquatic ecosystems, the value of ecosystem services and their relationship to the livelihoods of the local communities.

This large-scale observatory creates a new paradigm for interdisciplinary research by integrating extensive expertise in: climate; snow, ice and permafrost hydrology; agriculture, soil science and terrestrial ecology; aquatic ecology and cumulative effects assessment; water resource engineering; wastewater and contaminated systems toxicology; development of modelling and decision support tools; and knowledge translation and dissemination. New science and implementation tools are being developed using this exemplar set of Canadian applications of industrial and regulatory relevance that are transferable to the international stage. This reinforces Canada as a global leader in cold region and integrated water science.

#### 3.3 Research Outcomes

To bring its vision to fruition and advance the above research themes, GIWS has sponsored a total of 164 personnel as of December 31, 2013, including 17 research technicians, four research associates/scientists, 21 postdoctoral fellows, 17 doctoral students, 31 masters' students, and 60 undergraduate and graduate student assistants (Appendix 3). While a comprehensive presentation of all ongoing research is inconsistent with a summary report, below we highlight some key initiatives, which give a flavor of the scope and international relevance of ongoing GIWS research.

#### Research in the SaskRB – Integrating Themes A, B, C and D

The SaskRB provides a place-based focus for disciplinary research and new interdisciplinary integration. Twenty-three research projects in the SaskRB are producing data, models and outcomes that interpret complex effects of climate change and land-use management on available water resources and biomes of local and global relevance, and investigate societal dimensions of land and water management, including extreme events. These studies range from the development of new statistical downscaling tools for climate change impact studies in Western Canada to the assessment of links between water, animals and people in the

Saskatchewan River Delta, working with First Nations communities. The infrastructure includes a set of world-class Hydro-Ecological Research Facilities for observation, analysis and modelling of the SaskRB, as well as multi-site instrumentation, including analytical facilities and mobile sensors, and a data-base for archiving multi-site, multi-scale and multi-disciplinary data and relevant model outputs.

Canadian Rocky Mountains: Much of the water in Western Canada originates from source water areas ("headwaters" or "headwater basins") in the Rocky Mountains, where cold water processes involving snow, glaciers, wetlands and frozen soils control the storage and delivery of water to river systems. High precipitation, restricted infiltration, storage of frozen water and rapid seasonal melt provide high runoff



efficiencies for these headwaters. Seasonal and inter-annual storage of water as snow and ice make estimating basin runoff in cold regions extremely difficult. Climate variability further confounds adequate prediction from basins that contain snow, permafrost and glaciers. Hillslope processes impart important hydrological controls on headwater basins because terrestrial flowpaths control the timing and storage of water flow. Headwater cryospheric and hillslope processes have important ecohydrological interactions with the basin topography, vegetation and soils. Headwater ecosystems are highly dependent upon hydrological processes associated with snow and ice accumulation and melt, groundwater/lake/wetland exchange, drainage and runoff generation. Most headwater basins are ungauged, but remain extremely important for infrastructure, ecosystem function and large-scale water resources because of their prevalence and the accumulation of flow in river basins. The Marmot Creek observatory, led by Dr. John Pomeroy, has provided an important research focus for 50 years, but with CFI support, new instrumentation has been added and additional high elevation sites are being installed, including at Peyto Glacier. Marmot Creek was near the epicenter of the June 2013 flooding in Alberta, which has focused Canadian attention on flood risk management in a changing climate.

Specific objectives for these research sites are to:

- Improve the understanding and description of the governing cold regions hydrological factors for mountain water supply through intensive process studies in representative headwater research sites;
- Develop an improved cold regions hydrology modelling system based upon improved numerical descriptions of processes and enhanced basin representation; and,
- Use new scientific information and improved models to predict headwaters' resource sustainability in light of climate change and variability.

Hydro-ecological research into Rocky Mountain wetlands and the effects of current and legacy beaver activity is focused on Sibbald Wetlands, led by Drs. Cherie Westbrook and Angela Bedard-Haughn. This study is improving our understanding of how both present and historical

beaver ponds are affecting modern-day peat characteristics and hydrology. This is essential to determine and model how different climate futures will affect these important source areas with regards to water security.

**Boreal Forest:** The Boreal Forest is an important biome for Canada and the world, and plays a crucial, but not fully understood, role in global water and carbon cycles. Climate change impacts/feedback need to be better quantified, including ecosystem vulnerability to climate

change. Interactions between climate, hydrology and ecology (forest vegetation) are important in terms of climate responses, hydrological responses, ecosystem resilience and ecosystem services. Therefore, the overarching goal is to improve our understanding of the interactions between climate, hydrology and vegetation in the Southern Boreal Forest. GIWS has taken over management of globally-important experimental sites developed by EC under the international



BOREAS (Boreal Ecosystem-Atmosphere Study) and BERMS (Boreal Ecosystem Research and Monitoring Sites) initiatives to measure carbon, water and energy exchanges between land and atmosphere. Enhanced instrumentation includes improved measurements of soil water, groundwater and surface water, as well as ecological processes. A new integrated research program has been developed. Led by Dr. Jill Johnstone and involving multiple GIWS members,

including ecologists, hydrologists, soil scientists and hydrogeologists from U of S, EC and University of British Columbia, and links with NASA's AirMOSS (Airborne Microwave Observatory of Subcanopy and Subsurface) and SMAP (Soil Moisture Active Passive) remote sensing soil moisture missions. Specific, short-term research objectives are to assess the vulnerability of ecosystem response to climate



variability and change, and the performance of land surface schemes for simulating hydrological processes in the Boreal Forest. A particular focus is on vegetation, groundwater and cold region processes. Longer-term objectives are to synthesize, integrate and upscale our hydrological and ecological understanding of stand-scale processes to watershed scales by developing improved hydrological models for application to the Boreal Plains ecozone and within a wider SaskRB model.

**Prairies:** Prairie hydrology is complex and raises a series of challenges for modelling and management. Topography is difficult to define without high resolution data (e.g., LIDAR), and internal drainage basins include multiple lakes and wetlands with variable connectivity. Home to 80% of Canada's agriculture, the Prairie climate represents a fine balance between

precipitation and evaporation, and factors such as the snow/rain balance and agricultural tillage practices can have a strong effect on soil water and on runoff quantity and quality.

SaskRB research sites include the St. Denis National Wildlife Area, comprising undulating topography and multiple prairie pothole lakes of varying salinity, where enhanced instrumentation has been installed to build on a 60 year history of hydrological and ecological research. With leadership from Drs. Dan Pennock and Angela Bedard-Haughn, a team of GIWS researchers is integrating previous hydrological, water quality and



ecological research and developing new experimental and modelling work on runoff processes, surface—subsurface interactions and the dynamics of salinity in this landscape.

A second major GIWS site focusses on a multi-scale soil moisture remote sensing experiment at Brightwater Creek, near Kenaston, SK. In a relatively flat and typical agricultural area, a GIWS

team, led by Drs. Warren Helgason and Andrew Ireson, is installing state-of-the-art instrumentation to monitor spatial soil moisture, groundwater and land-atmosphere interactions at multiple scales. In collaboration with EC, AAFC and the University of Guelph, this site is a test-bed for NASA's SMAP soil moisture remote sensing mission, to be launched in 2014. The site provides a focus for hydrological and land-surface modelling and the study of land-atmosphere feedbacks from different agricultural land use and land management practices.



Two further GIWS sites have been used to address different aspects of prairie hydrology and agricultural management. Led by Drs. John Pomeroy and Cherie Westbrook, Smith Creek has been a focus of study of hydrological connectivity and the effects of agricultural drainage on flows and water quality. A multi-year observational record has shown the dramatic effects of inter-annual climate variability on runoff processes and water quality, and a complex response of flood generation and transmission to agricultural drainage. Led by Dr. Helen Baulch, GIWS has also been working with local community organizations and researchers from EC, AAFC and the University of Manitoba at the Tobacco Creek Watershed, Manitoba. With support from the Canadian Water Network, the main focus of this site is the effects of agricultural beneficial management practices on flows and water quality, principally associated with changing tillage practices and on-farm reservoirs.

In addition to these major field sites, GIWS is working with AAFC to build on the legacy of historical research on large-scale managed agricultural field plots at the Swift Current Research Station. Led by Dr. Jeffrey McDonnell, fundamental research into prairie runoff processes and

modelling is underway, including the exploration of wholly new approaches to the modelling of multi-scale surface connectivity and its implications for runoff processes.

At all of these Prairie sites, high quality hydrological and water quality data are being used to provide new process insights and to develop the improved models needed to support management and climate modelling. This includes the testing, inter-comparison and refinement of land-surface schemes for weather and climate models, working with a family of EC models, as well as the United Kingdom JULES (Joint Land Environment Simulator) model. One outcome is an improved large-scale prairie model for EC's MESH (Modélisation Environmentale Communautaire - Surface & Hydrology) modelling system. Modelling research is also providing new insights into the connectivity of prairie lakes and wetlands, in particular showing complex cycles of hysteresis as wetlands fill, spill and empty under cycles of wet and dry years. A major platform for process modelling is Dr. John Pomeroy's Cold Region Hydrological Modelling (CRHM) system. This represents key prairie hydrological processes such as frozen soils and blowing snow and has been used to explore effects such as changing cropping practices and agricultural drainage. A major new development is to build on the unique capability for representation of cold region processes and introduce agricultural water quality to this modelling system, which is one key focus of the Tobacco Creek research.

Water quality and Lake Diefenbaker: GIWS research into water quality is extensive and multifaceted, ranging from fundamental research into the winter biogeochemistry of lakes to the monitoring of pharmaceutical products and heavy metals in urban wastewater and stormwaters. As one example, the first major study of nutrient loads and exotic chemicals, and their ecological impacts, for Lake Diefenbaker and its tributary, Swift Current Creek, is underway. This brings together researchers from the U of S (Biology, Toxicology, Geography, Civil and Geological Engineering, the Schools of Environment and Sustainability and Public Health), EC and the SWSA. The research involves eight master's students, one PhD student, three postdoctoral researchers, seven research assistants and technicians, and three undergraduate students, and includes engagement with local communities. Lake Diefenbaker, which is the largest body of water in southern Saskatchewan, is a reservoir and bifurcation lake. The lake is more than 200 kilometers long with a maximum depth of 66 meters, while the water levels regularly fluctuate three to nine meters each year. Lake Diefenbaker provides drinking water for three major cities and many smaller towns (45% of Saskatchewan's population), hydro-power generation, irrigation, aquaculture, recreational and industrial uses. These (except for hydro-power) are expected to increase in the near future with the rapidly developing economy in Saskatchewan. However, the capabilities of the reservoir to continue to provide water of reasonable quality, under rapid economic development and under a changing climate, is unknown. Saskatchewan's economic growth is dependent on this valuable source of water. A comprehensive evaluation of the sensitivity of the reservoir to current and future nutrient inputs is essential to manage and protect this valuable resource for future use. The lake is home to many native and stocked fish species and provides water for domestic, irrigation and municipal water supplies. Lake Diefenbaker plays a major role in economic and social development of a large proportion of the province. Moreover, the unique ecology of the lake requires research and practical measures to guarantee the long-term sustainability of this water body. Therefore, as part of this study, the GIWS will:

- Determine the lake's trophic and nutrient status (current and future water quality issues);
- Determine lake's sensitivity to nutrient inputs;
- Characterize the limnology (physical, chemical and biological parameters);
- Understand the mixing regime and biological processes in the aquatic environment;
- Develop a plan to identify and implement mitigation strategies that may be required to achieve long-term sustainability and to minimize impacts to the aquatic system;
- Determine the change in faecal input into Lake Diefenbaker over time and also determine potential sources of contamination;
- Determine the historically dominant/responsible algal species that resulted in an increase in algal bloom frequency and intensity that has been anecdotally reported in the local community, and have led to concerns regarding water quality;
- Identify and detect potential toxins present within the lake sediment and collected surface waters;
- Create tools for the analysis and solution of water quality problems, which could be used by administrations, private companies or research institutions;
- Provide tools required to determine whether the water quality objectives set within the management system are being achieved;
- Describe how water quality modelling results can be applied for forecasting future scenarios;
- Identify nutrients and chemicals of concern in the South Saskatchewan River system, and assess their environmental/human health risks based on chemical loadings, degradation rates and their potential for adverse biological effects; and,
- Evaluate the environmental fate processes for chemicals and nutrients of concern identified to ensure that loadings to the river do not impact the sustainable use of this valuable resource.

An extensive research program led by Dr. Jeff Hudson has focused on the lake's thermal regime, nutrient loading and algal dynamics, while Dr. Lorne Doig and his Toxicology colleagues have undertaken paleolimnological analyses to look at the history of lake sediments and the potential for release of accumulated nutrients. Supported by a new bathymetric survey, undertaken by Dr. Dirk de Boer, a modelling team led by Dr. Karl-Erich Lindenschmidt, with support from Dr. Steve Chapra (Tufts University), is developing a lake hydrodynamic and water quality model to explore system sensitivities to future loadings and a warmer climate. After two years of field research, we have established that Lake Diefenbaker is accumulating some 90% of the incoming Phosphorus from the South Saskatchewan River, and that with observed high concentrations in bed sediments, there is significant concern for future eutrophication, with potentially adverse effects for aquatic ecosystems, human and animal health, drinking water treatment and amenity. We consider this important, not only in terms of new scientific

understanding, but also for providing essential management insights into the province's major water resource.

**Saskatchewan River Delta:** The upper Saskatchewan River Delta, located near the Saskatchewan/Manitoba border on the western side of the Pas Moraine, is a complex series of abandoned and active river channels, lakes and wetlands that include an area (Cumberland

Marshes) designated as an Important Bird Area. This region represents the culmination of water diversion and extraction occurring upstream in the SaskRB. Annual discharge has been reduced by approximately 30% since the beginning of last century, due in part to both the Gardiner and E.B. Campbell dams withholding flow. Winter baseflow is now higher and spring freshets are dampened due to capture and storage in the



dams. A team led by Dr. Tim Jardine is combining expertise in climate, hydrology, ecology and social science to address the implications of these changes in flow for the production of fish, water-birds and mammals. In addition, the team is working with local communities to understand how these changes impact their activities and livelihood. Also, given the likelihood of future changes associated with water resource development or climate change, models that predict ecological and social effects of modified flows are being developed. The sustainability of First Nations communities' livelihoods is in direct connection with the flora and fauna and is threatened by the construction of dams. The overall goal is to develop different scenarios and an operational plan which will provide a sustainable output without endangering the Delta habitat in the long-term. This research explores the following scientific research objectives:

- Determine how flows of the Saskatchewan River affect the distribution of aquatic habitats (lakes, wetlands) in the Cumberland Marsh portion of the Saskatchewan River Delta;
- Assess which of these habitats are the most important in spawning/breeding and production of fishes, birds and mammals;
- Evaluate market and non-market resources used by people in the region and assign value (social, cultural, economic) to this harvesting and any related conservation activities; and,
- Bring together the above objectives to examine the ecological and social implications of future flow scenarios using a conceptual tool called a Bayesian Belief Network.

**Saskatchewan River Basin – climate, water resource and large-scale modelling:** There are many challenges facing those responsible for the management of the world's water resources. These include increasing population, abstraction and waste disposal needs, and uncertainties in

water availability due to global climate and other environmental change. As discussed above, the SaskRB embodies all of these pressures, and an important objective of the research sites is to provide improved modelling tools and methodologies to address water management at the river basin scale, as well as the large-scale needs to support improved weather prediction and global and regional climate modelling.



A critical need is to better understand climate variability and change, and to provide improved tools to evaluate scenarios of future climate. Dr. Yanping Li joined GIWS in 2013, and will be leading research into climate processes and modelling, including Rocky Mountains precipitation and convective precipitation over the Prairies. Dr. Naveed Khaliq leads a GIWS team focusing on climate downscaling and statistical analysis. Improved statistical downscaling methods have now been developed for the Prairie Provinces, providing improved capability to generate timeseries of precipitation and evaporation for future climate scenarios, and detailed multi-model analyses have been made of the North American Regional Climate Change Assessment Program, providing new insights into the current skill levels of regional climate models, and the model uncertainty associated with future projections. Current work on extreme precipitation and drought is building on the IPCC AR5 (Intergovernmental Panel on Climate Change – Fifth Assessment Report) climate model results.

A significant research effort focused on water resources modelling and decision support is led by Dr. Amin Elshorbagy. The multi-disciplinary GIWS team includes the expertise of Dr. Patricia Gober (formerly Director of the National Science Foundation - funded Decision Center for a Desert City at Arizona State University (ASU)) in climate change adaptation, decision-making under uncertainty and stakeholder engagement. The team has been collaborating with Alberta Environment and Sustainable Resource Development in simulating the response of the complex South Saskatchewan River Basin water resource system in Southern Alberta, leading to a new approach to water resource vulnerability assessment to climate change. A major focus has been on the development of user-focused decision support modelling tools. A new systems dynamic modelling capability has been developed for the province of Saskatchewan that is capable of interactive exploration of scenarios of changing inflows from Alberta and changing agricultural, domestic and industrial water use in the Province. This includes capability for dynamic (climatedependent) irrigation demand and economic valuation. GIWS is working towards a basin-wide (multi-province) simulation capability that can be used for risk-based assessment of future water scenarios. To support this, new research with Dr. Dave Sauchyn (University of Regina) is developing improved reconstructions of paleoclimate, based on multi-variate tree-ring analysis.

Dr. Gober leads joint research with the Australian National University and ASU into water resource decision support systems and stakeholder-focused interactive modelling and visualization.

Basin-scale water quality modelling is also under development. The SaskRB is a tributary of Lake Winnipeg, and GIWS is assisting the work of the International Joint Commission by developing a nutrient model for the Saskatchewan River, based on the U.S. Geological Survey SPARROW (SPAtially Referenced Regressions On Watershed attributes) modelling platform. Led by Dr. Karl-Erich Lindenschmidt, this will provide the first basin-wide modelling capability, with which nutrient management issues can be explored. In addition, large-scale hydrological modelling is being addressed by development and implementation of EC's MESH modelling system for the basin. A current challenge is to include water management in the large-scale model, in particular irrigation water use and the impact of large dams.

Engagement with a wide range of stakeholders is an important aspect of GIWS research. Local communities have been actively engaged in the field and modelling research at many of the sites noted above. Socio-hydrology research has included a series of stakeholder workshops across the SaskRB to understand attitudes to, and concerns for, water security. The focus of the water resource modelling development is to provide a new capability for stakeholder engagement in the exploration of water futures. This has been preceded by GIWS input to a series of AAFC drought tournament workshops, and new methods of outreach include a planned series of drama productions around the issues of water management in the basin.

A research team led by Dr. Lalita Bharadwaj is exploring water resource management issues in partnership with the community of Lake Diefenbaker. They are characterizing the challenges and issues per locale, and identifying management issues that impact the community of water users in terms of social, economic, cultural, health and environmental dimensions. In addition, this research explores how new water policies and management strategies for Lake Diefenbaker address the concerns of the community.

# Theme C – Sustainable development of natural resources

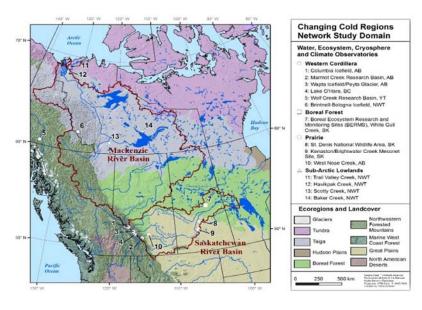
While the SaskRB is a natural focus for the integration of Themes A, B, C and D, much current GIWS research in Theme C lies outside the basin. GIWS members play a leading national and international role in mining, oil and gas technology development, landscape remediation and waste management. For example, Dr. Jim Hendry holds the Cameco-NSERC Industrial Research Chair (IRC), providing research leadership into uranium tailings management and environmental risk assessment. Dr. Lee Barbour holds the Syncrude-NSERC IRC, with a focus on oil sands reclamation and the environmental management of tailings and leachates. GIWS has major expertise in the toxicological assessment of oil sands and other mining leachates, through Drs. John Giesy and Karsten Liber and their teams. With substantial industrial funding to GIWS members in this area, GIWS direct support to-date has been limited to graduate student projects in the areas of oil sands landscape reclamation, the management of tailings and

effluents in end-pit lakes, and toxicological research. Ongoing discussions with mining and oil and gas industries are underway concerning hydrogeological research needs and the development of new research facilities for mine cover design and management. A new collaboration has been developed with Atomic Energy of Canada Limited (AECL) under the auspices of the Sylvia Fedoruk Canadian Centre for Nuclear Innovation (Fedoruk Centre), involving the development of improved risk-based assessment and modelling of a low-level radioactive waste repository in Ontario, Canada.

#### 4. CHANGING COLD REGIONS NETWORK

GIWS members have had considerable success attracting major new projects and building on the base CERC support. These are numerous and are summarized in section 5.2 below. We highlight here one major new initiative, due to its large scope and potential international significance. In an effort to better understand how a warmer climate is likely to impact ecosystems and water resources in Western Canada, GIWS is currently leading the Changing Cold Region Network (CCRN), funded by the Natural Science and Engineering Research Council (NSERC) through their Climate Change and Atmospheric Research (CCAR) program. CCRN aims to integrate climate and land-surface process observations and modelling in the region of the Saskatchewan and Mackenzie River Basins in Canada. The CCRN project studies the detailed

connections among changing climate, ecosystems water in the interior of Western Canada permafrost regions of the sub-arctic, the Boreal Forest, the Western Cordillera and the Prairies – some of the coldest, most extreme climates in the world. The network consists of researchers from Canada and 15 leading international scientists. Remote sensing and modelling products will



be used to analyze and predict changing land, water and climate interactions in the regions. Additionally, new and existing data will be used to understand the effects of climate change at local and regional levels, including flows in the major regional rivers (Saskatchewan, Mackenzie and Peace-Athabasca).

The CCRN is organized around five research themes, and includes 14 observatory sites located across Saskatchewan, Alberta, British Columbia, the North West Territories and the Yukon.

Participating institutions include the Universities of Saskatchewan, Calgary, Manitoba, British Columbia, Guelph, Québec à Montréal, McMaster University and Wilfrid Laurier University, as well as EC, Natural Resources Canada, Parks Canada, and AAFC. The Board of Directors, led by Dr. Jim Bruce, includes representation from key Federal partners and the governments of the Northwest Territories, Alberta and Saskatchewan. The International Advisory Panel includes representatives of the World Climate Research Program's GEWEX and CliC (Climate and Cryosphere) projects, as well as NASA's ABoVE (Arctic Boreal Vulnerability Experiment) project. CCRN includes international collaborators from China, France, Germany, the United States and United Kingdom, including NASA, the US National Centre for Atmospheric Research, and the Chinese Academy of Science.

For additional information, please refer to www.ccrnetwork.ca or contact the network manager Dr. Chris DeBeer (chris.debeer@usask.ca).

#### 5. PERFORMANCE INDICATORS

Since its inception in March 2011, GIWS has grown to include membership of 168 faculty, government scientists, postdoctoral fellows and graduate students (Appendix 1), as well as 157 support staff (Appendix 3). As described above, the GIWS membership and support staff are working in interdisciplinary teams to understand how climate change, land management practices, development of natural resources, socio-hydrology and water and health are affecting our water environment, and to develop the improved modelling tools needed to sustainably manage water. The institute combines expertise in natural sciences, engineering, health sciences, public policy and social sciences, recognizing that people and their activities are of critical importance for water science and management.

#### **5.1 Training of Highly Qualified Personnel**

Being a research intensive educational institution, a primary focus is the training of highly qualified personnel (HQP) in disciplinary and interdisciplinary research through exposure to both in-depth knowledge and understanding of broader water security concepts. We aim to achieve this objective through a combination of course work, field work, training in the use of cutting edge instrumentation and analytics, computer simulation modelling techniques, professional development workshops, student and postdoctoral group discussions, international exchanges, and provision of opportunities to interact with leaders in the international scientific community. In addition, HQP are encouraged to interact with provincial and federal water security agencies, and industry partners seeking to collaborate with the GIWS in the management and mitigation of their environmental issues, especially related to water sustainability, both in terms of water quality and quantity.

In the period 2011-13, GIWS financially supported a total of 157 personnel, including seven GIWS faculty members, seven administrative staff, 20 research technicians, four research

associates/ scientists, 21 postdoctoral fellows, 17 doctoral students, 31 masters' students, 49 undergraduate and graduate student assistants (Appendix 3) and 25 visiting scholars. Over the same period, our 64 members have supported an additional 96 graduate students (41 PhD, 55 masters'), 16 postdoctoral fellows, five research associates, two research scientists, 20 research technicians, and three visiting scholars related to water security research. The institute successfully attracted top international students and postdoctoral fellows, with the number more than doubling from 2011-12 to 2012-13.

GIWS is making significant efforts in developing and sustaining an excellent research platform that will assist HQP in launching their career and excelling in their respective fields. These include a training course on "The Future Professoriate," to facilitate discussions on how academia works for students interested in pursuing careers in the field, and a Distinguished Lecture Series, initiated in the Fall of 2013 called "Breakthroughs in Water Security Research," the lecture series brought world-leading scientists to Saskatoon for lectures, tutorials and workshops in the areas of soil physics, instrumentation, lab experiments, uncertainty estimation, hydro-ecological modeling, watershed observatory networks, instream flow modeling, engineering hydrology, aquatic ecosystem science, isotope hydrology and sociohydrology. This series provided students and postdoctoral fellows an opportunity to understand breakthroughs in various areas of water security and to network with these leaders. Lectures were streamed live to collaborating universities in Western Canada and are available through our website for viewing (<a href="http://www.usask.ca/water/news-and-events/dls/index.php">http://www.usask.ca/water/news-and-events/dls/index.php</a>). A second Distinguished Lecture Series is planned for 2014 and is likely to become an annual event.

To support our innovative research agenda, GIWS is currently developing a new interdisciplinary Graduate Program in Water Security (GPWS) which capitalizes on existing faculty excellence across the many facets of water-related research and research infrastructure present at U of S. The GPWS realizes some of the ambitions of the GIWS and fills a major training gap in Canada for industry and government. We anticipate that graduate students from around the world will be drawn to this unique, innovative graduate program, which has the potential to become the destination point internationally for those seeking integrated, comprehensive training. In addition, we foresee the development of specific training courses for individuals already in the workforce and short courses that engage U of S students with graduate students from other North American universities.

#### 5.2 Research Funding

To support our research and training endeavours, financial resources are critical. Healthy financial resources help attract and retain the 'best-of-the-best' from around the world, and help develop cutting edge research facilities. Therefore, another of the institute's main objectives has been the pursuit of research funding to leverage the base CERC funding of \$30 million over seven years. The seven core faculty hired through the CERC program have secured a total of \$10.7 million in additional research funds from organizations such as EC, CFI, the

Canadian Water Network, the SWSA, and NSERC's CCAR program. In addition, our broader GIWS membership has also secured further funding totaling \$14.5 million as of December 31, 2013 to support water security research. Further details are given in Appendix 4. We are pleased to note several new grants for collaborative research building on GIWS activities and led by our younger GIWS members. These include an \$880K NSERC Strategic Project grant to a team led by Dr. Helen Baulch for research into algal blooms and their impact on drinking water treatment, an \$866K grant to a team led by Dr. Grant Ferguson for joint research with Atomic Energy of Canada Limited into risk assessment of a low level radioactive waste repository, funded by the Fedoruk Centre, and a \$411K NSERC Collaborative Research and Development grant to a team led by Dr. Tim Jardine for research into the effects of hydropower generation on the Saskatchewan River Delta.

#### 5.3 Research Publications

Dissemination of research outcomes is critical to the development of knowledge, not only to inform the research community, but also regulatory organizations, provincial and federal governments, and society in general. Consequently, GIWS members have published a total of 295 journal articles (Appendix 5), participated in over 180 conference proceedings and presentations, and delivered more than 100 invited, key-note and plenary lectures.

For example, at the American Geophysical Union Fall Meeting 2013 in San Francisco, GIWS members gave 26 invited talks, presentations and poster sessions, and at the American Society for Limnology and Oceanography meeting in February 2013, members presented a special session on Lake Diefenbaker research work. In addition, Drs. Howard Wheater and Jeffrey McDonnell hosted a very well-attended 'Lab Night' social event at the AGU Fall Meeting in 2012 to promote the creation of GIWS.

The intensity of our research outputs has significantly increased over the reporting period, with an increase of 63% in the number of journal publications from 2011-12 to 2012-13.

#### 5.4 Honours and Awards

GIWS members have received numerous major national and international honours and awards. Highlights are mentioned here and a more detailed list follows in Appendix 6.

We are pleased to note various prestigious awards and recognitions for our senior faculty. Dr. Lee Barbour was appointed a Fellow of the Canadian Academy of Engineering and Dr. John Pomeroy a Fellow of the American Geophysical Union (AGU). Dr. John Giesy received the King Saud Award for Environmental Science, the Miroslaw Romanowski Medal from the Royal Society of Canada, the Society of Environmental Toxicology and Chemistry Capacity-Building Award, and the University of Saskatchewan J.W. George Ivany Internationalization Award. He was the top rated environmental scientist in Canada as reported by the Globe and Mail in 2012. Dr. Jeffrey McDonnell was the 2011 Birdsall-Driess Distinguished Lecturer for the Geological

Society of America and 2012 Borland Lecturer for AGU Hydrology Days. Dr. Karsten Liber received the title of Concurrent Professor at Shanxi University at a ceremony in 2011.

Equally, we are delighted to note recognition of our graduate students. Shawn Beitel, Jonathon Doering, Chris Marsh, Sarah Patterson, Amber Tompsett, Fengchang Wu and Jenna Zee have won top paper and poster awards and recognitions at various conferences (see Appendix 6). Chris Marsh, MSc student, was awarded the D.M. Gray Award for Best Student Paper in Hydrology at the Canadian Geophysical Union (CGU) in 2013 for his paper and talk "Implication of mountain shading and topographic scaling on energy for snowmelt." Nicholas Kinar, PhD student, was awarded the D.M. Gray Award at the 2012 CGU meeting in Banff, Alberta on June 8 for his paper and presentation on "Acoustic Imaging and Measurement of Snow." Nicholas also won the Horton Award from the AGU in December 2011 and was featured in *Canadian Geographic* regarding a new instrument he has developed using sonar technology to sense snow depth, density, temperature and wetness. A team of GIWS graduate students and postdoctoral fellows won AAFC's drought competition in March 2012.

One of our promising postdoctoral fellows, Saman Razavi, won the Editor's Choice Award for 2012 from the journal *Water Resources Research*. The award was presented to him during the AGU Fall Meeting in December 2013 and is given to the top 1% of published articles to provide professional recognition to scientists and students for their outstanding work.

#### **5.5 National and International Appointments**

A further indicator of the prestige of our members is their role in national and international scientific management, and as advisors to national and international states and governments. Below is a list that highlights the significant international presence and contribution of our members and their role at a national level within Canada.

#### International appointment and responsibilities

Dr. Patricia Gober joined the panel of the Stockholm Water Prize Nomination Committee in 2013 and is currently co-chairing the USA National Climate Assessment Adaptation and Hazards Indicators Team. In addition, she was a member of various USA National Science Foundation Program and Project review panels. She was an invited speaker to the USA National Center for Atmospheric Research (NCAR) Uncertainty in Climate Change Research Workshop in August 2012. During the reporting period she also chaired the Israeli Council of Higher Education Geography Review Committee, served on the Water Resources Review Committee for the Prince Sultan bin Abdulaziz International Prize for Water and was appointed to the Geoscience Review Panel for the German Excellence Initiative, German Research Foundation in 2011.

Dr. Howard Wheater completed his role as Vice-Chair of the World Climate Research Program's GEWEX project in December 2013, but continues as Science Steering Group member and also as co-Chair of UNESCO's GWADI arid zone water resources program. He was a member of an International Court of Arbitration for a dispute between Pakistan and India concerning the

Indus Waters Treaty, with the Final Award issued in December 2013. During the reporting period, he has been a member of international review panels for the Universities of Melbourne and Zurich, as well as ETH Zurich. Dr. Wheater continues as Member of Council for the Prince Sultan bin Abdulaziz International Water Prize. He also continues as consultant to the State of Nevada concerning the proposed Yucca Mountain high level radioactive waste repository. Also, Dr. Wheater served as an Editorial Board member of the journal *Hydrology Research*.

Drs. John Pomeroy and Howard Wheater were recently invited to become members of the International Advisory Committee for the Heihe Watershed Allied Telemetry Experimental Research (HiWATER) team based in China.

Dr. Jeffrey McDonnell is an expert advisor to the International Atomic Energy Agency (IAEA), United Nations (UN) on uranium mining in Brazil. As part of his appointment, he will teach a UN short course on isotope tracers to water managers in Manilla, Philippines in February 2014. Dr. McDonnell served as the Associate Editor for the *Journal of Hydrology and Hydromechanics*, and was members of the editorial boards of the *Journal of Hydrogeology and Hydrologic Engineering*, *Riparian Ecology* and *Conservation*, *Water*, *Advances in Water Science* (China) UNESCO, and *International Journal of Hydrology Science and Technology*.

Dr. John Giesy served as the member of the grant review panel for the Office of Research and Development, US Environmental Protection Agency, Exploratory Research-Biology. Similarly, Dr. Karsten Liber served as a member and on the board of directors for the Student Advisory Council, Society of Environmental Toxicology and Chemistry (SETAC) — North America, and Hyalelle azteca advisory group, US Geological Survey.

Dr. John Giesy also served as the Editor of the Environmental Toxicology and Risk Assessment Section of Chemosphere Journal, Associate Editor for Environmental Development — The Transdisciplinary Journal of Scientific Committee for Pollution in the Environment (SCOPE) of United Nations, Associate Editor for the International Association for Sediment-Water Science Journal, and Associate Editor for Special Publications-Biology, Society of Environmental Toxicology and Chemistry Journal. In addition, he was on the editorial boards of the Environmental Geochemistry and Health, Environmental Bioindicators, and Reviews in Environmental Contamination and Toxicology, Environmental Toxicology and Pharmacology, Environmental Science and Pollution Research, Toxicological and Environmental Chemistry journals, European Journal of Pharmacology, Environmental Science, Management and Policy — An International Journal of SCOPE, The Handbook of Environmental Chemistry series, The Handbook of Ecotoxicology, Chemical Speciation and Bioavailability, and on an editorial panel of the Office of Toxic Substances, US Environmental Protection Agency.

Dr. Grant Ferguson was invited as an expert at the Fifth Regional Consultation on Groundwater Governance hosted by the United Nations Education, Scientific and Cultural Organization (UNESCO) in The Hague, Netherlands. He is also an Associate Editor for the *Ground Water* 

Journal published by the National Ground Water Association, and served as the guest editor for a special issue of the Groundwater and Thermal Energy of the Hydrogeology Journal.

Dr. Ingrid Pickering was the member of the Brookhaven National Laboratory Photon Sciences Science Advisory Committee, which advised the Associate Laboratory Director for Photon Sciences on issues related to the scientific utilization and developments of the National Synchrotron Light Source. Dr. Helen Baulch was an invited panelist to the United Kingdom Natural Environment Research Council (UK-NERC) Macronutrient-Cycles Program, Grant Selection Committee in November 2011.

Dr. Jim Hendry is an advisor to the Belgian Government concerning repository geological containment and is chairing a working group for the IAEA on the application of stable and radiogenic isotopes to characterize the long-term transport of nuclear wastes contained in argillaceous formations.

#### National appointments and responsibilities

During the reporting period, Dr. Howard Wheater's role as Chair of a Council of Canadian Academies Expert Panel saw the release of a report titled *Water and Agriculture in Canada: Towards Sustainable Management of Water Resources*. Released in February 2013, the report responds to the question "What additional science is needed to better guide sustainable management of water to meet the needs of agriculture?" by exploring effective water and land management strategies, governance and policy mechanisms and technological developments to assist in sustainable resource management. Dr. Wheater presented the report to the Ministry of Agriculture and Agri-Food and at a number of national meetings.

Dr. Karsten Liber served as member for Canadian Uranium Mining Cumulative Environmental Effects Monitoring Working Group, Syncrude Coke Knowledge Synthesis Project Team, Cumulative Effects Management Association (CEMA) Oil Sands Wetlands Technology Transfer Working Group and Canadian Eco-Toxicological and Environmental Services Inc.

One of our younger faculty members, Dr. Grant Ferguson, is currently serving as the President for the Canadian Chapter of the International Association of Hydrogeologists.

Dr. Jim Kells is currently serving as the President of the Canadian Society for Civil Engineering. He is also on the board of national council for the Engineering Institute of Canada.

#### 6. INTERNATIONAL COLLABORATION

GIWS is rapidly building its international links and networks. Current collaborative research includes projects in Asia, Australia, Europe, North America and South America (see Appendix 7). GIWS faculty members hold visiting positions in leading universities worldwide.

For example, Dr. Jeffrey McDonnell holds visiting appointments at the University of Aberdeen and Oregon State University, Dr. Howard Wheater is Distinguished Research Fellow and Emeritus Professor at Imperial College London, and Dr. John Giesy has a wide range of appointments: Emeritus Distinguished Professor of Zoology, Michigan State University; Einstein Professor, Chinese Academy of Science; Honorary Professor, School of Biological Sciences, University of Hong Kong; Visiting Distinguished Professor, Dept. Biology and Chemistry, and State Key Laboratory in Marine Pollution, City University of Hong Kong; Concurrent Professor, School of Environment, Nanjing University; Visiting Professor, Xiamen University; Honorary Professor, State Key Laboratory of Environmental Criteria and Risk Assessment, Chinese Research Academy of Environmental sciences, Beijing.

GIWS's international visitors provide the opportunity for Canadian researchers to interact with the world's leading scientists. Over the reporting period, GIWS hosted an international workshop to address the World Climate Research Program's Grand Challenge related to Water Resources, and a further 25 distinguished international visitors were hosted by GIWS over the reporting period, including:

- Larry Band, Voit Gilmore Distinguished Professor of Geography and Director, Institute for the Environment, University of North Carolina;
- Keith Beven, Distinguished Professor, Lancaster Environment Centre, Lancaster University;
- Allen Burton, Professor and Director, The University of Michigan Water Center;
- Adrian Butler, Reader, Civil and Environmental Engineering, Imperial College London;
- Wouter Buytaert, Lecturer, Faculty of Engineering, Imperial College London;
- Steve Chapra, Professor and Berger Chair, Civil and Environmental Engineering, Tufts University;
- Xuefeng (Michael) Chu, Assistant Professor, North Dakota State University;
- Jay Famiglietti, Professor of Earth System Science and Director, Center for Hydrologic Modeling, University of California, Irvine;
- Nelson Fernandes, University of Rio de Janeiro;
- Efi Foufoula-Georgiou, McKnight Distinguished Professor, University of Minnesota;
- Gordon Grant, Research Hydrologist, United States Department of Agriculture (USDA)
   Forest Service;
- Rick Hooper, Executive Director, CUAHSI;
- Tony Jakeman, Director, Integrated Catchment Assessment and Management Centre (iCAM), Australian National University;
- Carol Kendall, Research Hydrologist, U.S. Geological Survey;
- Annukka Lipponen, Environmental Affairs Officer, UN Economic Commission for Europe;

- Andrew Millington, Foundation Dean, School of Environment Flinders University;
- Dani Or, Professor and Director, Institute of Terrestrial Ecosystems, Swiss Federal Institute of Technology (ETH) Zurich;
- Denis Peach, Chief Scientist (retired), British Geological Survey;
- Laurent Pfister, Research Unit Leader, Environment and Agro-biotechnologies Department (EVA), Centre de Recherche Public Gabriel Lippmann;
- Leroy Poff, Professor and Director, Interdisciplinary Graduate Degree Program in Ecology, Colorado State University;
- John Selker, Professor and Director, Center for Transformative Environmental Monitoring, Oregon State University;
- Murugesu (Siva) Sivapalan, Professor, University of Illinois, Urbana-Champaign;
- Peter Troch, Professor of Surface Water Hydrology and Director, Biosphere 2, The University of Arizona; and,
- Harry Vereecken, Professor, Bonn University and Director, Agrosphere (IBG-3).

#### 7. INDUSTRY ENGAGEMENT

Industry involvement helps sustain research programs of economic benefit to Saskatchewan and to Canada, and facilitates training of HQP of relevance to industry partners. This helps our programs remain attractive to students and postdoctoral fellows and to industry who are seeking training opportunities for their employees and for the incoming workforce.

GIWS members have extensive ongoing collaborations with industry in Canada and internationally. A major focus is the development of natural resources, in particular the mining and oil and gas industries. The two previously noted Industrial Research Chairs, Lee Barbour, Syncrude-NSERC Chair in Hydrogeological Characterization of Oil Sands Mine Closure Landforms and Jim Hendry, Cameco-NSERC Chair in Environmental and Aqueous Geochemistry are leading efforts in sustaining existing and developing new industrial collaborations in these areas. Research includes work on active and legacy mine sites, including effluent treatment and toxicology, rock tailings geochemistry and cover design, and post-closure design and safety assessment. Oil sands research includes landscape reclamation, effluent treatment and the long-term hydrogeochemical evolution of tailings and end-pit lakes. Also, collaboration has been established with Suncor Energy, Crescent Point Energy Corporation and other oil and gas industries operating in southeastern Saskatchewan for development of graduate field courses and research programs of mutual benefit. Topics include sustainability of groundwater resources, the disposal of mine effluents, and fracking technologies and practices. In addition, various efforts are ongoing to foster and enhance sustainable collaborations with the International Minerals Innovation Institute (IMII), which is a consortium of major mining industries in Saskatchewan, through development of research and training programs.

Other areas of collaboration include the following:

Dr. Tim Jardine and his team have partnered with SaskPower and successfully secured additional funding from NSERC for research on inundation at the EB Campbell hydroelectric facility to understand the timing and magnitude of the biological response to flooding in large rivers in the boreal region. The results of this work will improve knowledge on the importance of the natural flood regime for the Saskatchewan River Delta that sits downstream, and may lead to changes in operational management of these reservoirs.

Dr. Helen Baulch and her team are collaborating with the Buffalo Pound Water Treatment Plant to study the effects of anthropogenic activities on aquatic ecosystems leading to major challenges for the provision of safe drinking water (e.g., high nutrient loads leading to algal blooms). Algal blooms frequently include nuisance species which can form a variety of compounds, some of which are toxic and can induce neurological damage, liver damage, gastrointestinal distress and even death in fish, wildlife, domestic animals and humans. Numerous toxins can also produce compounds which impart unpleasant taste and odour to drinking water. Cost-effective and adaptive monitoring tools and techniques are needed to provide water managers and regulators with the information necessary to effectively manage drinking water supplies, particularly in water-scarce areas and areas susceptible to harmful algal blooms and degraded water quality, such as the Canadian Prairies. This project provides an opportunity to link new technology, scientific insights and mathematical modelling to inform drinking water treatment processes and lake management in a partnership between researchers, the water treatment plant, and the SWSA.

In collaborations with the City of Saskatoon, Dr. Patricia Gober has initiated a project to assess neighborhood responses to the City's mandated water restrictions in summer 2011. Comparison of neighborhoods over space and time reveals the sensitivity of demand to the City's ban on outdoor use because of limitations on intake to the water treatment plant. Results of the study will reveal the characteristics of neighbourhoods that responded to restrictions and guide future conservation policy. In addition, she is exploring the opportunity to establish a Decision Theatre for Water Security in collaboration with the South Saskatchewan River Water Stewards, Meewasin Valley Authority and the IMII. If funded, the Decision Theatre would consist of a water simulation model, graphical user interface and immersive setting to engage water planners and the general public in a process of futures planning for water security and is based on the one developed by Dr. Gober at Arizona State University.

Dr. Karl-Erich Lindenschmidt is collaborating with Aquastructure Solutions Inc. to design a monitoring scheme which best captures the changes in surface water quality along the South Saskatchewan River (SSR). This is important to quantify potential sources of nutrient loadings entering Lake Diefenbaker and for real-time monitoring of surface water extracted for drinking water treatment and used as a receiving body for treated wastewater (e.g., in Saskatoon). In

addition, he is also collaborating with Ecofish Research Ltd. to develop a geospatial model to help identify areas along rivers in British Columbia that are utilized for hydroelectric power generation and prone to extensive anchor ice formation impacting fish habitat.

Dr. Paul Jones was invited as an expert to provide input to the Joint Canada-Alberta Oil Sands Monitoring Plan (JOSMP) during the Ecological Effects Monitoring Workshop in Calgary, 2013. The purpose was to further refine the Ecological Effects Monitoring Framework and to validate and confirm that the JOSMP monitoring activities are collecting the appropriate biological/ecological and chemical end-point information at appropriate spatial and temporal scales. In addition, he also served as an expert to report and testify to the Jackpine Mine Expansion Review Panel, November 2012.

As an expert advisor, Dr. Markus Hecker, Canada Research Chair in Predictive Aquatic Toxicology, has engaged with municipalities in Saskatchewan (Saskatoon, Swift Current and Regina) in matters of effluent and stormwater monitoring. It is anticipated that these interactions will lead to various research projects in the near future.

#### 8. OUTREACH AND ENGAGEMENT

In addition to members' national and international activities as described in Section 5, GIWS and its members have been engaged in various local, regional, national and international outreach activities, communicating science to a wide range of stakeholders, as well as engaging partners in our research.

Efforts to engage with a broad range of stakeholder groups across Western Canada remain a priority for GIWS. An internal U of S Science in Society Grant helped to initiate this priority with a pilot project called "A Collaborative Approach to Understanding Water Security in the Saskatchewan River Basin." The project consisted of a web-based survey and eight multistakeholder workshops to capture perspectives about water security among those engaged in the management of water resources, or who have livelihood responsibilities attached to water. It was found that participants in the research prioritized water management issues differently depending on their level of environmental concern, descriptions of water security, provincial location (Saskatchewan or Alberta) and sector (industry, government, or NGO). This engagement with stakeholders is ongoing with funding from a SSHRC Connections Grant, led by research associate Dr. Graham Strickert, which mobilizes research results using forum theatre to communicate perspectives on water security and to elicit participation from audience members. In addition, a SSHRC Insight Development Grant is in place to refine the methodologies used in the pilot program and engage more stakeholders to understand the links between values, attitudes and decisions regarding the management of water resources.

Outreach and engagement is also an important component of CCRN. Several activities occurred throughout 2013. A workshop about the quantification of uncertainty was hosted at the U of S

in October. In partnership with the AAFC and the GIWS, an Invitational Drought Tournament (a game-based simulation workshop to examine peoples' knowledge and decisions about drought) was hosted at the U of S Johnson-Shoyama Graduate School for Public Policy in November. A public presentation by Dr. John Pomeroy and Bob Sandford called "Come Swell or High Water: Understanding Canada's Changing Hydrology" was hosted by the town of Canmore, AB in November.

Formal linkages with the newly established SWSA and with the provincial Ministries of Environment and Agriculture are ongoing. Engagement in collaborative research with Alberta Environment and Sustainable Resource Development is also underway, with a particular focus on water resource vulnerability to climate change in the SSR in Alberta. In April 2012, Dr. Howard Wheater was invited to make a presentation at a meeting of Saskatchewan Deputy Ministers. GIWS also participated in the consultative process which led to the Water Security Agency's release of its 25 Year Saskatchewan Water Security Plan, and was very pleased to be formally recognized by SWSA in the plan, which articulated their intent to support the institute's research endeavors on assessment of the water supply and quality issues in the SSR. GIWS works with local stakeholders on a number of its research projects, including the First Nations of the Saskatchewan River Delta and local non-governmental organizations and First Nations communities around Lake Diefenbaker. In addition to an ongoing dialogue with The Partners for the SaskRB, and the Meewasin Valley Authority, GIWS has given numerous addresses to other organizations including the SRC, the Canadian Water Resources Association (CWRA), Ducks Unlimited, the Saskatchewan Institute of Agrologists, the Saskatchewan Conservation Development Association, the Saskatchewan Association of Watersheds and the Saskatoon International Club.

The 22nd Annual Summit of the Pacific North West Economic Region (PNWER) was hosted in Saskatoon in mid-June 2012. As part of this summit, Dr. Howard Wheater gave an invited lecture on water security and participated in a session on water policy along with stakeholders representing a range of water management interests.

Both the Provinces of Alberta and Saskatchewan have called on GIWS members for strategic advice. In 2012, Dr. John Pomeroy produced an expert report for the SWSA regarding the operational management of Lake Diefenbaker following the flooding of 2011. Dr. Howard Wheater was a member of Alberta's Provincial Monitoring Panel which reported in June 2011 to Minister Rob Renner, Minister of Environment, Government of Alberta for establishment of a world class environmental monitoring, evaluation and reporting system for Alberta oil sands. One key recommendation of the panel was the creation of the Alberta Environmental Monitoring Commission — a body operating at arm's length from the government, regulators and those being regulated. Dr. Howard Wheater is also serving as a member of the board of directors for the Fedoruk Centre, U of S.

Annually on March 22, GIWS celebrates World Water Day. The institute was launched formally on World Water Day 2011 with an announcement and presentation by Dr. Howard Wheater.

That event kicked-off a week of special presentations by U of S water experts and local authors and wrapped up with a social event and U of S Wind Orchestra premier of a piece titled *Strange and Mysterious Waters*. GIWS marked the event in 2013 with a public lecture by Dr. Howard Wheater providing an overview of the activities of the institute since its opening in 2011. In addition, GIWS co-organizes a paper and poster session featuring students and young professionals with the CWRA and Engineers Without Borders each World Water Day.



Each year, GIWS World Water Day activities have received media coverage, including stories in U of S' *On Campus* News, The Saskatoon Star Phoenix, The Regina Leader Post, CBC Radio, Rawlco NewsTalk Radio and CTV *FarmGate*.



GIWS has received extensive media coverage to-date. In 2013 alone, Dr. Howard Wheater was interviewed or mentioned in over 40 media articles. He appeared on various local and provincial radio and television talk shows discussing the water and agriculture interface, the state and outlook for water in Saskatchewan, water security in the Saskatchewan River Basin, GIWS as a global hub for research activity and GIWS research at Lake Diefenbaker. In addition, Dr. Wheater received national and international media

attention for his report on water and agriculture management in Canada as the chair of the Council of Canadian Academies Expert Panel on the subject, and for his attendance at the American Association for the Advancement of Science (AAAS) 2013 annual meeting.

Dr. John Pomeroy is called on frequently to lend his expert views on climate change, flooding and hydrology. In the wake of the Alberta floods in June 2013, Dr. John Pomeroy was cited in over 60 media stories in the period of June – December alone and included daily, weekly and monthly news publications. Highlights included CBC's *The National*, The Discovery Channel's *Daily Planet* and CBC Radio One's *The World at Six*.



In 2013, Dr. Jeffrey McDonnell appeared with Dr. Tim Burt of Durham University (UK), on North Carolina State University radio. The hot topic for discussion was the global freshwater crisis – what it is, why it is a problem and how we can predict it. Drs. McDonnell and Burt talked about such issues as depleting freshwater sources, agricultural pollution, groundwater recharge and geo-political water conflicts, with perspectives from techniques such as long-term hydroclimatological data analysis and isotope hydrology.

In December 2012, Dr. Howard Wheater was invited to give the keynote address in Minneapolis at a half-day forum – Shared Waters/ Shared Responsibility – that was coordinated by the Consulate General of Canada and attended by the Premier of Manitoba and his Environment Minister. The Forum's objective was to raise awareness of the challenges faced in the Lake Winnipeg Watershed and Red River Basin and to facilitate opportunities for scientists and policy practitioners to exchange information and best practices related to regional water management. Arising from this, the institute has agreed to work with the Canada/US International Joint Commission to develop a model of nutrient fate and transport in the Lake Winnipeg Basin.

At the annual AAAS meeting in February 2012, Dr. Howard Wheater was invited to participate in a panel discussion and to give a presentation on water security. For the AAAS annual meeting in 2013, the CFI held a press breakfast to introduce the agency's funded researchers, including Dr. Howard Wheater, to top-tier media internationally and to demonstrate the significance of research being undertaken in Canada.

### 9. STUDENT SOCIETY



GIWS is particularly proud of the achievements of our student society. We are committed to offering opportunities for students to join in activities that develop their understanding of the challenges of water security, and foster in them an appreciation for the need to bring a wide range of research backgrounds and expertise together to address these critical issues. The institute welcomes student members, at the

undergraduate and graduate level, from the natural sciences and engineering, as well as the humanities and social sciences, and encourages them to learn from each other about the many dimensions of water security. Consequently, a student outreach committee was created in May 2012 to increase the student membership of GIWS and promote connectivity between graduate students from various departments at the U of S involved in water-related research. As of December 2013, membership in the GIWS Student Outreach Committee included the following individuals:

- Kristin Bruce, Johnson-Shoyama Graduate School of Public Policy;
- Manuel Chavez Ortiz, School of Environment and Sustainability;
- Anna Coles, School of Environment and Sustainability;
- Kathryn Dompierre, Civil and Geological Engineering;
- Noel Galuschik, School of Environment and Sustainability;
- Raea Gooding, School of Environment and Sustainability; and,
- Chris Marsh, Geography and Planning.

The Student Outreach Committee organized a variety of social and educational events throughout the 2012-2013 school year. The committee's inaugural event was a dinner and drinks evening at Browsers Café, U of S. Dr. Howard Wheater was the guest of honour, who introduced the student outreach committee and provided information on GIWS to the students in attendance. Following this first successful event, the outreach committee organized a panel discussion titled 'Attack of the Blue-Green Algae', with panelists from the U of S Toxicology Centre, SENS, Engineering, and Geography and Planning Departments, in addition to a panelist from Environment Canada.

Over the winter months in 2012, the outreach team organized two water-themed movie nights at Lydia's Pub and Amigos Cantina in Saskatoon. For World Water Week, a student luncheon was held in the Graduate Student Commons, University of Saskatchewan allowing students to discuss the implications of their research. This event was planned especially to develop relationships between graduate students in various departments focused on similar, parallel or complimentary work. The student outreach team also organized a tour of the Saskatoon water treatment facility during World Water Week. Finally, the outreach committee held a water-themed pub quiz evening at Louis' to close the school year 2012-2013. Over the course of the year, student membership in GIWS increased from a handful of students when the outreach committee was formed, to 88 members.

The GIWS Student Outreach Committee, in conjunction with the School of Environment and Sustainability Students' Association (SENSSA) and the Toxicology Graduate Student Association, organized the Let's Talk About Water film event on April 18, 2013. The event, which included a catered networking event, a feature presentation (*Last Call at the Oasis*) and a panel discussion was a huge success and attracted close to 200 attendees.



Among those guests were Professor Jay Famiglietti (University of California, Irvine), who appeared in the film, and Professor Rick Hooper (The Consortium of Universities for the Advancement of Hydrologic Science, Inc., based in Boston). Both Professors Famiglietti and Hooper were part of the post-film expert panel, along with Drs. Howard Wheater and Jeffrey McDonnell (U of S), Dr. Wayne Dybvig (Saskatchewan Water Security Agency) and Mr.

Brian Ayres (O'Kane Consultants). Last Call at the Oasis examines the growing issue of water security around the world, and how some communities are struggling with its ill effects.

Activities for the 2013-2014 year began on September 29, in celebration of World Rivers' Day. The Student Outreach Committee set up a booth in Saskatoon's Friendship Park along with other organizations. The purpose of the event was to raise awareness and appreciation for rivers, worldwide and locally. Engagement with the general public at this event was high and was facilitated through an interactive trivia game and through responses to public questions. The students also participated in a tap water campaign on the U of S campus on November 12, along with SENSSA. The aim of this campaign was to promote the use of tap water over bottled water. Students set up an educational and interactive display and encouraged students, faculty and staff to sign a petition in support of a campus-wide ban on bottled water.

In addition to events planned for U of S students, the student outreach committee also teamed up with the student president of the Canadian Meteorological and Oceanographic Society (CMOS) to organize a student pub night for the Joint Scientific Congress 2013 in Saskatoon. This event provided a relaxed venue for students from CMOS, CWRA and CGU attending the conference to meet one another and build relationships with those studying across Canada. This event was held at Amigos Cantina, and was attended by approximately 70 students.

For further information on our student members and their activities, please visit: http://www.usask.ca/water/people/Student Members.php

#### **10. CONCLUDING REMARKS**

In this brief overview of the recent work of GIWS it has not been possible to do full justice to the work of our members, and we encourage those interested to visit our web-site <a href="www.usask.ca/water">www.usask.ca/water</a> or to contact our members directly. As mentioned by Associate Director Dr. Jeffrey McDonnell, we welcome students and postdoctoral researchers to either join our team full time or spend time with us as visiting researchers and we also welcome academic colleagues for short or longer visits. Our Assistant Director, Dr. Phani Adapa <a href="mailto:phani.adapa@usask.ca">phani.adapa@usask.ca</a> is always available for contact regarding the work of GIWS and welcomes enquiries from individuals, governments, industry and others concerning research collaboration.

## APPENDIX 1 – Current GIWS Membership

**Members:** Individuals working at a level of responsibility which includes initiating and leading water research activities. This may include, but is not limited to faculty members at the U of S; Research Scientists, Staff Scientists, or Science Associates in recognized co-located (e.g. Saskatoon-based) research institutions (i.e. Environment Canada, Saskatchewan Research Council, Canadian Light Source, Agriculture and Agri-food Canada); and U of S Research Scientists.

**Barbour, Lee**, Professor, Civil and Geological Engineering Geotechnical/Geo-environmental: Saturated/Unsaturated Groundwater Flow and Contaminant Transport, Mine Waste Reclamation

**Baulch, Helen**, Assistant Professor, School of Environment and Sustainability Water quality; Aquatic ecology; Global change; Biogeochemical cycles; Greenhouse gas emissions; Eutrophication

Bedard-Haughn, Angela, Associate Professor, Soil Science

Study fundamental understanding of pedologic properties of Canadian ecosystems and how land use and climate changes affect, and are affected by, these properties

**Belcher, Ken**, Professor, Bioresource Policy, Business and Economics Ecological economics; Resource and environmental economics; Environmental policy; Climate change; Wetland and wildlife conservation policy

**Bharadwaj, Lalita**, Associate Professor, School of Public Health
Barriers and Key Issues to the Access of Safe and Sustainable Drinking Water Sources in First
Nations Communities; Community Based Participatory Research with Indigenous Communities;
Human and Environmental Health Risk Assessment; Community-Based Education

**Cessna, Allan**, Research Scientist, Agriculture and Agri-Food Canada Agricultural pesticides and veterinary pharmaceuticals

**Chambers, Patricia**, Research Scientist and Section Head, Environment Canada Human Impacts on Aquatic Ecosystems Processes

**Chang, Won Jae**, Assistant Professor, Civil and Geological Engineering Contaminated site assessment and remediation; Bioremediation of oil sands pollutants, mine wastes, frozen contaminated sites; Characterization of microbial communities/populations; Molecular biology techniques for contaminated environmental matrices

**Clark, Bob**, Research Scientist and Adjunct Professor, Environment Canada Avian Ecology, Reproduction and breeding habitat selection, Landscape ecology

Clark, Doug, Centennial Chair and Assistant Professor, School of Environment and Sustainability

Polar bear-human conflicts; Decision-making under conditions of rapid social-ecological change; Wildlife and protected area management; Environmental governance and policy processes

Davison, Bruce, Research Scientist, Environment Canada

Hydrometeorological modelling, including incorporating physical or statistical processes into models; Operationalization of modelling tools; Incorporating software engineering tools into model development; Models for decision making

**de Boer, Dirk**, Research Scientist, Environment Canada Drainage basin; Suspended sediment; Fluvial geomorphology; Soil Erosion

**Doig, Lorne**, Research Scientist, Toxicology Centre
Bioavailability and toxicity of metals, including nanomaterials, in surface waters and sediments;
Deriving environmental quality criteria (water, sediment, and tissue-based); Aquatic ecotoxicology; Aquatic paleoecotoxicology

**Elliott, Jane**, Research Scientist, Environment Canada Soil processes; Soil-water interactions and agrochemical leaching; Impacts of management practices on water transport of nutrients and contaminants

**Elshorbagy, Amin**, Professor, Civil and Geological Engineering Water Resources Engineering: Hydroinformatics - mechanistic & data-driven watershed modeling, soft-computing techniques; Multi-criterion decision analysis, system dynamics

**Ferguson, Grant**, Associate Professor, Civil and Geological Engineering Hydrogeology; Geothermal Energy; Climate Change

**Fulton, Murray**, Professor and Graduate Chair, Johnson-Shoyama School of Public Policy Economics of biotechnology; Policy analysis of corruption; Performance of co-operatives

**Giesy, John**, Professor and Canada Research Chair in Environmental Toxicology Ecology; Ecotoxicology; Aquatic toxicology; Environmental analytical chemistry of organic compounds; Environmental chemistry (Fates of trace substances in aquatic ecosystems)

**Gober, Patricia**, Professor, Johnson-Shoyama School of Public Policy Water policy; Sustainability science; Decision making under uncertainty; Urban systems; Human migration and population geography; Science-policy interface and stakeholder engagement; Applied climatology

**Gray, Richard**, Professor, Bioresource Policy, Business and Economics Agricultural trade; Agricultural marketing; Environmental economics

**Hecker, Markus**, Associate Professor and Canada Research Chair in Predictive Aquatic Ecotoxicology

Investigation of biological effects of environmental stressors; Environmental risk assessment; Development and application of bioanalytical techniques to assess environmental pollution; Aquatic ecology/fish biology

**Helgason, Warren**, Assistant Professor, Chemical and Biological Engineering Atmospheric boundary layer processes; Energy and mass transport in the soil-plant-atmosphere continuum; Irrigation

Hendry, Jim, Professor and NSERC-Cameco Industrial Research Chair
Aqueous and environmental geochemistry of contaminants in uranium tailings;
Characterization of biogeochemical reaction rates in vadose zones; Fate and transport of solutes in aquitards; Sorption controls on the transport of bacteria in saturated porous media; Reactive barrier technologies

**Hill, Harvey**, Research Scientist, Agriculture and Agri-Food Canada Economics; Climate decision support and adaptation

**Hobson, Keith**, Research Scientist, Environment Canada

Conservation and management of boreal forest birds and other wildlife; Conservation and management of water birds with particular emphasis on the interactions between fish-eating birds and commercial and sport fisheries; Use of stable isotopes to track the source and fate of environmental contaminants in terrestrial and marine systems

**Hogan, Natacha**, Assistant Professor, Animal and Poultry Science Aquatic toxicology; Sources and fate of aquatic contaminants; Aquatic animal health; Agricultural intensity and water quality

Howard, Allan, Manager, Agriculture and Agri-Food Canada

Adaptation techniques for drought and conditions of extreme wetness; Best practices for monitoring soil moisture; Models for assessing drought and for forecasting regional scale crop yield; Develop systems for accessing local and regional scale information on climate impacts

**Hudson, Jeff**, Associate Professor, Biology

Biogeochemical cycles in aquatic ecosystems; Effects of food web structure, ultraviolet radiation, climate change and biodiversity on elemental cycling and energy flow

**Ireson, Andrew**, Assistant Professor, School of Environment and Sustainability Climate change and water security; Land-water management and environmental change; Sustainable development of natural resources

Janz, David, Professor, Veterinary Biomedical Sciences Climate change and water security; Land-water management and environmental change

Jardine, Tim, Assistant Professor, School of Environment and Sustainability

Freshwater food webs; Applications of stable isotope analysis in ecology; Tropical floodplain hydrology and ecology; Contaminant biomagnification in aquatic ecosystems; Sources and fate of trace metals; Fish migration; Land-water and river-ocean connectivity

**Johnstone, Jill**, Associate Professor, Biology Climate change and water security

**Jones, Paul**, Associate Professor, School of Environment and Sustainability Land-water management and environmental change; Naphthenic Acid

**Kells, Jim**, Professor and Head, Civil and Geological Engineering
Hydraulic Structures; Use of Rock in Hydraulic Engineering; Scour Processes in Cohesionless
Materials; Water Quality of Stormwater Runoff; Ecologically Engineered Systems

**Khaliq, Naveed**, Associate Professor, School of Environment and Sustainability Stochastic modeling of hydrometeorological variables; Extreme value analysis; Impacts of climate and land use changes on water resource systems; Storm water modeling and river flow forecasting; Soil and water management; Applied software development

**Li, Yanping**, Assistant Professor, School of Environment and Sustainability Regional climate modelling; Mesoscale dynamics; Boundary layer meteorology; Air-sea interaction

**Liber, Karsten**, Professor and Director, Toxicology Centre Bioavailability and toxicity of metals, including nanomaterials, in surface waters and sediments; Deriving environmental quality criteria (water, sediment, and tissue-based); Aquatic ecotoxicology; Aquatic paleoecotoxicology

**Lindenschmidt, Karl-Erich**, Associate Professor, School of Environment and Sustainability Surface water quality modelling; River ice processes; Climate change and river morphology; Flood and flood risk management

**Lindsay, Matt**, Assistant Professor, Geological Sciences Groundwater; Biogeochemistry; Mining management and reclamation

Marsh, Phil, Research Scientist, Geography and Planning Hydrologic processes and modelling of snowmelt and rainfall runoff in cold environments; Impact of climate change on water resources of the Canadian Arctic

Martz, Lawrence, Professor, Geography and Planning
Soil erosion and sediment transport; Impacts of climate change on water use in the South
Saskatchewan River Basin

**McDonnell, Jeffrey**, Professor and Associate Director, Global Institute for Water Security Watershed hydrology; Runoff processes; Modelling, Isotope hydrology

**McKenzie, Marcia**, Associate Professor and Director, Sustainability Education Research Institute Place, environment and sustainability

Morrissey, Christy, Assistant Professor, Biology

Ecotoxicology; Water pollution; River and wetland ecology; Freshwater biology; avian and aquatic ecotoxicology

Noble, Bram, Professor, Geography and Planning

Environmental impact assessment; Cumulative effects assessment; Strategic environmental assessment; Environmental planning and management; Environmental decision making

Patrick, Bob, Associate Professor, Geography and Planning

Water Policy and Governance; Watershed Planning and Management; Source Water Protection; Integrated Water Resource Management; First Nations access to safe Drinking Water; Regional Planning; Urban Water Issues

Pennock, Dan, Professor, Soil Science

Landscape-scale soil processes and the spatial pattern of soil properties

**Pickering, Ingrid**, Professor and Canada Research Chair in Molecular Environmental Science Development of new synchrotron radiation techniques; Metals and metalloids transformation in the environment; Identification of toxicologically significant compounds in vivo

**Pomeroy, John**, Professor and Canada Research Chair in Water Resources and Climate Change Hydrological processes and modelling in mountain, prairie and arctic environments; Climate change, hydrology and water resources; Snow chemistry and ecology; Droughts in the Canadian Prairies; Cold regions hydrometeorological modelling and surface-atmosphere feedbacks

**Putz, Gordon**, Professor, Civil and Geological Engineering Water quality modelling and management; Water and wastewater treatment

**Reed, Maureen**, Professor, School of Environment and Sustainability Environmental Governance; Sustainability of Rural Communities; Feminist and Gender-based Analysis; Social Resilience; Political Ecology; Forestry; Model Forests; Biosphere Reserves; National Parks

**Shook, Kevin**, Research Scientist and SGI Canada Research Fellow, Geography and Planning Snowmelt modelling; Fractal analysis of hydrological phenomena; Flood modelling and extreme events analysis

Si, Bing, Professor, Soil Science

Understand the mechanisms of soil water dynamics and thermal regimes in non-level landscapes—at the pedon, hillslope (catchment) and landscape scale

Singh, Satya, Research Scientist, Geological Sciences

Environmental geochemistry particularly in trace metal biogeochemistry; geochemical cycling; Remediation of contaminated soils, sediment, surface and groundwater; Quantification of geochemical processes in wetlands and mining wastes

**Spence, Christopher**, Research Scientist, Environment Canada Hydrology and hydrometeorology of Canada's cold regions, especially the subarctic Canadian Shield; Hydrological processes in the Prairie Pothole region of Saskatchewan

van der Kamp, Garth, Research Scientist, Environment Canada Impacts of climate changes and land-use changes on prairie wetlands and lakes; Evaluation of groundwater availability and sustainability; Impacts of groundwater withdrawals on aquatic ecosystems; Groundwater flow and solute transport in low -permeability formations; Study of the hydrology of peatlands

van Rees, Ken, Professor, Soil Science Agroforestry and biomass energy systems and their impacts on soils

**Waiser, Marley**, Research Scientist, Environment Canada Effects of Human and Veterinary Pharmaceuticals and Herbicides on Indices of Aquatic Ecosystem Health

**Westbrook, Cherie**, Associate Professor, Geography and Planning Wetland Ecohydrology; Effect of beavers and humans on pathways between surface and ground waters; Transport of water and nutrients from wetlands and riparian areas

**Wheater, Howard**, Professor, Canada Excellence Research Chair in Water Security, and Director, Global Institute for Water Security

Hydrological processes and modelling, with applications to the management of flood risk, water resources, water quality, wastes and climate change adaptation

**Wheaton, Elaine**, Senior Research Scientist, Saskatchewan Research Council Climatology; Climate impacts and adaptation; Climate change; Hazards climatology

**Wittrock, Virginia**, Research Scientist, Saskatchewan Research Council Climatology; Climate impacts and adaptation; Climate change; Hazards climatology

**Wilson, Lee**, Associate Professor, Chemistry

Water, Solution Chemistry, Hydration Phenomena, Polymers, Biomaterials, Membranes, Porous Materials, Colloids & Surfactants, Materials & Environmental Science, and Chemical Separations

Yang, Daqing, Research Scientist, Environment Canada Global water resources and availability; Climate change; Extreme hydrological events; Human impact on water systems; Arid and cold region hydrology Associate Members: Individuals who are making a significant contribution to water research or who are providing support for water research activities in areas relevant to GIWS. This may include, but is not limited to, U of S research staff (e.g. Research Associates, Research Assistants, Research officers or Postdoctoral fellows); Research staff from recognized national or international research institutions who are affiliated with a member of the Institute; and Professional affiliates – individuals who may not hold a PhD, but who can serve on graduate student advisory committees and/or teach graduate courses.

**Ryan, Chris**, Director of Business Development, Level Science Inc. Environmental forensics; Athabasca oils sands; Synchrotron radiation; Absorption spectroscopy; Naphthenic acids; Petroleum Coke; Mine drainage; Industrial effluent

**Chun, Kwok Pan**, Postdoctoral Fellow, Global Institute for Water Security Hydrology; Statistics; Climate change

**Ghanbarpour, Reza**, Water Allocation Modeller, Alberta Energy and utilities Board Flood-risk modelling, Watershed hydrology, Decision analysis, Optimization

**Klaus, Julian**, Centre de Recherche Public - Gabriel Lippmann, Luxembourg Runoff generation processes; Catchment and Hillslope Hydrology; Stable Isotope Methods in Hydrology; Modeling of water and solute transport at hillslope and headwater scale

**Mamet, Steven**, Postdoctoral Fellow, Biology, University of Saskatchewan Effect of climate and environmental change on tree line dynamic

**Mekonnen, Muluneh**, Water Modelling Engineer, Alberta Environment and Sustainable Resource Development

Linked atmospheric-hydrologic-land surface model development and application

**Musselman, Keith**, Postdoctoral Fellow, Centre for Hydrology, University of Saskatchewan Hydrology; Water Resources; Snow; Hydrometeorology

**Nachshon, Uri**, Postdoctoral Fellow, Global Institute for Water Security Hydrology; Vadose zone; Salinization; Land-atmosphere interaction; Salt dynamics; Evaporation

**Nazemi, Ali**, Research Associate, Global Institute for Water Security Water resources modelling and management under climate change conditions

**North, Rebecca**, Postdoctoral Fellow, Global Institute for Water Security Eutrophication issues; Phytoplankton physiology and ecology; Land use practices and nutrient bioavailability; Nutrient limitation of algae; Aquatic biogeochemistry

**Pan, Xicai**, Postdoctoral Fellow, Global Institute for Water Security Hydrology; Cryosphere; Climate; Soil physics; Hydrogeophysics

Razavi, Saman, Postdoctoral Fellow, Civil and Geological Engineering

Environmental and Water Resources Systems Planning and Management; Hydrologic and Groundwater Modelling; Climate Change and Impacts on Hydrology and Water Resources; Reconstruction of Paleo-hydrology – Implications for Climate Change Analysis; Rainfall and runoff forecasting; Artificial Intelligence, and Machine Learning

Sagin, Jay, Postdoctoral Fellow, Global Institute for Water Security Remote Sensing and GIS applications; Hydrology; Hydrogeology; Modelling; Trans-boundary basins

**Strickert, Graham**, Research Associate, Global Institute for Water Security Complex human-environmental systems; Socio-hydrology; Mixed-methods; Fuzzy cognitive maps

**Affiliates:** Distinguished individuals who have demonstrated a commitment to the goals and objectives of the institute's SaskRB program. Affiliates are generally positioned outside traditional research environments.

Halliday, Bob, Senior Vice President, Chief Financial Officer, Applied Materials, Inc.

**Lamb, Susan**, Chief Executive Officer, Meewasin Valley Authority and Chair of VIDO/InterVac liaison committee

**Sanford, Bob**, EPCOR Chair of the Canadian Partnership Initiative in support of United Nations "Water for Life" Decade, Director of the Western Watersheds Research Collaborative

**Student Members:** Students registered at a postsecondary institution and who are engaged in water-related research activities, and who are under the supervision or co-supervision of a GIWS member, or any graduate or undergraduate student registered at the University of Saskatchewan.

Glossary: MSc – Master of Science; PhD – Doctor of Philosophy; MSEM – Master in Sustainable Environmental Management; MPP – Master of Public Policy; MES – Master of Environment and Sustainability; MPH – Master of Public health; MPA – Master of Public Administration; SENS – School of Environment and Sustainability; JSGS – Johnson Shoyama Graduate School of Public Policy; SPH – School of Public Health

Name	College/ School	Supervisor	Degree
Abirhire, Oghenemise	Biology	J. Hudson	Masters
Adesokan, Adedoyonsola	SENS	n/a	MSEM
Ahmed, Hafiz	Chemical & Biological Engineering	W. Helgason	MSc
Aksamit, Nikolas	Centre for Hydrology	J. Pomeroy	PhD
Amin, Mahmud Rashedul	Civil & Geological Engineering	K. Mazurek	MSc
Amos, Mike	Civil & Geological Engineering	L. Barbour	
Armstrong, James	Biology	N. Chilton	MSc
Awume, Bennet	SENS	n/a	MSEM
Baer, Thomas	Civil & Geological Engineering	L. Barbour	MSc

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	Bam, Edward	SENS	A. Ireson	PhD
	Bihum, Samantha	Arts & Science	n/a	Undergraduate
	Brannen, Rosa	SENS	A. Ireson	MES
	Brown, Robyn	Arts & Science	n/a	Undergraduate
	Bruce, Kristin	JSGS	P. Gober	MPP
	Buchanan, Astri	SENS	M. Reed	MES
	Burke, Amanda	SENS	H. Wheater	MES
	Burlock, David	Arts & Science	n/a	Undergraduate
	Carr, Meghan	SENS	K-E.	MES
			Lindenschmidt	
	Chowdhury, Rocky	Civil & Geological Engineering	K. Mazurek	MSc
	Coles, Anna	SENS	J. McDonnell	PhD
	David, Cody	Soil Science	W. Helgason	MSc
	Demuth, Brandon	Biology	D. Chivers	PhD
	Dobrovolskaya,	SENS	B. Si	MES
	Yekaterina			
	Doering, Jonathon	Toxicology	M. Hecker	PhD
	Dompierre, Kathryn	Civil & Geological Engineering	L. Barbour	PhD
	Dudiak, Scott	Arts & Science	n/a	Undergraduate
	Dumanski, Stacey	Geography & Planning	J. Pomeroy	MSc
	Ferdous, Jannatul	Chemical & Biological	W. Helgason	PhD
		Engineering		
	From, Richard	Geological Sciences	K. Larson	MSc
	Galuschik, Noel	SENS	H. Baulch	MES
	Garvey, Phillip	Soil Science	S. Siciliano	PhD
	Gibb, Josh	SENS	K. Mazurek	PhD
	Gonda, Jordan	Civil & Geological Engineering	A. Elshorbagy	MSc
	Gooding, Raea	SENS	H. Baulch	MES
	Harder, Phillip	Geography & Planning	J. Pomeroy	MSc
	Hassanzadeh, Elmira	Civil & Geological Engineering	A. Elshorbagy	PhD
	Hatzel, Kayla	Arts & Science	n/a	Undergraduate
	Head, Kerry	Biology	J. Hudson	MSc
	Hermann, Kristian	Geological Sciences	J. Hendry	MSc
	Hoemsen, Brittney	Biology	D. Chivers	MSc
	Howitt, Nicholas	SENS	n/a	MSEM
	Hueser, James	Arts & Science	n/a	Undergraduate
	Hunter, Kristine	Biology	J. Hudson	M.Sc.
	Jafri, Syed	SPH	A. Backman	MPH
	Johansson, Jess	Biology	J. Hudson	MSc
	Kardas, Jeffrey	Geography & Planning	n/a	Undergraduate
	Kelly, Meghan	SENS	n/a	MSEM
	Lakken, Nils	SENS	D. Clark	MES
	Leroux, Nicolas	Geography & Planning	J. Pomeroy	PhD
-	Lokken, Torbjom	RRM	n/a	Undergraduate

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Lucas, Brett	Toxicology	K. Liber	MSc
Madaeni, Fatemeh	Civil & Geological Engineering	A. Elshorbagy	PhD
Mahmood, Fazilatun	Geological Sciences	J. Hendry	PhD
Mamo, Moges	Civil & Geological Engineering	A. Ireson	MSc
Masse, Anita	Toxicology	D. Janz	Masters
Masud, Badrul	SENS	N. Khaliq	PhD
Mekonnen, Balew	Civil & Geological Engineering	K. Mazurek	PhD
Mercer, Jason	Geography & Planning	C. Westbrook	MSc
Mohamadmahdi, Kowsari	Chemical & Biological	J. Soltan	MSc
Morrison, Alasdair	Engineering Geography & Planning	C. Westbrook	MSc
Mulhall, Liam	SENS	H. Baulch	MSEM
Parratt, Toomas	Civil & Geological Engineering	G. Putz	PhD
Payton, Diana	JSGS	P. Gober	MPP
Perry, Tom	Arts & Science	n/a	Undergraduate
Peterson, Amber	Civil & Geological Engineering	A. Ireson	MSc
Phillips, Iain	Biology	D. Chivers	PhD
Prestie, Chance	Biology	J. Hudson	MSc
Rahimova, Nargiz	SENS	H. Hesseln	MES
Rasouli, Kabir	Geography & Planning	J. Pomeroy	PhD
Roste, Jennifer	Geography & Planning	H. Wheater/J.	MSc
noste, semme	Geography a manning	Pomeroy	50
Sadeghi, Azam	Chemical & Biological	J. Soltan	MSc
	Engineering		
Sadeghian, Amir	SENS	K-E.	PhD
		Lindenschmidt	
Saunders, David	Toxicology	J. Giesy	MSc
Schabert, Marcie	Arts & Science	n/a	Undergraduate
Sizo, Anton	Geography & Planning	B. Noble	PhD
Steeves, Joel	Civil & Geological Engineering	L. Barbour	MSc
Tritschler, Felix	SENS	J. McDonnell	MSc
Tse, Timothy	Toxicology	P. Jones	MSc
Ufondu, Lotanna	Civil & Geological Engineering	G. Ferguson	PhD
Virdi, Satpal	JSGS	D. Beland	MPA
Weber, Darian	Arts & Science	n/a	Undergraduate
Yee, Briana	Arts & Science	n/a	Undergraduate
Yip, Hayden	Biology	J. Hudson	MSc
Younes, Firas	SENS	R. Patrick	MSEM
Zee, Jenna	SENS	M. Hecker	MES
Zilefac, Elvis	SENS	H. Wheater	PhD

## **APPENDIX 2 – List of GIWS Funded Projects**

- 1. Effects of urbanization and agriculture on microbial communities in a creek from the semi-arid ecozone of the Canadian Prairies: Swift Current Creek, SK
- 2. Development of monitoring strategies and identification of hydrological and biogeochemical indicators in the Tobacco Creek
- 3. Prairie Hydrological Modelling: Understand implications of hysteresis in discharge storage relationships; use multifractal methods to downscale climate model products over Prairies; surface-groundwater modelling; nutrient and contaminant flux from snowmelt over frozen soils
- 4. Effects of climate change and climate-induced land-use change on hydrology, pedology, and ecology of a hummocky morainal agroecosystem
- 5. Evaluation of NARCCAP RCM precipitation simulations over the Canadian Prairies
- 6. Understanding of the interactions between climate, hydrology, and vegetation in the southern boreal forest
- 7. Sensitivity of Hydrology and Forest Resilience to Climate Variation in the Southern Boreal Forest of Western Canada
- 8. Boreal forest flux tower operations (BERMS Boreal Ecosystem Research and Monitoring Sites)
- 9. Advance development and integration of information on how hydrological and cryospheric processes interact to form streamflow: Canadian Rockies
- 10. Develop and run hydrological models to produce water resource predictions for past and future climates: Canadian Rockies
- 11. Exploring water resource management in partnership with the community of water users of Lake Diefenbaker
- 12. Reconstructing the history of the phototrophic community within Lake Diefenbaker and analysis of biotoxins produced from a recent algal bloom
- 13. An investigation into the past and present ecological status of Lake Diefenbaker using paleolimnological and whole sediment toxicity techniques
- 14. Water quality modelling of Lake Diefenbaker
- 15. The contribution of point and diffuse sources of nutrients to Lake Diefenbaker: A sensitivity analysis
- 16. Brightwater Creek multi-scale measurement and modelling programme
- 17. Peat properties and groundwater flows in relation to beaver paleoponds in mountain peatlands
- 18. Assessing links between water, animals and people in the Saskatchewan River delta
- 19. A collaborative approach to better understand the links between water, animals, and people in the Saskatchewan River Delta
- 20. Assessing links between water, animals and people in the Saskatchewan River delta (People dimension)
- 21. 'Exotic' chemical contaminants in the South Saskatchewan River Basin
- 22. Stakeholder definitions of water security in the South Saskatchewan River Basin

23. Investigating links between Lake Sturgeon (*Acipenser fulvescens*) habitat and geomorphology in the Saskatchewan River system using geomorphic response units (GRU)

# **APPENDIX 3 – GIWS Employees and Students 2011-2013**

The following table provides information on GIWS employees and students funded during the period of 2011-2013. A total of 157 personnel were funded during this period, including 7 GIWS faculty members, 8 administrative staff, 20 research technicians, 4 research associates/scientists, 21 postdoctoral fellows, 17 doctoral students, 31 masters' students and 49 undergraduate and graduate student assistants.

Name	Title/ Area	Supervisor/ Unit
CERC Faculty		
Baulch, Helen	Assistant Professor	SENS
Ireson, Andrew	Assistant Professor	SENS
Khaliq, Naveed	Associate Professor	SENS
Li, Yanping	Assistant Professor	SENS
Lindenschmidt, Karl-Eric	Associate Professor	SENS
McDonnell, Jeffrey	Professor and Associate Director	SENS
Wheater, Howard	Professor and Director	SENS
Administrative Staff		
Adapa, Phani	Assistant Director	H. Wheater
Hinther, Meagan	Communication Specialist – 0.5 FTE	H. Wheater
Olauson, Sherry	Clerical Assistant	H. Wheater
Porter, Lesley	Communication Specialist – 0.5 FTE	H. Wheater
Rudovica, Twyla	Financial Officer – 0.5 FTE	H. Wheater
Schlosser, Tiffany	Financial Officer	H. Wheater
Wilson, Katherine	Executive Assistant	H. Wheater
Zdravkovic, Branislav	IT Administrator – Data	H. Wheater
Technical Support		
Ahsan, Mahbubu	Research Assistant	J. Hudson
Al-mahdawe, Mohammed	Undergraduate Research Assistant	W. Helgason
Asante, Christian	Undergraduate Student Assistant	T. Jardine
Bayne, Dell	Research Technician	W. Helgason
Belosowsky, Tayler	Undergraduate Student Assistant	J. Hudson
Bertollo, Steve	Research Technician	J. Pomeroy
Bishop, Jill	Research Assistant	H. Wheater
Briens, Jennifer	Undergraduate Student Assistant	H. Baulch
Brunet, Nathalie	Research Assistant	A. Bedard-Haughn
Brydges, Torben	Research Assistant	J. Hudson
Bush, James	Undergraduate Student Assistant	A. Bedard-Haughn

Campbell, Jordan	Undergraduate Student Assistant	J. McDonnell
Carriere, Michela	Undergraduate Student Assistant	T. Jardine
Carter, Colleen	Undergraduate Student Assistant	K. Liber
Chilima, Jania	Research Assistant	L. Bharadwaj
Cowell, Mattea	Undergraduate Research Assistant	J. McDonnell
Crawford, Caley	Undergraduate Student Assistant	J. Hudson
Davies, Samuel	Summer Intern	A. Ireson
DeBeer, Chris	Research Associate	H. Wheater
Doig, Lorne	Research Technician	K. Liber
Dumanski, Stacey	Research Assistant	P. Jones
Duncan, Andrew	Research Technician	J. Pomeroy
Eisner, Bryanna	Undergraduate Student Assistant	M. Hecker
Fang, Xing	Research Officer	J. Pomeroy
Geeraert, Bryce	Research Technician	D. de Boer
Guan, Juan	Research Officer	J. Pomeroy
Haines, Llewellyn	Research Assistant	J. Hudson
Hewlett, Curtis	Undergraduate Student Assistant	J. Hudson
Higley, Eric	Research Technician	M. Hecker
Hill, Allison	Research Assistant	P. Jones
Hills, Erin	Research Assistant	H. Baulch
Hoggart, Cameron	Research Assistant	H. Baulch
Hopkins, Joe	Research Assistant	J. Hudson
Horton, Alex	Summer Intern	A. Ireson
Hosseini, Nasim	Research Assistant	K. Lindenschmidt
Huber, Leah	Undergraduate Student Assistant	J. Hudson
Isbister, Dallas	Research Assistant	K. Liber
Johnson, Bruce	Research Technician	Helgason/ Wheater/
		McDonnell
Johnson, Laurie	Research Technician	J. Hudson
Kardas, Jeffrey	Research Technician	C. Westbrook
Kautzman, Mike	Research Technician	K. Liber
Kittisenee, Jetana	Research Technician	J. Hudson
Kogo, Seraphine	Grad. Student Assistant	L. Bharadwaj
Livingston, Andrew	Research Assistant	L. Bharadwaj
Mackinnon, Brett	Research Assistant	T. Jardine
Markwart, Blue	Undergraduate Student Assistant	K. Liber
McInnes, Sheena	Research Technician	J. Hudson
Mock, Tyler	Undergraduate Student Assistant	J. Hudson
Monteiro, Meagan	Undergraduate Student Assistant	W. Helgason
Nazemi, Ali	Research Assistant	Wheater/ Elshorbagy
Patterson, Sarah	Undergraduate Student Assistant	Liber/ Hecker
Perry, Tom	Undergraduate Student Assistant	J. Hudson
Pomedli, Michelle	Undergraduate Student Assistant	J. Hudson
Ponomarenko, Yakiv	Undergraduate Student Assistant	J. Hudson

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Rawlyk, Franny	Research Technician	D. de Boer
Reid, Shelby	Research Assistant	M. Hecker
Restrepo, Pablo	Undergraduate Student Assistant	N. Khaliq
Sarauer, Bryan	Research Technician	M. Hecker
Sholohub, Michael	Research Technician	W. Helgason
Shook, Kevin	Research Scientist	J. Pomeroy
Sit, Victor	Lab manager	H. Baulch
Smith, Paul	Undergraduate Student Assistant	A. Wheater
Strickert, Graham	Research Associate	Wheater/ Clark
Sura, Srinivas	Research Assistant	M. Waiser
Timsic, Sandra	Research Associate	McDonnell
Todman, Lindsay	Summer Intern	A. Ireson
Vandergucht, David	Research Technician	J. Hudson
Vashchyshyn, Ilona	Undergraduate Student Assistant	H. Wheater
Wade, Kristy	Research Assistant	M. Waiser
Weber, Darian	Undergraduate Student Assistant	K. Lindenschmidt
Welter, Sarah	Student Assistant	J. Hudson
Williams, Tyler	Research Assistant	J. Pomeroy
Wilson, Heather	Research Technician	Bedard-Haughn/Spence
<b>Postdoctoral Fellows</b>		
Apples, Willemijn	Postdoctoral Fellow	J. McDonnell
Chun, Kwok Pan	Postdoctoral Fellow	H. Wheater
Codling, Garry	Postdoctoral Fellow	J. Giesy
Ghanbarpour, Reza	Postdoctoral Fellow	H. Wheater
Guerrero, Jose-Luis	Postdoctoral Fellow	H. Wheater
Janzen, Daryl	Postdoctoral Fellow	Ireson/Wheater
Kinar, Nicholas	Postdoctoral Fellow	J. Pomeroy
Klaus, Julian	Postdoctoral Fellow	J. McDonnell
Mahmood, Taufique	Postdoctoral Fellow	Wheater/Pomeroy
Mamet, Steve	Postdoctoral Fellow	J. Johnstone
Mekonnen, Muluneh	Postdoctoral Fellow	Ireson/ Wheater
Morales, Luis	Postdoctoral Fellow	Lindenschmidt/Wheater
Musselman, Keith	Postdoctoral Fellow	J. Pomeroy
Nachshon, Uri	Postdoctoral Fellow	Ireson/Wheater
North, Rebecca	Postdoctoral Fellow	Wheater/Hudson
Pan, Xicai	Postdoctoral Fellow	Ireson/ Helgason
Paule, Armelle	Postdoctoral Fellow	J. Lawrence
Razavi, Saman	Postdoctoral Fellow	Wheater/Elshorbagy
Sagin, Jay	Postdoctoral Fellow	Lindenschmidt/Wheater
Sereda, Jeff	Postdoctoral Fellow	H. Wheater
Vogt, Anja	Postdoctoral Fellow	Giesy/Jones
Graduate Students		
Bam, Edward	Doctoral Student	A. Ireson
Beveridge, Danny	Doctoral Student	C. Westbrook

Cavaliere, Emily	Doctoral Student	H. Baulch
Coles, Anna	Doctoral Student	J. McDonnell
Deguignet, Marine	Doctoral Student	C. Westbrook
Dompierre, Kathryn	Doctoral Student	Wheater/Barbour
Gabrielli, Chris	Doctoral Student	J. McDonnell
Marsh, Chris	Doctoral Student	Wheater/Pomeroy
Masud, Mohammed	Doctoral Student	N. Khaliq
Pradhananga, Dhiraj	Doctoral Student	J. Pomeroy
Sadeghian, Amir	Doctoral Student	K. Lindenschmidt
Safa, Hamideh	Doctoral Student	H. Wheater
Shahariar, Shayeb	Doctoral Student	A. Bedard-Haughn
Tse, Tim	Doctoral Student	P. Jones
Wang, Xiaoyue	Doctoral Student	A. Bedard-Haughn
Yang, Mu Chun	Doctoral Student	Wheater/Barbour/Ireson
Zilefac, Asong	Doctoral Student	Wheater/Khaliq
Abirhire, Oghenemise	Masters Student	J. Hudson
Beitel, Shawn	Masters Student	M. Hecker
Brannen, Rosa	Masters Student	A. Ireson
Bruce, Kristin	Masters Student	P. Gober
Burke, Amanda	Masters Student	Wheater/Putz
Carlson, Hayley	Masters Student	M. Fulton
Carr, Meghan	Masters Student	K. Lindenschmidt
Dubourg, Paul	Masters Student	J. Hudson
Flahr, Leanne	Masters Student	T. Jardine
Galuschik, Noel	Masters Student	H. Baulch
Gonda, Jordan	Masters Student	Wheater/Elshorbagy
Gooding, Raea	Masters Student	H. Baulch
Head, Kerry	Masters Student	J. Hudson
Hunter, Kristine	Masters Student	J. Hudson
Johansson, Jessica	Masters Student	J. Hudson
Leedham, Kellie	Masters Student	J. Pomeroy
Lucas, Brett	Masters Student	Liber/Doig
Maher, Allen	Masters Student	C. Westbrook
Mamo, Moges	Masters Student	A. Ireson
Morrison, Alasdair	Masters Student	C. Westbrook
Payton, Diana	Masters Student	P. Gober
Peterson, Amber	Masters Student	Ireson/Helgason
Prestie, Chance	Masters Student	J. Hudson
Ross, Jamie	Masters Student	M. Fulton
Roste, Jennifer	Masters Student	Wheater/Baulch
Schiffer, Stephanie	Masters Student	K. Liber
Siemens, Evan	Masters Student	J. Pomeroy
Wang, Hanyang	Masters Student	B. Patrick
Wu, Hongye	Masters Student	C. Westbrook

Yip, Hayden	Masters Student	J. Hudson	C. S.
Yuan, Hongda	Masters Student	P. Jones	

## **APPENDIX 4 – GRANTS 2011-2013**

The following table outlines grants received by members of GIWS during the reporting period of March 2011 – December 2013. The CERC program provided a base funding of \$30 million, which was further augmented by additional funding of \$15 million secured by core GIWS researchers and \$14.4 million secured by our members.

Baulch, Helen	
\$347,259	Monitoring and assessment of beneficial management practices: insight from
	the Tobacco Creek Watershed, Canadian Water Network (Co-I: H. Wheater and J. Pomeroy)
\$880,000	Undertaking lake metabolism and algal blooms: New tools for the
	management of potable water sources, Natural Sciences and Engineering
	Research Council (NSERC) Strategic Project Grant (Co-I: P. Giesy, R. Leavitt, P.
	Jones, K. Liber, K-E. Lindenschmidt)
\$130,000	Biogeochemistry of lakes in winter and the implications of declining ice cover,
	NSERC Discovery Grant
\$106,436	Environmental Change and Aquatic Ecosystems Facility (ECAEF), Canada
	Foundation for Innovation (CFI)
\$12,000	Winter conditions in prairie waters, Environment Canada
\$12,000	Indicators of nutrient saturation in prairie waters, Science Horizons -
	Environment Canada
	Identifying flood- and food-related limits to fish and wildlife production in the
	Saskatchewan River Delta, NSERC Collaborative Research and Development
	Grant – SaskPower, \$411,158 (PI: T. Jardine)

## Bedard-Haughn, Angela

\$190,000	Hydric Soils of the Prairie Pothole Region, NSERC Discovery grant
\$80,755	Nutrient Dynamics in Drained Agricultural Soils and Drainage Ditches,
	Saskatchewan Agricultural Development Fund

Ferguson, Gra	ant
\$100,000	Exploring Data Needs for Geothermal Energy Development, NSERC Discovery Grant
\$6,000	Geothermal Potential for CFS Alert, Geological Survey of Canada
\$72,000	Infrared Imaging to Support Hydrogeological Modeling and Characterization, CFI - Leaders Opportunity Fund
\$865,735	Probabilistic Risk Assessment of Groundwater Flow and Contaminant Transport, Sylvia Fedoruk Canadian Centre for Nuclear Innovation and Atomic Energy of Canada Limited

Giesy, John	
\$200,000	Ricks of Polyfluorinated Compounds in the Environment MSERC Discovery
	Risks of Polyfluorinated Compounds in the Environment, NSERC Discovery Grant
\$789,000	Marine biogeochemistry and ecotoxicology, Chinese Ministry of Education and the State Administration of Foreign Experts
\$80,129	Environmental Screening, Computational and Biological Characterization of Endocrine Disruptors in Respect to Receptor Binding, Embryo and Gonad Physiology, Hong Kong Research Grants Council, Group Research Program
\$2,817,692	Environmental Research and Innovative Technology (MERIT), Hong Kong Research Grants Council, Group Research Program
\$46,795	Understanding the relationship between gender, estrogen and telomere biology in fish: Towards developing an alternative vertebrate model for aging studies, Hong Kong General Research Fund
\$46,795	Study on marine environmental physiology and toxicology, Chinese Ministry of Education
\$204,287	CREATE Training Program in Human and Ecological Risk Assessment (HERA), NSERC (Co-I: S.D. Siciliano, L. Bharadwaj)
\$1,000,000	Great Lakes Restoration Initiative, Toxic Substances and Areas of Concern, Program: I-A-6 Great Lakes Sediment Core Surveillance Program, US EPA
\$30,830	Impact of Common Environmental Chemicals on the Allergy and Asthma Epidemic, NSERC/CIHR
\$2,035,700	Development of Technology to Extract petroleum Hydrocarbons and Waste Products from Oil Sands, Western Economic Diversification
\$12,478	Endocrine Disrupting Chemicals: Potential Effects on Female Reproductive Health in Saskatchewan, Royal University Hospital Foundation (Co-I: P.D. Jones)
\$175,632	Effects of Polybrominated Flame Retardants from Electronic Waste on the Cellular DNA and Carcinogenesis, National Plan for Science and Technology of Saudi Arabia
\$130,000	Beneficial Uses of Natural Brominated Chemicals in the Marine Environment, King Saud University, Visiting Professor Program
\$260,000	Global Research Network for Environmental Science, King Saud University Vice Rector for Research
\$62,704	Uncovering the Molecular Links Between Hypoxia and Endocrine Disruption: A Functional Study of Zebrafish Leptin, Hong Kong Research Grants Council
\$18,845	Health Risk Assessments of Residents in the Pearl River Delta Exposed to Brominated Flame Retardants, State Key Laboratory for Marine Pollution, Hong Kong, Seed Grant
\$132,480	In Land and Life: Cadmium and Health Implications for Indigenous Communities in Central Alberta, National First Nations Environmental Contaminants Programme Health Canada (Co-I P.D. Jones)
\$62,500	Analysis of Fish Collected from the Slave River NWT in Fall and Winter 2011-2012, Aboriginal Affairs and Northern Development Canada (Co-I P.D. Jones)

\$33,333	Novel Natural and Synthetic Brominated Compounds in the Environment,
	NSERC Discovery
\$132,688	The Base Mine Lake Toxicity Identification and Evaluation Study; Advancing
	knowledge for water reclamation and return, Syncrude Canada Limited
\$45,000	Expansion and commercialization of in vitro screening assays for the detection
	and assessment of endocrine disrupting potentials of chemicals, waste- and
	drinking-water, Communities of Tomorrow - MITACS (Co-I M. Hecker)
\$11,015	Sino-Canadian cooperation on microbial and phytoremediation technologies
	for clean-up of PAHs and heavy metals contaminated soils in Shanxi industrial
	regions, Shanxi Science and Technology Department
\$142,180	Marine Biogeochemistry and Ecotoxicology Program of Introducing Talents of
	Discipline to Universities, Ministry of Education and the State Administration
	of Foreign Experts, China to State Key Lab of Marine Environmental Science,
	Xiamen University
\$18,682	High Tier Foreign Expert Program, Minister of Education, China
	Undertaking lake metabolism and algal blooms: New tools for the
	management of potable water sources, NSERC Strategic Project Grant,
	\$880,000 (PI: H. Baulch)
	Saskatchewan River Basin: a large-scale observatory for new interdisciplinary
	water science, Canada Foundation for Innovation, \$2,000,000 (PI: H. Wheater)

# **Gober, Patricia**

\$35,000

A collaborative approach to defining water security in the Saskatchewan River Basin: A science and society proposal, University of Saskatchewan, Office of Vice President Research (Co-I: D. Clark, L. Bharadwaj, B. Noble, R. Patrick, H. Wheater)

Hecker, Marku	IS
\$402,261	Predictive Aquatic Ecotoxicology Facility; CFI and matching CRC portion
\$299,140	Safe Water for Health Research Team (SWHRT), Saskatchewan Health
	Research Foundation (PI: L. Bharadwaj and others)
\$500,000	Aquatic impact assessment of municipal effluents, Canadian Water Networks
\$200,000	Functional Transcriptomics of Native Canadian Fish Species; NSERC Discovery
Hudson, Jeff	
\$875,097	Lake Diefenbaker water quality assessment, Saskatchewan water Security Agency

Ireson, Andrew	
\$110,000	Groundwater-surface water interactions in the prairies, NSERC Discovery Grant
\$100,000	Understanding and modeling the Hydrology of the Southern Boreal Forest, Canadian Foundation for Climate and Atmospheric Sciences (T. Black, A. Barr, G. van der Kamp, W. Helgason, J. Johnstone)

\$393,795 Causes and health impacts of saline intrusion into drinking water ponds in Bangladesh, Leverhulme Trust, England

Jardine, Tim	
\$411,158	Identifying flood- and food-related limits to fish and wildlife production in the
, ,	Saskatchewan River delta, NSERC Collaborative Research and Development Grant - SaskPower (Co-I: H. Baulch, K. Hobson, D. Janz )
\$135,000	Ecological benefits and toxicological consequences of flooding in river ecosystems, NSERC Discovery Grant
\$250,000	SWEEP – The Slave Watershed Environmental Effects Program, Canadian Water Network
\$61,535	Infrastructure to investigate the sensitivity of aquatic ecosystems to trace element bioaccumulation, LOF CFI
\$10,000	Effects of beaver activity on mercury bioaccumulation in streams, Science Horizons Youth Internship funding
Johnstone, Jill	
\$105,000	Resistance, resilience, and vulnerability of boreal forests to environmental change, NSERC Discovery Grant
Jones, Paul	
\$125,000	Analysis of fish collected from the Slave River, Department of Aboriginal Affairs and Northern Development Canada
\$75,000	Investigation of fish health and environmental effects program from the Peace and Slave Rivers, Government of the Northwest Territories  Undertaking lake metabolism and algal blooms: New tools for the management of potable water sources, NSERC Strategic Project Grant, \$880,000 (PI: H. Baulch)  SWEEP — The Slave Watershed Environmental Effects Program, Canadian water Network, \$250,000 (PI: T. Jardine)
Liber, Karsten	
\$24,900	Effectiveness of model constructed wetlands for removal of selenium from mine effluent: Selenium accumulation in the larvae of the midge, Chironomus dilutus, NSERC Engage
\$320,329	Distribution and impact of neonicotinoid insecticides on agricultural wetlands and water birds of Prairie Canada, NSERC Strategic Project Grant
\$289,973	Vanadium toxicity to aquatic organisms representative of the Athabasca oil sands region, Syncrude Canada Ltd.
\$27,250	Sino-Canadian cooperation on microbial and phytoremediation technologies for clean-up of PAH and heavy metal contaminated soils in Shanxi industrial regions, Shanxi Science and Technology Department, Taiyuan, Shanxi, China
¢22.400	And the of the court of the cou

Analysis of river otter (Lontra canadensis) livers and kidneys from Northern

\$23,100

Saskatchewan for metals and trace elements via ICP-MS. Saskatchewan
Ministry of Environment
Network on environmental impact assessment of industry-contaminated
areas in the Arctic, Nordic Council of Ministers' Arctic Co-operation
Programme, Denmark
CFI Infrastructure Operating Fund, Canada Foundation for Innovation, Ottawa,
ON, Canada
Quantifying and modeling the bioavailability and toxicity of sediment-
associated uranium to the freshwater midge Chironomus dilutus. AREVA
Resources Canada Ltd.
Undertaking lake metabolism and algal blooms: New tools for the
management of potable water sources, NSERC Strategic Project Grant,
\$880,000 (PI: H. Baulch)

## Lindenschmidt, Karl-Erich

,	
\$24,954	Developing a geospatial model to characterize the ice regime and fish habitat
	of rivers impacted by hydroelectric generating power stations, NSERC Engage
	Grant with EcoFish
	Undertaking lake metabolism and algal blooms: New tools for the
	management of potable water sources, NSERC Strategic Project Grant,
	\$880,000 (PI: H. Baulch)
	SWEEP - The Slave Watershed Environmental Effects Program, Canadian
	Water Network, \$250,000 (PI: T. Jardine)

McDonnell, Jeffrey	
\$999,844	Total water use and source partitioning, United States Department of Agriculture
\$28,250	An integrated investigation of nutrient generation and delivery processes and pathways from paddock to small catchment scales, Australian Research Council Grant
\$1,290,000	Water sustainability in the Willamette Basin, Oregon, National Science Foundation Hydrological Science Grant

Noble, Bram	
\$49,955	Development of a cumulative effects monitoring framework: review and
	options assessment, Aboriginal Affairs and Northern Development Canada

# Pickering, Ingrid \$250,000 Spectroscopic Speciation of Selenium in the Environment, NSERC Discovery Grant

# \$30,000,000 Canada Excellence Research Chair in Water Security: Sustainable freshwater resources and environmental change, Government of Canada, Government of

90	Saskatchewan and University of Saskatchewan
\$5,000,000	Changing Cold Regions network, Climate Change and Atmospheric Research,
	NSERC (36 Canadian Scientists and 15 International Collaborators)
\$2,000,000	Saskatchewan River Basin: a large-scale observatory for new interdisciplinary
	water science, CFI (Co-I: J. Giesy, J. Pomeroy)
\$1,059,806	Hydrological extremes and feedback in the changing water cycle, Natural
	Environment research Council, UK
\$475,000	Water Sciences research in Western Canada, Environment Canada
	CLIMATE KIC Addressing climate change mitigation and adaptation, European
	institute of Technology, \$4,409,191 (PI: R. Anderson)
	Monitoring and assessment of beneficial management practices: insight from
	the Tobacco Creek Watershed, Canadian water Networks, \$347,259 (PI: H.
	Baulch)

### **APPENDIX 5 – Journal Publications**

#### **Journal Publications - 2013**

- Ali, G., Birkel, C., Tetzlaff, D., Soulsby, C., **McDonnell, J.J.** and Paola, T. 2013. A comparison of wetness indices for the prediction of connected saturated areas under contrasting conditions. *Earth Surface Processes and Landforms*. DOI: 10.1002/esp.3506.
- Ali, G., Tetzlaff, D., Kruitbos, L., Soulsby, C., Carey, S., **McDonnell, J.J.**, Buttle, J., Laudon, H., McGuire, K., Seibert, J. and Shanley, J. 2013. Analysis of hydrological seasonality and functionality across northern 1 catchments using monthly precipitation-runoff polygon metrics. *Hydrological Sciences Journal*, 59 (1), 1–17.
- Baranowska, K.A., **North, R.L.,** Winter, J.G. and Dillon, P.J. 2013. Long-term seasonal effects of dreissenid mussels on phytoplankton in Lake Simcoe, Ontario, Canada. Inland Waters, Special Issue on Lake Simcoe, 3: 285-296.
- **Baulch, H.M.**, Futter, M.N., Jin, L., Whitehead, P.G., Woods, D.T., Dillon, P.J., Butterfield, D.A., Oni,S.K., Aspden, L.P., O'Connor, E.M. and Crossman, J. 2013. Phosphorus dynamics across intensively monitored sub-catchments in the Beaver River. *Inland Waters*, 3(2): 187-206.
- Brinkmann, M., Hudjetz, S., Kammann, U., Hennig, M., Kuckelkorn, J., Chinoraks, M., Cofalla, C., Wiseman, S., **Giesy, J.P.**, Schäffer, A., **Hecker, M.**, Wölz, J., Schüttrumpf, H. and Hollert, H. 2013. How Flood Events Affect Rainbow Trout: Evidence of a Biomarker Cascade in Rainbow Trout After Exposure to PAH Contaminated Sediment Suspensions. *Aquatic Toxicology*, 128-129: 147-157. DOI:org/10.1016/j.aquatox.2012.11.010.
- Burnett-Seidel, C. and **Liber, K.** 2013. Derivation of no-effect and reference-level sediment quality values for application at Saskatchewan uranium operations. *Environmental Monitoring and Assessment*, 185(11): 9481-94, 1573-2959.
- Carey, S., Tetzlaff, D., Buttle, J., Laudon, H., **McDonnell, J.J.**, McGuire, K., Seibert, J., Soulsby, C. and Shanley, J. 2013. Use of color maps and wavelet coherence to discern short and longer-term climate influences on streamflow variability in northern catchments. *Water Resources Research*, 49(10): 6194-6207, DOI: 10.1002/wrcr.20469.

- Chang, W., Snelgrove, J., Akbari, A., Frigon, D., Ghoshal, S., 2012, Enhanced biodegradation of petroleum hydrocarbon-contaminated clayey soil: the role of aggregate sizes and microstructures. Chemosphere 2013 Jun; 91(11):1620-6. DOI: 10.1016/j.chemosphere.2012.12.058. Epub 2013 Feb 28.
- **Chilima, J.**, Gunn, J., **Noble, B.F.** and **Patrick, R.** 2013 Institutional Considerations in Watershed-Scale Cumulative Effects Assessment Impact Assessment and Project Appraisal. *Special Issue on Governance*, 31(1): 74-84.
- **Chun, K.P., Wheater, H.S.** and Onof, C.J. 2013. Comparison of drought projections using two UK weather generators. *Hydrological Sciences Journal*, 58(2): 1-15. DOI: 10.1080/02626667.2012.754544.
- Chun, K.P., Wheater, H.S., Nazemi, A. and Khaliq, M.N. 2013. Precipitation downscaling in Canadian prairies using the LARS-WG and GLM approaches. *Canadian Journal of Water Resources*, 38(4): 1-22, DOI: 10.1080/07011784.2013.830368.
- Doering, J.A., **Giesy, J.P.**, Wiseman, S. and **Hecker, M.** 2013. Predicting the sensitivity of fishes to dioxin-like compounds: possible role of the aryl hydrocarbon receptor (AhR) ligand binding domain. *Environmental Science and Pollution Research*, 20(3): 1219-1224. DOI 10.1007/s11356-012-1203-7.
- Edmunds, W.M., Jayakumar, R., Mishra, A., Salih, A., Sorooshian, S., **Wheater, H.S.** and Logan, W. 2013. G-WADI the first decade. *Sciences in Cold and Arid Regions*, 5(1): 0001-0005.
- Ellis, C.R., **Pomeroy, J.W.** and Link, T.E. 2013. Modelling increases in snowmelt yield and desynchronization resulting from forest gap-thinning treatments in a northern mountain headwater basin. *Water Resources Research*, 49: 1-14. DOI: 10.1002/wrcr.20089.
- **Ferguson, G.** 2013. Subsurface Energy Footprints. *Environmental Research Letters,* 8: 014037 (6pp). Institute of Physics Publishing.
- Gallego-Gallegos, M., **Doig, L.E.**, Tse, J.J., **Pickering, I.J.**, and **Liber, K**. 2013. Bioavailability, Toxicity and Biotransformation of Selenium in Midge (*Chironomus dilutus*) Larvae Exposed via Water or Diet to Elemental Selenium Particles, Selenite, or Selenized Algae. *Environmental Science and Technology*, 47(1): 584-592. DOI: 10.1021/es300828r.
- **Gober, P.** 2013. Getting outside the water box: The need for new approaches to water planning and policy. *Water Resources Management*, 27(4): 955-957.
- **Gober, P.**, Larson, K., Quay, R., Polsky, C., Chang, H. and Shandas, V. 2013 Why land planners and water managers don't talk to one another and why they should! *Society and Natural Resources*, 26(3): 356-364.
- **Gober, P.** and **Wheater, H.S.** 2013. Socio-hydrology and the science-policy interface: A case study of the Saskatchewan River Basin. *Hydrology and Earth System Sciences Discussion Paper Series*, 10: 6669-6693. DOI:10.5194/hessd-10-6669-2013.
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- **Hassanzadeh, E., Nazemi, A.-R.** and **Elshorbagy, A.** 2013. Quantile-based Downscaling of Precipitation using Genetic Programming: Application to IDF Curves in the City of

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- **Lindenschmidt, K.E.** and **Chun, K.P.** 2013. Evaluating the impact of fluvial geomorphology on river ice cover formation based on a global sensitivity analysis of river ice model. *Canadian Journal of Civil Engineering*, 40(7): 623-632.
- **Lindenschmidt, K.E.** and **Chun, K.P.** 2013. Geospatial modelling to determine the behaviour of ice cover formation during river freeze-up. *Hydrology Research*, doi:10.2166/nh.2013.193.
- **Lindenschmidt, K.-E.** and Long, J. 2013. A GIS approach to define the hydro-geomorphological regime for instream flow requirements using geomorphic response units (GRU). *River Systems*, 20(23-4): 261-275, http://dx.doi.org/10.1127/1868-5749/2012/0053.
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- **Mahmood T.H.** and Vivoni E.R. 2013 Forest ecohydrological response to bimodal precipitation during contrasting winter to summer transitions. *Ecohydrology*, DOI: 10.1002/eco.1424.
- Maletz, S., Floehr, T., Beier, S., Klümper, C., Brouwer, A., Behnisch, P., Higley, E., **Giesy, J.P.**, **Hecker, M.**, Gebhardt, W., Linnemann, V., Pinnekamp, J. and Hollert, H. 2013. In vitro Characterization of the Effectiveness of Enhanced Sewage Treatment Processes to Eliminate Endocrine Activity of Hospital Effluents. *Water Research*, 47: 1545-1557. DOI: 10.1016/j.watres.2012.12.008.
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- McIntyre, N., Ballard, C., Bruen, M., Bulygina, N., Buytaert, W., Cluckie, I., Dunn, S., Ehret, U., Ewen, J., Gelfan, A., Hess, T., Hughes, D., Jackson, B., Kjeldsen, T., Merz, R., Park, J.-S., O'Connell, E., O'Donnell, G., Oudin, L., Todini, E., Wagener, T. and **Wheater, H.** 2013. Modelling the hydrological impacts of rural land use change. *Hydrology Research. DOI*: 10.2166/nh.2013.
- Miles, J.J., Eimers, M.C., **North, R.L.** and Dillon, P.J. 2013. Spatial distribution and temporal variability in the forms of phosphorus in the Beaver River subwatershed of Lake Simcoe, Ontario, Canada. Inland Waters, Special Issue on Lake Simcoe, 3: 179-186.
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#### **Journal Publications - 2012**

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# **APPENDIX 6 – Major Awards and Recognitions**

### **Student and Postdoctoral Awards**

- Shawn Beitel won the first place Best Student Poster Presentation at the 33rd Annual SETAC North America Meeting, Long Beach, USA, November 2012. S. Beitel, J. Doering, E. Higley, S. Patterson, H. Prodahl, and M. Hecker. Assessment of the species specific sensitivity of North American fishes to disruptors of steroidogenesis *in vitro*. Also, Shawn Beitel received the Saskatchewan Innovation and Opportunity Scholarship for 2012.
- A team of graduate students and postdoctoral fellows from GIWS won the AAFC's drought competition in March 2012 over teams from University of Alberta, University of Manitoba and University of Regina. The competition was held to test a new planning tool designed to prepare the Canadian Prairies for future extreme climate events like drought. The U of S drought team members were Jania Chilima, PhD student, SENS; Alana Debusschere, masters student, College of Agriculture and Bioresources; and postdoctoral fellows Merle Massie, Uri Nachshon and Sun Chun, SENS, and Ali Nazemi, College of Engineering. Andrew Ireson, Assistant Professor, SENS, participated as team coach.
- Kristin Bielefeld was awarded \$10,000 from the Alberta Conservation Association to study the effects of beaver activity on mercury bioaccumulation in Rocky Mountain streams.
- Jonathon Doering won the 2nd Place Poster Award at the 19th Life and Health Sciences Research Day Symposium, March 2012. Doering, J., S. Wiseman, S. Beitel, B. Tendler, J.P. Giesy, and M. Hecker. Tissue specificity of aryl hydrocarbon receptor (AhR) mediated responses and relative sensitivity of white sturgeon (Acipenser transmontanus) to an AhR agonist. In addition, Jonathon Doering won the 1st Place Platform Award at the 3rd Society of Toxicology and Chemistry Prairie Northern Chapter, June 2012. Doering, J., S. Wiseman, S. Beitel, J.P. Giesy, and M. Hecker. The aryl hydrocarbon receptor signaling pathway of white sturgeon: Implications for sturgeon sensitivity to dioxin-like compounds. Also, Jonathon Doering won the Student Poster Competition Award at Alberta Innovates Technology Futures for 2012. He received the prestigious NSERC

- Vanier Doctoral Fellowship for 2013-2016, and also received the Saskatchewan Innovation and Opportunity Scholarship for 2012 and 2013.
- Steven Mamet received a postdoctoral fellowship from the Garfield-Weston Foundation and Canadian Northern Studies Trust, 2013-2015.
- Chris Marsh won the Outstanding Student Paper Award at the American Geophysical Union (AGU) Fall Meeting 2012 in San Francisco. Marsh, C.B., J.W. Pomeroy, and R.J. Spiteri. Implications of mountain shading on calculating energy for snowmelt using unstructured triangular meshes, Hydrological Processes, 26(12), pp. 1767–1778, DOI: 10.1002/hyp.9329, URL: http://doi.wiley.com/10.1002/hyp.9329
- Sarah Patterson received an Honorable Mention for her poster presentation at the 39th Aquatic Toxicity Workshop in Sun Peaks, Canada, 2012. Patterson, S., Y. He, M. Hecker, J. Martin, M. El-Din and S. Wiseman. Toxicity of Untreated and Ozone-Treated Oil Sands Process Affected Water on Early Life States of the Fathead Minnow (Pimephales promelis).
- Saman Razavi, postdoctoral fellow, won the Editor's Choice Award for 2012 from the
  Water Resources Research Journal, which was presented to him during the AGU Fall
  meeting in December 2013. The award is given to top 1% of published articles to
  provide professional recognition to scientists and students for their outstanding work.
- Amber Tompsett won the 3rd Place Poster Award at the 3rd Society of Toxicology and Chemistry Prairie Northern Chapter, 2012.
- Fengchang Wu has won the 2nd Runner up Award for Best Paper of the Year in Environmental Science and Technology for 2012. Wu, F.-C. Y.-S., Mu, C. Hong, X Zhao, J.P. Giesy and K.B. Wu. 2013. Predicting Water Quality Criteria for Protecting Aquatic Life from Physico-chemical Properties of Metals. Environ. Sci. Technol. 2013, 47:446–453. DOI.org/10.1021/es303309h
- Jenna Zee was one of four winners of the poster competition at the U of S Aboriginal Symposium in 2013.

## **Member Awards and Recognitions**

- Dr. Lee Barbour was elected a Fellow of the Canadian Academy of Engineering (CAE) in 2013.
- Dr. John Giesy was the number one rated environmental scientist in Canada, based on the Hirsch Index Benchmarking of Academic Research (HI BAR). Globe and Mail, Report on Business Supplement page B7, Tuesday, March 27, 2012.
- Dr. John Giesy received the SCOPE-Zhongyu Environmental Sciences Life Achievements Award. This award, presented by The Scientific Committee on Problems of the Environment (SCOPE) and the Zhongyu Environmental Technologies Corporation recognizes a scientist or expert whose significant contributions have moved the

- frontiers of environmental science and technological innovation and environmental engineering.
- Four of Dr. Giesy's papers were in the top 100 papers published in *Envrionmental Toxicology and Chemistry* (SETAC) over the last 30 years. The rankings with number of citation in parentheses were: 4th (461), 23rd (225), 50th (160) and 53 (156).
- Dr. John Giesy was selected as fellow of the "High Tier Foreign Expert Program" Ministry of Education, China: Through Nanjing University, 2012-2013.
- In 2013, Dr. John Giesy received the Miroslaw Romanowski Medal from the Royal Society of Canada, the Society of Environmental Toxicology and Chemistry Capacity-Building Award, and the U of S J.W. George Ivany Internationalization Award.
- Dr. Patricia Gober received the prestigious Association of American Geographers
  Presidential Achievement Award in April, 2011 for her extraordinarily rich record of
  peer-reviewed publications in population, water resource management, and climate
  change, her creation and implementation of public fora for science-engaged decisionmaking, and her influential leadership in the discipline in service to society.
- Dr. Patricia Gober has been appointed to the Stockholm Water Prize Nomination Committee by the Royal Swedish Academy of Sciences for 2013-14.
- Dr. Paul Jones received the "Premiers Award for Collaboration Team Category" from the Premier of the Northwest Territories.
- Dr. Karsten Liber was the judge for the prestigious Toyota Earth Day Scholarship—Western Canada Region competition. This is a national award for high school students who have "demonstrated outstanding commitment to and involvement in community environmental issues, have exceptional academic achievement, a superior record of participation in volunteer and extracurricular activity at school and in the community, and demonstrated capacity for leadership."
- Dr. Jeffrey McDonnell was named a Fellow of the Geological Society of America.
- Dr. Jeffrey McDonnell was invited to give the Nannerl Keohane Distinguished Lecture, University of North Carolina Chapel Hill, NC, 2013.
- Dr. Jeffrey McDonnell was co-author of a paper published in *Nature* (Climate Change). A research vision for hydrology of the humid tropics: Balancing water, energy, and land use. *Nature* (Climate Change), 2: 655-662.
- Dr. Jeffrey McDonnell was appointed as the Distinguished Professor of Hydrology (Adjunct), Oregon State University, Corvallis, 2012.
- Dr. Jeffrey McDonnell was invited to give the Borland Lecture, Hydrology Days, Colorado State University, Fort Collins CO, 2012.
- Dr. Jeffrey McDonnell was recognized by John Wiley and Sons as the author having the highest sited paper in *Hydrological Processes*, 2012.
- Dr. Jeffrey McDonnell received the Environmental Protection Agency's (EPA) Scientific and Technological Achievement Award, 2011.

- Dr. John Pomeroy was named a Fellow of the American Geophysical Union, one of only three Canadians selected in 2013.
- Dr. Howard Wheater Chaired the Council of Canadian Academies Expert Panel on Sustainable Management of Water in Agriculture for Canada.
- Dr. Howard Wheater is appointed as the member of the Water Partners Advisory Committee which advises the Council of the Federation Water Stewardship Council (WSC).

# **APPENDIX 7 – International Collaborations**

### Asia

Internationally, GIWS is developing a wide range of partnerships and proposals. One significant ongoing study led by the Imperial College London, addresses salinity in the Bangladesh Delta and its impacts on the health of 20 million people. The study is co-led by Drs. Andrew Ireson and Howard Wheater from GIWS. In addition, in Bangladesh and parts of India, naturally-occurring arsenic in the drinking water is causing what has been termed "the world's worst mass poisoning." At the lowest estimate, 57 million people are affected. Drs. Ingrid Pickering and Graham George and their international collaborators are using synchrotron light to uncover the mechanism and come-up with a possible solution. They are currently pursuing further field trials in Bangladesh.

Dr. Tim Jardine is collaborating with the National University of Singapore to better understand biological interactions in urban reservoirs. This project was recently awarded \$2.6 million SGD (\$2.1 million CAD) by the Singapore Public Utilities Board with the aim of improving biodiversity conservation and water quality management. Similarly, Dr. Jill Johnstone has active research and collaborations in the area of boreal forest ecology in Northern China with Jian Yang, Scientist, Institute of Applied Ecology, Chinese Academy of Sciences, Shenyang, China.

Dr. Jeffrey McDonnell is working in collaboration with Dr. Keith Beven, Lancaster University on a watershed tracer project in China. Together, they are working with the Nanjing Hydraulic Research Institute to dose a small manmade watershed just outside of Nanjing with a cocktail of tracers.

As part of ongoing research collaborations, Dr. Markus Hecker delivered a short course on Ecotoxicology and Risk Assessment at the Xiamen University and a summer course in Environmental Toxicology at the Nanjing University, China.

Dr. Karsten Liber has established and executed a research partnership with Shanxi University, Taiyuan, Shanxi, P.R. China to assist with the assessment of heavily contaminated river systems in Shanxi Province, and pursuing opportunities for graduate student exchanges between Shanxi University and the U of S.

### Australia

Dr. Tim Jardine continued his collaborative research with the Australian Rivers Institute during a research/field work visit in August 2012 to Kakadu National Park, NT, Australia. This is part of an AUD \$16 million project (funded by the Australia's National Environmental Research Program) aimed at improving biodiversity conservation in northern Australia. In addition, Dr. Helen Baulch hosted visiting PhD student Chrystal Mantyka-Pringle from the University of Queensland, School of Geography, Planning and Environmental Management who studied interactions between climate change and land-use change, and their interacting effects on freshwater biodiversity.

GIWS members are collaborating with Dr. Tony Jakeman, Deputy Director, Centre of Excellence in Groundwater Research, Australian National University in designing, developing, and implementing models that integrate hydrology, agriculture, ecology, water resources, economics, and social behaviour. The group also collaborated with Dr. Matthias Bernhardt, Ludwig-Maximilians Universität München; Dr. Martyn Clark, National Center for Atmospheric Research; Stuart Davies, Harvard University; Richard Essery, University of Edinburgh; Eugenie Euskirchen, University of Alaska Fairbanks; Hoshin Gupta, University of Arizona; Richard Janowicz, Yukon Department of Environment; Dennis Lettenmaier, University of Washington; Xin Li, Chinese Academy of Sciences; Timothy Link, University of Idaho; Danny Marks, USDA Agricultural Research Service; Neil McIntyre, Imperial College London; Roy Rasmussen, National Center for Atmospheric Research; Jean Emmanuel Sicart, L'Institut de recherché pour le développement; and Thorsten Wagener, University of Bristol on integration of climate and land-surface process observations and modelling in the region of the Saskatchewan and the MacKenzie River Basins as part of the CCRN.

Dr. Jeffrey McDonnell is also involved with two projects sponsored by the Australian Research Council on agricultural systems in Southern Australia near Melbourne, which has direct relevance to water and nutrients and runoff generation work conducted at Tobacco Creek, Manitoba. In addition, Chris Gabrielli, one of his PhD students, is conducting research at the Maimai catchment in New Zealand.

#### Europe

As a MESPOM (Erasmus Mundus funded Master's program in Environmental Science and Policy) scholar, Dr. Markus Hecker cooperated with the Central European University in Budapest (Hungary) and the University of the Aegean in Mytinlene (Greece). He initiated a joint research project with Dr. O. Kalantzi at the University of the Aegean to assess water quality in streams in Greece and also contributed to MESPOM course on Mytinlene and interacted with prospective graduate students. In addition, he participated in the UROP (undergraduate research opportunity program) with the Rheinisch-Westfaelische Technische Hochschule Aachen University and University of Heidelberg in Germany and hosted a total of 8 students in 2012 and 2013.

Dr. Jeffrey McDonnell also has research collaborations with the University of Aberdeen at two sites in the Scottish Highlands. One of Dr. McDonnell's PhD students, Jay Frentress is conducting his field research on near-stream controls on water chemistry in a series of experimental watersheds in Luxembourg in Central Europe.

#### North America

Currently, GIWS is assisting the Canada/USA International Joint Commission's water quality modelling work aimed at addressing major eutrophication of Lake Winnipeg, Manitoba, Canada.

Until his move to Saskatoon in 2012, Dr. Jeffrey McDonnell was the Richardson Chair in Watershed Science and University Distinguished Professor of Hydrology at Oregon State University. He also has a forestry-based project funded by the US Forest Service and US Department of Energy at the Savannah River Site in South Carolina, examining cellulosic biofuel production impacts on water quality and quantity.

Dr. Angela Bedard-Haughn spent her recent sabbatical as a visiting scientist to the Pacific Agri-Food Research Centre (Agriculture and Agri-Food Canada) in Summerland, British Columbia, Canada and at University of California – Davis, USA. In both locations, the emphasis of her research was on using digital soil mapping techniques to predict the distribution of hydric soils in the hummocky prairie landscape, to facilitate scaling (down and up). Dr. Angela Bedard-Haughn also served as an Expert Reviewer for the 2012 and 2013 Supplements to the Intergovernmental Panel on Climate Change (IPCC) Guidelines on National Greenhouse Gas Inventories: Wetlands, IPCC Task Force on National Greenhouse Gas Inventories.

### South America

In order to further our international agenda, GIWS is pursuing joint research projects involving HQP training and exchange. Consequently, the institute (Dr. Jeffrey McDonnell is the lead applicant) and its partner in Brazil (Federal University of Rio de Janeiro) has successfully secured funding from the Canadian and Brazilian Federal governments to facilitate the exchange of eight doctoral students. Four students from Brazil will examine the impact of land-use change on water quantity and quality in headwater catchments in the Rocky Mountains (cold region) in Canada and similarly, four students from GIWS will examine headwater regions upstream of the Rio de Janeiro, Brazil in the mountains west of the city (tropical climate). In addition, the Department of Foreign Affairs and International Trades (DFAIT) Canada has approved two graduate student exchange scholarships through their Emerging Leaders of Americas Program (ELAP) to support visits of students from Chile who will study "Evaluation of vulnerability in a context of uncertainty and climate change in semi-arid and Mediterranean watersheds" and "Use of stable isotopes for assessing the contribution of glacier melting to runoff in Andean basins." Through these projects, we envision developing a mechanism to share research expertise and information, exchange research personnel, share research facilities, build a history of collaborations and develop joint research publications. In addition, Dr. Jeffrey

McDonnell has begun a project in Chile with colleagues from Austral University in Valdivia to examine forest impacts on water resources.

In addition, Dr. Karsten Liber established a formal academic and research partnership with the Faculty of Sciences and Philosophy at Universidad Peruana Cayetano Heredia (UPCH; Lima, Peru) to promote bilateral graduate student exchange opportunities and collaborative research related to water quality, environmental pollution and natural resource extraction.

Also, Dr. Karsten Liber collaborated with Universidad Nacional de Ancash Santiago "Antúnez de Mayolo" (Huaraz, Peru) on Development of Sustainable Monitoring and Bioremediation Alternatives for the Santa River. A special undergraduate-level course offered in compressed format over a 4-day period (through the Faculty of Environmental Science). The course was designed to introduce environmental science and environmental engineering students to principles and methodologies in environmental monitoring and impact assessment, with a focus on water, mining activities and tailings management.

