Centre for Water Resources Management

Fifth Annual Brace Research Day
March 23 2006, 9:30-17:00
Raymond Building, Room R2-046
Macdonald Campus / McGill University

2006 Brace Research Day – Abstracts of Presentations

Phosphorus Removal Efficiencies in a Pilot Scale Wetland Treating Agricultural Runoff

Peter Enright, Anne-Caroline Kroeger, Chandra Madrammootoo & Christina La Flamme
Brace Centre for Water Resources Management & Bioresource Engineering Dept.
McGill University, Macdonald Campus

Constructed wetlands have been used extensively to treat waste waters from a variety of point sources in industrial, municipal and agricultural settings. Currently, there is interest in using constructed wetland systems to treat agricultural non-point source pollution, particularly in the Missisquoi Bay watershed. In recent years, the Missisquoi Bay has experienced outbreaks of cyanobacteria (blue-green algae). Given that phosphorus is a key cause of toxic algae blooms and that the dominant source of P loading into the bay is agricultural non-point source pollution, there is a particular need to assess how efficient constructed wetlands are at reducing P concentrations and loads.

A pilot scale wetland (0.12 ha) was constructed during the fall of 2002 in the Mystic sector of Saint Ignadce de Stanbridge, and was monitored from May to November, 2003, 2004 and 2005, to assess sediment and nutrient removal efficiencies. The wetland consists of a sedimentation basin (76 m^2), a horizontal subsurface flow section (369 m^2) and an open water body (1215 m^2). Flow into and through the system is gravity controlled. A gate control structure allows for variable inflow rates, and flow rates are monitored using composite V-notch weirs located at the outlet of each section. A combination of grab and automated sampling are used to obtain samples at least once per week at each of the sampling points: in stream, in the intake control structure, and at the outlets of the sedimentation basin, submerged flow section and open water body.

The average flow rate in the wetland system was 4.83 l/s (0.01 to 35.8) in 2003, 4.42 l/s (0.11 -31.7) in 2004 and 5.22 l/s (0.0 to 46.0) in 2005. For 2003, the mean annual TP (Total phosphorus) concentration decreased from 125 to 84 µg/l (-33%). For 2004, the concentrations were reduced from 69 to 42 µg/l (-40%), and for 2005, reductions were from 71 µg/l to 51 µg/l (-28%). Annual reductions in the TP loads in the wetland were -33.6%, -42.8%, and -37 % for 2003, 2004 and 2005, respectively. Seasonal treatment efficiencies, the evolution of the treatment efficiencies over time, and the influence of hydrologic conditions on system performance are discussed in the presentation.

Modeling Surface and Subsurface Nitrogen Transport in an Agricultural Watershed

Shadi Dayyani, *Bioresource Engineering*

Abstract

Agricultural non-point source pollution (NPS) has been recognized as a major threat to water quality in many countries around the world. Many efforts have been made to reduce agricultural NPS pollution; however, many watersheds continue to experience this problem. Comprehensive management plans are required for these watersheds to deal with both quality and quantity issues. Non-point source pollution originates at the field scale but usually water quality problems occur at the watershed scale. This research project is designed to improve our understanding of the processes contributing to non-point source pollution from agricultural activities on a watershed scale. An integrated approach is taken to model surface and subsurface nitrogen transport on a watershed scale through a combination of DRAINMOD-N II with MIKE SHE model, and a regional GIS. The linked model will be evaluated for the St. Esprit Watershed, located approximately 50 km northeast of Montreal. Once this is validated, different alternatives and beneficial management practices, to reduce the risk of water contamination, will be examined.

Measuring tillage translocation and erosion by tillage implements common to intensive potato production systems of Atlantic Canada

Kevin Tiessen, McGill University; Guy Mehuys, McGill University; David Lobb, University of Manitoba; Herb Rees, AAFC Fredericton; Edward McKyes, McGill University

In Canada, tillage erosion is increasingly being recognized as a serious form of soil degradation in cultivated landscapes. However, to date, tillage erosion experiments have only been conducted on conventionally tilled corn-based production systems in Ontario. The objective of this project is to generate tillage translocation and erosivity values for implements common to conventionally and conservation tilled potato production systems in Atlantic Canada. Both systems require numerous tillage operations: primary fall tillage (mouldboard (MP) vs. chisel plough (CP)), secondary spring tillage (offset disc (OD) vs. vibrashank (VS)), and "tertiary" tillage operations (i.e. planting, cultivating and hilling (PCH) and harvesting (HARV)). Preliminary analysis of our data suggests that each primary, secondary and tertiary tillage operation moves vast quantities of soil and is potentially erosive. All six tillage operations moved small quantities of tracer at least 3 m, with the greatest translocated distances observed for the PCH sequence (≈ 24m) and for the CP, VS and HARV (≈ 6m). For the primary and secondary implements, the mass of translocated soil (T_M) was greatest for the CP, followed by the MP, VS and OD. In addition, the T_M for the PCH sequence and HARV were equal to, or larger than, the T_M of the primary or secondary implements. A direct relationship was observed between T_M and slope gradient for the CP, MP, OD and PCH sequence. Overall, the potential for tillage erosion (β) was greatest for the PCH sequence and HARV (4.2 and 3.4 kg/m/% slope respectively), followed by the MP, CP and OD (≈ 2.0 kg/m/% slope), and finally the VS (0.20 kg/m/% slope). The effect of slope gradient and slope curvature on tillage translocation will be further examined in order to predict rates of tillage erosion across the landscape for a full sequence of conventionally and conservation tilled potatoes.

A Decision Support System for Phosphorus Management at the Field and Small Watershed Scale

Baldur Bujatzeck[1] and Chandra Madramootoo[2]

Surfaces water is an abundant natural source in Quebec, covering about 10 % of the province. After extensive pollution until the seventies, the overall quality of river water in the province has improved greatly improved over the last 30 years. Those improvements are mainly due to an effective point source management. Due to the fact that phosphorous from non point sources still enters the water bodies eutrophication is still an issue in the southern part of the province,.

To address this problem, decision support systems (DSS) was developed. The DSS consists of a screening component, a land use management evaluation component (LUMPE), a non-point source pollution modelling component, and a decision support component including a phosphorus reduction assessment, a cost/benefit and a trade off routine.

With respect to phosphorus losses, the system will allow the identification of critical source areas in small watersheds using the P Index model, diagnose possible causes, and provide recommendations of appropriate best management practises (BMP) at the field scale. It will create different scenarios and the environmental effects will be simulated using AnnAGNPS. The results for different scenarios will be analyzed toward meeting existing or recommended reduction goals. Furthermore, basic cost analyzes are undertaken to examine the net benefits for each scenario looking at it from different angles (e.g. agricultural, environmental).

Since the management of the rural landscape is not a process that can't be seen as a single-sector oriented productive entity anymore, a trade off analysis routine was incorporated using Wymorian standard scoring functions to account for different stakeholder preferences.

1 *Ph.D. Student, Department of Bioresource Engineering, Macdonald Campus of McGill University, Montreal, QC, Canada, E-mail: baldur.bujatzeck@elf.mcgill.ca*

2 *Dean, Faculty of Agricultural and Environmental Sciences and Professor, Bioresource Engineering Department, Macdonald Campus of McGill University, Ste. Anne de Bellevue, QC, Canada,E-mail: chandra.madramootoo@mcgill.ca*

MODELING MICROORGANISM TRANSPORT IN RIVERBANK FILTRATION SYSTEMS

Laura Mesones, *Bioresource Engineering*

Disproportioned growth of population, agricultural practices, and industrialization, has led to the contamination of fresh water resources around the world. Microbial contamination of water continues to be a major problem, specifically the pathogenic protozoa, Cryptosporidium, due to its resistance to traditional water treatment methods, including chlorine disinfection.

Riverbank filtration (RBF) is a cost-effective system that employs natural or induced transport of water from the river, through the soil, into the wells, situated near the river banks. They improve water quality through three different methods, i.e. physical, chemical, and biological processes, thus resulting in color and odor enhancement, turbidity control, organic contaminant reduction, and microorganism removal. Several studies have found RBF to be very effective in removing Cryptosporidium.

There is a need to develop mathematical models that can simulate water quantity and quality parameters in a RBF system. In particular, the roles played by the distance of the well from the river, soil properties, pumping rates and pumping schedules, river water quality, and water quality in the well need to be investigated.

In this study, we are using MODFLOW, a 3-D saturated water flow model, along with, RT3DMS, a multi-species reactive solute transport model. The coupled models will be used to evaluate the efficacy of an RBF system in removing Cryptosporidium oocysts from the river water under a given set of hydrologic, geologic, and biologic conditions.

ADAPTING TO CLIMATE CHANGE IN THE WATER RESOURCES SECTOR

Bano Mehdi
C-CIARN Water Resources, McGill University, 21 111 Lakeshore, Ste-Anne-de-Bellevue, Qc, H9X 3V9,
bano.mehdi@mcgill.ca

Abstract
Climate change and variation is starting to emerge as an issue of concern for planners and decision-makers. As such, steps are being taken to plan for and to anticipate the changes that may be brought about in the water resources sector. The presentation will present a synopsis of the research and case studies related to agriculture that highlighted how to move forward towards adapting to climate variability and change.

Adaptations success stories include, water table management being researched in Quebec, and computer models that are being used for irrigation water management in Alberta, and untapped sources of irrigation water that are being looked into in Saskatchewan. In Ontario, conflict resolution is being addressed by setting up farmer driven water management committees.

Overall in Canada, actual adaptation work is few and far between. However, part of this may be because data collection and monitoring remains seriously limited. On the positive side, past and current events, such as droughts and floods may be triggering solutions or ideas that can help water managers adapt to upcoming changes.

Net Ecosystem CO_2 Exchange from a Cattail Marsh in Eastern Ontario, Canada.

Marie-Claude Bonneville[1]

[1] Dept. of Natural Resource Sciences, McGill University, Macdonald Campus, Montreal, Quebec, H9X 3V9. Phone: 514-398-7950 Fax: 514-398-7990
Email: marie-claude.bonneville@mail.mcgill.ca

Many physical, chemical and biological conditions contribute to making most wetlands net sinks for carbon dioxide (CO_2) and sources for methane (CH_4), two important greenhouse gases. However, the carbon balance of different wetland types largely depends on the interactions of interdependent controlling factors, which are specific to every wetland ecosystem. Most studies on wetland gas exchange have focused on organic wetlands (peatlands). The purpose of the present study is to investigate the net ecosystem CO_2 exchange (NEE) from a mineral wetland (cattail marsh), which is characterized by distinctive hydrological, vegetative and substrate conditions compared to most bogs and fens.

The cattail marsh is the end product of a series of land-use changes involving agriculture and road construction, but has been left to natural succession for the last 40 years. Since May 2005, NEE has been measured using the eddy covariance technique. The marsh switched from a net source to a net sink of CO_2 in mid-June. Peak CO_2 uptake was reached in mid-August, and switched back to a net CO_2 source in beginning of October as the cattails started to die off. Preliminary analyses show that the marsh wetland was a net source of carbon to the atmosphere in May, October, November, December, and January (0.86, 1.21, 0.57, 0.15, and 0.19 g C m^{-2} d^{-1}, respectively), almost neutral in June (0.03 g C m^{-2} d^{-1}), and a net carbon sink in July, August, and September (-4.68, -4.10, and -1.82 g C m^{-2} d^{-1}, respectively). Cattails started to grow at the end of May and were fully senesced by mid-October. Peak aboveground biomass (average of 1156 g m^{-2}) and peak green LAI (average of 3.63) were reached in mid-August. Growing season CO_2 fluxes are well correlated with live biomass (r^2=0.83) and green LAI (r^2=0.95).

STATISTICAL DOWNSCALING OF PRECIPITATION USING NCEP PREDICTORS AT A LOCAL SITE IN QUEBEC

SIDDHARTH PHARASI
Department of Environmental Engineering, McGill University

Climate change will have important impacts on the hydrologic cycle at different temporal and spatial scales. The temporal scales could vary from a very short time interval of 5 minutes (for urban water cycle) to a yearly time scale (for annual water balance computation). The spatial resolutions could be from a few square kilometers (for urban watersheds) to several thousand square kilometers (for large river basins). General Circulation Models (GCMs) have been recognized to be able to represent reasonably well the main features of the global distribution of basic climate parameters, but outputs from these models are usually at resolution that is too coarse (generally greater than 200km) for many impact studies. Hence, there is a great need to develop tools for downscaling GCM predictions of climate change to regional and local or station scales. In recent years, different downscaling methods have been proposed. Of particular importance for hydrological impact studies are those procedures dealing with the linkage of the large-scale climate variability to the historical observations of the daily precipitation process at a local site. If this linkage could be established, then the projected change of climate conditions given by a GCM could be used to predict the resulting change of the local precipitation characteristics. The required linkage can be developed using a wide range of downscaling methods.Two broad categories of downscaling procedures currently exist: dynamical downscaling (DD), based on the modeling of regional climate dynamical processes, and statistical downscaling (SD) methods that relied on the empirical relationships between observed (or analyzed) large-scale atmospheric variables and observed surface environment parameters. In particular, it has been widely recognized that SD methods offer several practical advantages over DD procedures, especially in terms of flexible adaptation to specific study purposes, and inexpensive computing resource requirements. However, several different SD techniques currently exist, but there is no general agreement regarding the choice of the best method. Hence, it is necessary to test different SD methods in order to find the most suitable approach for a particular region of interest.This paper presents therefore a critical assessment of several regression-based SD methods that have been widely used for constructing climate change scenarios for daily precipitations at local sites using GCM grid point information The selected SD techniques include the popular Statistical Downscaling Model (SDSM), the stepwise regression, the weighted least square regression, and the principal component regression. These SD methods were evaluated using the large-scale NCEP re-analysis atmospheric data and the historical daily precipitations available at Dorval Airport station in Quebec (Canada) for the period from 1961 to 1990, of which the first 15 years were used for models' calibration and the remaining 15 years for models' validation. The performance of the selected methods was examined by comparing the statistics of observed data time series to those of 100 simulated time sequences. On the basis of this comparison, the strength and weaknesses of these SD methods are identified and discussed in this presentation.

Irrigation Scheduling as an Adaptation Measure for the Ontario Fruit Industry to Climate Change

Doria, R., Madramootoo, C. A., and Mehdi, B. B.
Bioresource Engineering

The objective of this study was to build and test a soil water model that will assist growers to estimate and predict crop water requirements, and their corresponding irrigation needs, in order to develop water management strategies that reduce risks associated with projected future climatic and hydrologic conditions.

Local effects of global warming are difficult to predict with General Circulation Models (GCMs) since they encompass large land areas. However, statistical downscaling of these model outputs can be used to simulate the climate for a specific local area. A Statistical Downscaling Model (SDSM 3.1) was used in conjunction with historical temperature and precipitation data to develop possible climate change scenarios for two fruit producing regions in Southern Ontario (Niagara Peninsula and the Lake Erie North Shore). The resulting climate scenarios were input in the CROPWAT model to estimate the crop water requirements.

Proper irrigation scheduling is required to optimize water use, however, very often water for irrigation use is limited and this situation may be exacerbated under a warmer climate. A soil moisture monitoring probe monitoring (capacitance probe) was installed at four experimental producer field sites to provide a complete picture of the soil-water dynamics throughout the rooting depths (up to 30 cm for grapes, up to 60 cm for peaches) during the entire growing season. This information, together with the crop data and management practices of the producers constituted the input set for the CROPWAT, from which an irrigation schedule can be determined.

The presentation will provide an overview of the statistically downscaled climate data and the real time soil moisture data combined with the simulation and predictive capabilities of CROPWAT to come up with irrigation schedules for the two regions.

Immunogenicity of a *Giardia lamblia* transmission-blocking DNA vaccine delivered by *Salmonella typhimurium* (STM1 strain) to the intestinal mucosal immune system.

Aws Abdul-Wahid, *Institute of Parasitology*

The process of encystation is a key step in the *Giardia lamblia* life cycle which allows for survival between hosts during person-to-person, animal-to-person, waterborne, or foodborne transmission. The release of cysts from infected persons and animals is the main contributing contamination factor of the environment. Hence, designing a vaccine against the cyst stage can interfere with parasite transmission and reduce the level of environmental contamination.

In this study, we investigated the use of *S. typhimurium* for the purpose of delivering a transmission-blocking DNA vaccine to the intestinal immune system. The *cwp2* gene, encoding the full length CWP2 protein (Pro-CWP2), was subcloned into the pCDNA3 mammalian expression vector (Pro-CWP2 / pCDNA3) and introduced into *S. typhimurium* (STM1 strain). Eight to twelve weeks-old female BALB/c mice (*n*=8) were immunized every 2 weeks, for a total of 3 immunizations each delivering 10 ng of DNA. Vaccinated and control mice were sacrificed one week following the last injection.

Analysis of the cellular responses invoked by the immunization demonstrated the development of a strong lympho-proliferation reaction following stimulation of leukocytes with rPro-CWP2 *in vitro*. Using IL-4 and IFN-γ cytokine ELISPOT, the Th phenotype of the Pro-CWP2-specific immune response was found to be a mixed Th1/Th2 response.

Using ELISA, antigen-specific IgA and IgG antibodies were detected in intestinal secretions. Moreover, analysis of sera demonstrated that the immunization stimulated the production of specific IgG antibodies that were mainly of the IgG2a isotype. These results demonstrate the immunogenicity of Pro-CWP2 administered in the context of a *Salmonella*-delivered DNA vaccine, as well as its ability in stimulating both the systemic and mucosal immune systems.

Spatio-temporal distribution of potential aquifer recharge in the Basin of Mexico.

Jamie Carrera, *Civil Engineering and Applied Mechanics*

The Basin of Mexico, home to Mexico City and its Metropolitan Area (MCMA) depends heavily on its aquifer system for water supply to its nearly 20 million inhabitants. Despite the fact that groundwater represents near 80% of the total water supply in the Basin, there are no studies that have attempted to analyze the spatio-temporal variation of aquifer recharge in this region, as well as the impact that land cover change has had on both its quantity and quality. To overcome this problem, the present work analyzed the spatio temporal variation of aquifer recharge through a one dimensional soil budget undertaken at a daily time step using the FAO-56 method along with ancillary and remotely sensed imagery. In order to undertake this analysis, all relevant information was processed and stored in the Valley of Mexico Hydrogeological Database (VMHDB) (Carrera-Hernández and Gaskin, in review), which was used to develop a three dimensional groundwater flow model through the Groundwater Modelling Tool for GRASS (GMTG) (Carrera-Hernández and Gaskin, 2005). This work shows a general framework to estimate aquifer recharge for regional studies using the Basin of Mexico as a case study.

References

Carrera-Hernández, J. J. and Gaskin, S. J. (2006). The Groundwater Modelling Tool for GRASS (GMTG): Open source groundwater flow modeling. Computers & Geosciences. 32:339-351

Carrera-Hernández, J. J. and Gaskin, S. J. (In review). The Valley of Mexico Hydrogeological Database (VMHDB): Implementation and basic queries. Submitted to Hydrogeology Journal.

Statistical Downscaling of Daily Temperature Extremes by Regression Methods

Qinglan Li, *Civil Engineering and Applied Mechanics*

Climate change will have important impacts on the hydrologic cycle at different temporal and spatial scales. The temporal scales could vary from a very short time interval of 5 minutes (for urban water cycle) to a yearly time scale (for annual water balance computation). The spatial resolutions could be from a few square kilometers (for urban watersheds) to several thousand square kilometers (for large river basins). General Circulation Models (GCMs) have been recognized to be able to represent reasonably well the main features of the global distribution of basic climate parameters, but outputs from these models are usually at resolution that is too coarse (generally greater than 200km) for many impact studies. Hence, there is a great need to develop tools for downscaling GCM predictions of climate change to regional and local or station scales. In recent years, different downscaling methods have been proposed. Of particular importance for hydrological impact studies are those procedures dealing with the linkage of the large-scale climate variability to the historical observations of the daily extreme temperature processes at a local site. If this linkage could be established, then the projected change of climate conditions given by a GCM could be used to predict the resulting change of the local temperature characteristics. The required linkage can be developed using a wide range of downscaling methods.

Two broad categories of downscaling procedures currently exist: dynamical downscaling (DD), based on the modeling of regional climate dynamical processes, and statistical downscaling (SD) methods that relied on the empirical relationships between observed (or analyzed) large-scale atmospheric variables and observed surface environment parameters. In particular, it has been widely recognized that SD methods offer several practical advantages over DD procedures, especially in terms of flexible adaptation to specific study purposes, and inexpensive computing resource requirements. However, several different SD techniques currently exist, but there is no general agreement regarding the choice of the best method. Hence, it is necessary to test different SD methods in order to find the most suitable approach for a particular region of interest.

This paper presents therefore a critical assessment of several regression-based SD methods that have been widely used for constructing climate change scenarios for daily temperature extremes at a local site using GCM grid point information The selected SD techniques include the popular Statistical Downscaling Model (SDSM), the stepwise linear regression, and the robust linear regression. These SD methods were evaluated using the large-scale NCEP re-analysis atmospheric data and the historical daily minimum and maximum temperatures available at Dorval Airport station in Quebec (Canada) for the period from 1961 to 1990, of which the first 15 years were used for models' calibration and the remaining 15 years for models' validation. The performance of the selected methods was examined by comparing the statistics of observed data time series to those of 100 simulated time sequences. On the basis of this comparison, the strength and weaknesses of these SD methods are identified and discussed in the present paper.

Expression of a *Giardia lamblia* Cyst Wall Protein in *Lactococccus lactis*

Peter Lee, *Institute of Parasitology*

In this study, we are reporting, for the first time, on the expression of a protein originating from an early diverging eukaryote, *Giardia lamblia*, in a food-grade bacterium. *L. lactis* was engineered to express *G. lamblia* cyst wall protein 2 (CWP2), at three different sub-cellular locations. Using 10 ng/ml nisin as an inducing agent, CWP2 was expressed intracellularly, secreted, or cell surface anchored. In addition, CWP2 expression does not appear to be detrimental to *L. lactis* viability. No particular sub-cellular location of CWP2 expression offers any advantages over the others with respect to decreased toxicity towards the bacteria. All recombinant lactococci experienced a similar reduction in growth rate when induced..

Flexibility of *L. lactis* to express CWP2 at multiple cellular locations has important implications for vaccine design since the immune system may respond differently depending on how the antigen is presented to antigen presenting cells. Since we are primarily interested in the cell surface expression form of CWP2 for vaccine development, we determined whether recombinant lactococci engineered for cell surface expression of CWP2 was capable of inducing a CWP2 specific mucosal IgA and IgG antibody response. We are reporting that recombinant lactococci expressing CWP2 on the cell surface were successful at inducing CWP2 specific mucosal IgA antibodies. Moreover, in a preliminary challenge experiment, mice immunized with the recombinant lactococci demonstrated a significant 63% reduction in cyst output. The highlights of this study are: the expression of a protein from an early diverting eukaryote, and confirming the potential of *L. lactis* as a delivery vehicle to the intestinal mucosal site.

Solving World Sustainable and Urban Issues through Better Rural Economy

Bijaya Adhikari, Bioresource Engineering

Abstract

Growing urbanization across the world exerts both financial and environmental pressures on municipal waste management system. Furthermore, most large world cities are situated on the bank of major river systems. Directly or indirectly, waste produced in the urban centers enters those river systems as a result of poor management. Consequently, controlled and uncontrolled waste management systems affect both terrestrial and aquatic ecosystems. The landfilling of municipal solid wastes leads to several environmental problems such as the formation of leachate contaminating water and land resources and the emission of greenhouse gases leading to even more earth warming trends. On the other hand, uncollected waste may accumulate on the streets and clog drains when it rains, which may cause flooding and wastes can also be carried away by run off water to rivers, lakes and seas, and affecting those ecosystems.

Economic activity is considered one of the key factors governing the growth of the percentage of population living in urban as opposed to rural areas, and determining the production of municipal solid waste (MSW). Because of high economic growth rate, Asia is expected to experience the largest increase in urban waste production. From 1995 to 2025, food waste disposed in landfills will potentiality increase world CH_4 emissions from 27 to 48 million tons and the landfill share of global anthropogenic emissions from 8 to 10%. Therefore, urban waste management should be considered seriously and the current planning should reflect a will to deal this looming problem. Encouraging people to stay in rural areas can be considered as a sustainable approach to deal with this complex urban waste issue.