Teleconference and Webinar Information Meeting Hosted by the International Joint Commission (IJC)

Ottawa, Canada
(May 20, 2015)

Presentation by the University of Guelph and Greenland® Group About the CANWET Model

CANWET Presentation Team

- **Hussein A. Abdullah, Ph.D., P.Eng., Director of Engineering, University of Guelph**

- **Bill Van Heyst Ph.D., P.Eng., Associate Director of Engineering, University of Guelph**

- **Ed McBean Ph.D., P.Eng., Canada Research Chair in Water Supply Security, College of Physical & Engineering Science (CPES), University of Guelph**

- **R. Mark Palmer, P. Eng., President / CEO - Greenland Group**
- **Trevor Boston, M. Eng., Associate – Greenland Group**
- **Barry Evans, Ph.D., Penn State University & Stroud Research Center**
- **Murray Maracle Sr., Director - Stragis Environmental (Greenland Group)**

Overview of the University of Guelph and the College of Physical & Engineering Science (CPES)

- **Hussein A. Abdullah, Ph.D., P.Eng.,**
  Director of Engineering, University of Guelph
  (Via Telephone)

School of Engineering
Re-construction Opening
(March 2014)

UNIVERSITY of GUELPH

Greenland® Group - Mission Statement

Through the dedication of multi-disciplinary teams of reputable professionals, the **Greenland® Group** provides integrated professional engineering and landscape architecture services. We strive to offer excellence in our niche disciplines and provide exceptional service in developing new environmental technologies, while also maintaining the integrity of our services for the Public, First Nations, Business Community, our Clients and Employees.

Since 1994, the Greenland® Group has been committed to developing ***innovative solutions*** with a ***conservationist ethic*** that respects the **environment** from the outset **and incorporates best available science, open data, and defendable technologies to address climate change concerns (and opportunities).**

GREENLAND® consulting engineers

Urban Watershed Group

STRAGIS Environmental Services Inc.

Greenland technologies group

SECURITY AND SOURCE PROTECTION

▲ Continued from page 29

Prof. Ramesh Rudra is tailoring computer watershed models to Ontario conditions.

Water-source protection is taken seriously by environmental guardians such as the Lake Simcoe Region Conservation Authority. The authority uses a watershed model called the Canadian Nutrient and Water Evaluation Tool (CANWET). This model weighs economic costs and benefits, considers options based on social acceptability and then recommends the best management practices. These practices can sometimes be complicated, but they can also be as simple as planting a strip of vegetation beside a riverbank to prevent erosion along waterways. The Guelph Watershed Research Group has been involved in enhancing CANWET for application in Ontario conditions.

Distributed by Ontario-based Greenland International Consulting Engineers, CANWET is moving towards a user-friendly web-based service that could be used nationwide. Greenland International is staffed largely by University of Guelph alumni and hopes to incorporate the Guelph engineers' recommendations into their models.

Models such as CANWET aren't used just by conservation authorities, says Rudra. Governments use these models to make development plans such as Ontario's "Places to Grow" initiative, which encourages development in areas where the impact on source water will be minimal. By improving the suitability of these models, he and his colleagues in the Guelph Watershed Research Group will be improving the ability of water planners to protect water consumers from source to tap.

Funding for this research has been provided by the Ontario Ministry of Agriculture, Food and Rural Affairs; the Ontario Ministry of the Environment; the Ontario Ministry of Natural Resources; the Greenland International Group of Companies; and Ontario conservation authorities.

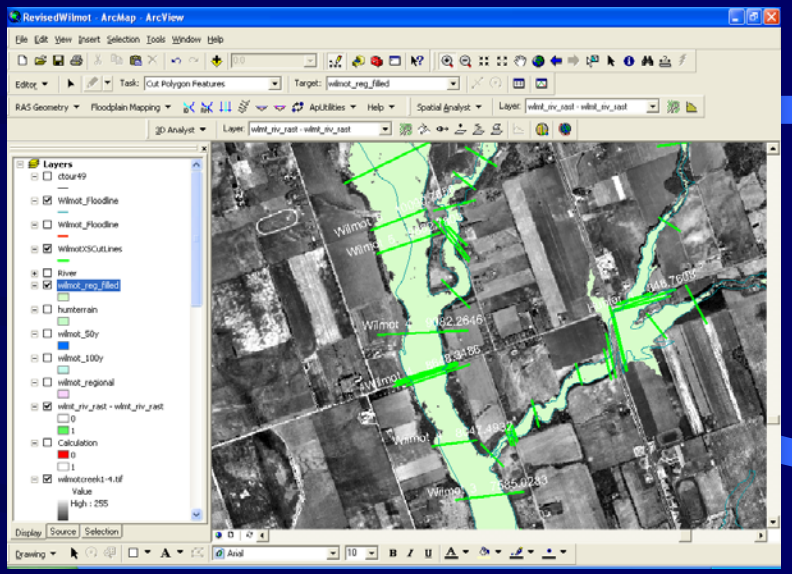
More information about the Guelph Watershed Research Group can be found at www.soe.uoguelph.ca/webfiles/watershed/Guelphwatershed.htm

University of Guelph Partnership (Since 2003)

Watershed Science Software Tools and Training *(Since 1994)*

Environment Canada Software

CANWET™ CANadian Watershed Evaluation Tool



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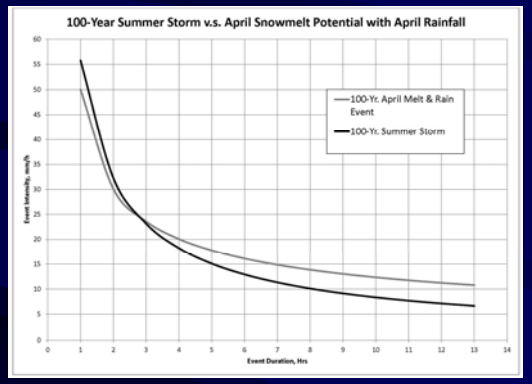

WATERSHEDatlas

Greenland International Consulting
ISWMS
Integrated Stormwater and Watershed Management System
Windows 95/98
Version 1.0.0

GREENLAND Group of Companies

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THE PENNSYLVANIA STATE UNIVERSITY 1855

University of Waterloo

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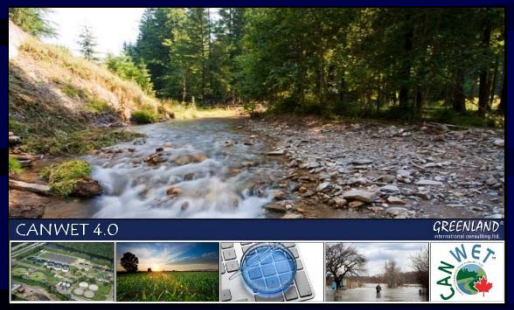
COMMUNITECH

CANadian Watershed Evaluation Tool (CANWET)



CANWET is an open source GIS and integrated water budget, nutrient and contaminant transport plus climate change impact decision support system. Since 2004, it has been used for Assimilative Capacity Studies; Master Drainage Plans; TMDL and Other Nutrient Management Studies; Source Water Protection Studies; and, Municipal Infrastructure Planning, Design and Environmental Assessment Projects.

Over the past 5 years, the "Best Available Practices (BMP)" analytical tool built into **CANWET- 4** (originally called PRedICT and part-of CANWET's U.S. model "cousin" called **MapShed**) has been used in Southern Ontario to estimate the reduction in nutrient, pathogen and sediment loadings associated with a variety of watershed practices. CANWET- 4 has been used to develop subwatershed offsetting targets and implementation programs involving Ontario CAs, Municipalities and other partners.

Version '5' (with a web interface) has now been completed in partnership with the University of Waterloo and COMAP.

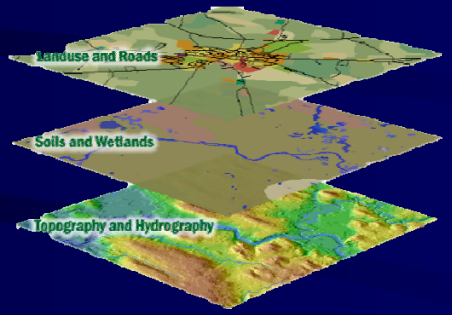
comap.ca

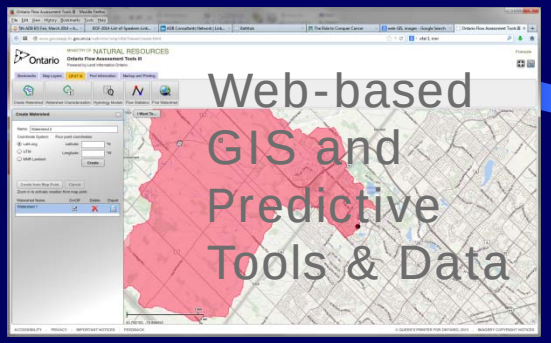
Evolution of Watershed Decision Support Systems

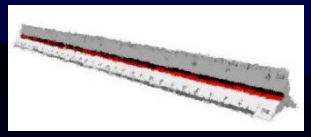
Since 2013

Intelligence Information Age

Integrated GIS and Geo-processing that incorporates best-available science







Mobile Devices and Sharing

1980-90's

Since 2000

Information Technology Age

University of Guelph
CANWET Science (Since 2003)

Evaluation, Enhancement, and Improvement of CANWET Model (Annual Progress Report)

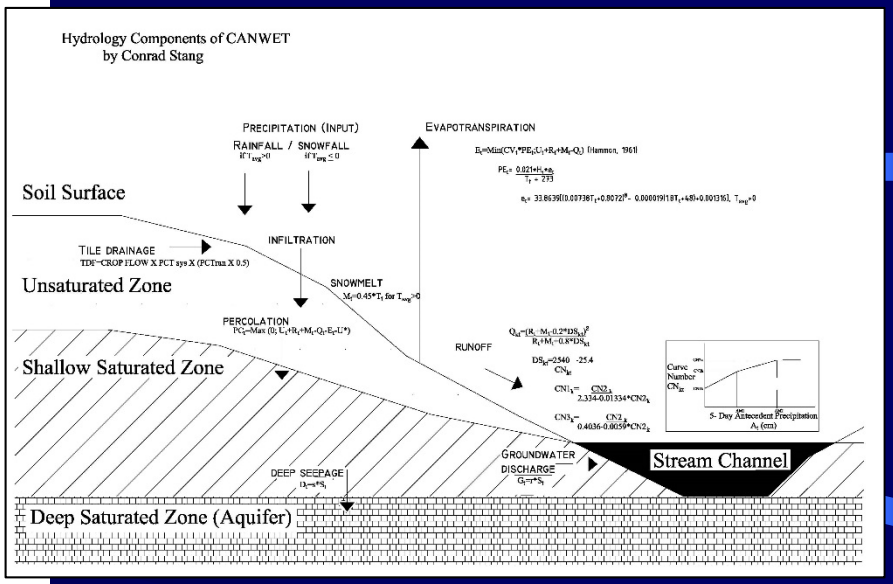
Prepared for

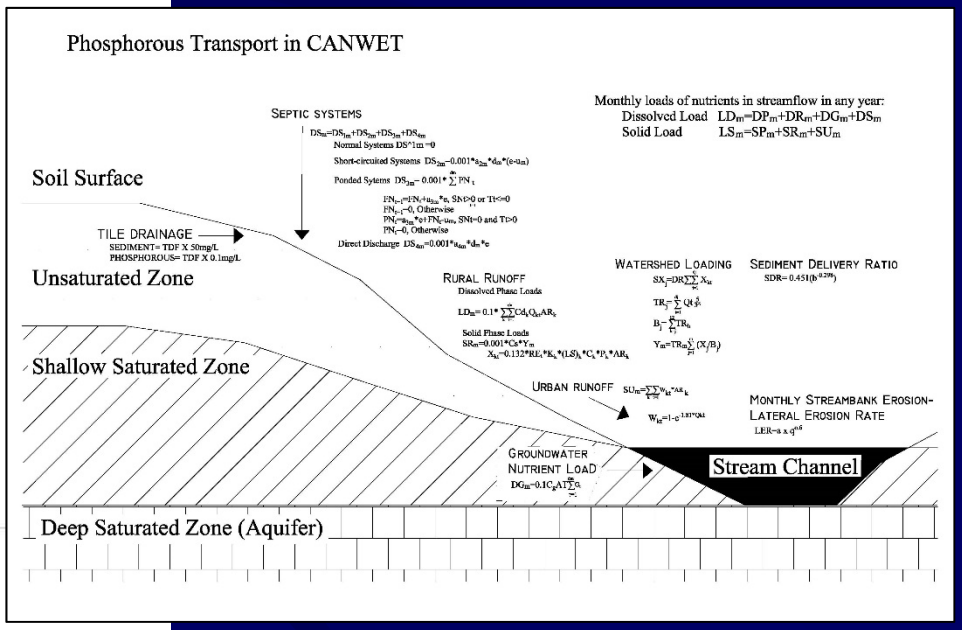
Greenland International Consulting Ltd.

Prepared by

Dr. R. P. Rudra
Dr. B. Gharabaghi
Dr. S. Das
Dr. A. Singh
Ms. Sarah Watts

July 31, 2006





Comparison of CANWET and HSPF for Hydrological and Water quality Assessment under Southern Ontario Conditions

ABSTRACT

Sediment impairs water quality and transports other pollutants and it is by far one of the greatest non-point source (NPS) pollutants in rural environments. The main objective of this study was to evaluate hydrology and sediment yield from upper Canagagigue Creek watershed in southern Ontario, by using two models [Hydrological Simulation Program Fortran (HSPF), and Canadian ArcView Nutrient and Water Evaluation Tool (CANWET)]. Both models were calibrated, validated, and applied to the watershed. Modeling results showed that BASINS/HSPF and CANWET models have capabilities to simulate various hydrological processes at watershed scale. A comparison of simulated stream flow, surface runoff, subsurface runoff, evapotranspiration, and sediment yield to their corresponding observed values showed similar trends. Overall, both the models predicted the water budget components accurately on annual and seasonal basis. Also, stream flow comparison between observed and simulated values from HSPF and CANWET showed Nash-E of 0.80 and 0.72, respectively on seasonal basis. When averaged over the nine-year study period, monthly analysis of the observed and simulated stream flow data revealed Nash-E of 0.88 and 0.94 for HSPF and CANWET, respectively. However, lack of long-term observed data on watershed scale are needed to simulate these models for longer durations and future scenarios.

Key words: water pollution, sediment, modeling, best management practices

INTRODUCTION

Since last few years researchers have attempted to address the problem of non-point source pollution by combining the relationships between land management practices and water quality degradation. The Source Water Protection Act has been passed by Ontario Ministry of Environment (MOE) and received the royal assent for implementation in Ontario, Canada (MOE, 2006). The conservation authorities and other government agencies are currently involved in assessment of drinking water sources and water budget at field and watershed scale. Two systems, the surface water system and groundwater system, are being worked upon and different tools researched for quantifying elements of both the systems individually and in integration.

Due to the complexity of the soil-water processes, one of the strategies to protect the natural water resources is to understand and manage these processes on a watershed basis. A better understanding of the environmental conditions and hydrological processes of a watershed such as climate, topography, management practices, and water balance is the first step in protecting the water and other natural resources of the area. Specifically, there is also a need of understanding of spring hydrology and snowmelt dynamics to develop effective techniques for treating surface and subsurface runoff in Ontario.

AGRICULTURAL BEST MANAGEMENT PRACTICES AND THEIR EFFECTS ON SEDIMENT TRANSPORT CURVES FOR IMPROVED WATERSHED HEALTH

by

Conrad Stang

A Thesis
presented to
The University of Guelph

In partial fulfillment of requirements
for the degree of
Master of Applied Science
in
Engineering

Guelph, Ontario, Canada

A Model Evaluation and Modification Strategy

R.P. Rudra, A. Singh, S. Das, S.I. Ahmed, B. Gharabaghi & W.T. Dickinson
School of Engineering, University of Guelph, Guelph, Ontario, Canada

Abstract: *Watershed models have been used as management tools for an ever increasing array of water resource issues such as source water protection and non-point source pollution management. This paper outlines a strategy that has been adopted for the evaluation and improvement of watershed models. The strategy involves model calibration for annual, seasonal, monthly, and daily flows, and includes careful consideration of the rapid and slow response components for each flow variable. This evaluation step clarifies how well or poorly a model captures the most significant hydrologic processes and flow paths in the watershed for the time period under consideration. It also helps to flag algorithms requiring modification for reliable use of the model. An example implementation of the strategy is presented and discussed.*

Keywords: Hydrologic model, model evaluation, model modification, water budget.

Introduction

Land use changes due to deforestation, agricultural intensification, and urban development have resulted changes in watershed hydrologic regimes. With these alterations water-transported pollutants are increasingly identified in the water bodies, and agricultural activities have been identified as one of the prime sources of pollution in the Canadian Great Lakes basin (Hartt, 2000). To ensure sustainable water quality, the Ontario province has enforced source water protection and nutrient management acts. Modeling approaches have being proposed to assess the water budget at watershed level and then relate it to the pollutant movement. The modelling approaches are becoming more popular due to fast and relatively inexpensive results, and availability of digitized soil, land use, and topographic information in form of GIS layers. However, application of modeling approaches has also created challenge for the model developers and model users to address issues related to their portability from the regions, where developed, to the regions to be applied, which may have entirely different hydrologic regimes.

The common practices for evaluating hydrologic models include calibration and validation using statistical techniques to ensure realistic results. These approaches have been applied for the comparison and evaluation of models (Pathak et al., 1984; Loague and Freeze 1985; Binger et al., 1985; Amatya et al., 1997; Legates and McCabe 1999; Van Liew et al., 2003; and Krause et al., 2005). Kraus et al. (2005) investigated the use of coefficient of determination, Nash-Sutcliffe efficiency, Nash-Sutcliffe efficiency with logarithmic values and index of agreement in various forms to obtain information about the magnitude of systematic and dynamic errors present in the simulation results. Overall conclusion was that none of the efficiency criteria described and tested performed ideally. Each of the criterion had specific pros and cons which require careful attention during model evaluation. Legates and McCabe (1999) while investigating some useful goodness-of-fit measures concluded that correlation and correlation-based procedures should not be used to assess the performance of hydrologic or hydroclimatic models and suggested additional evaluation measures to supplement model evaluation tools. Martinec and Rango (1989) compared

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APPLICATION OF CANWET AND HSPF FOR TMDL EVALUATION UNDER SOUTHERN ONTARIO CONDITIONS

Amanjot Singh[1], R P Rudra[1], I Ahmed[1], S Das[1], B Gharabaghi[1], and P K Goel[2]
[1]School of Engineering, University of Guelph, Canada. [2]Ontario Ministry of Environment, Canada.

Abstract: The CANWET (Canadian ArcView Nutrient and Water Evaluation Tool) and HSPF (Hydrologic Simulation Program – FORTRAN) models were applied to Upper Canagagigue Creek watershed of the Grand River basin in southern Ontario, Canada, for hydrology and sediment evaluations. Both the models have similarity in structure where CANWET is simpler, both in algorithms and use, than HSPF. The outputs of both the models for water budgeting components were compared on annual, seasonal, and monthly basis. The water budget components, evapotranspiration, surface runoff, and subsurface runoff produced by both the models were comparable on annual and seasonal time steps, however, there were some discrepancies in monthly and daily simulations. The seasonal, monthly, and daily Nash-Sutcliffe efficiency coefficients with observed stream flows were 0.85, 0.81, and 0.68 for HSPF, respectively, and 0.90, 0.87, and 0.71 for CANWET, respectively. The monthly and daily simulations by HSPF model were better since HSPF algorithm has more control on temporal variation to parameters sensitive for hydrologic simulations. The sediment simulations by both the models were consistently close for erosion and sediment yield on annual basis. However, supervisory to predictions for total suspended sediment yield of one model over the other could not be concluded because of lack of observed data. The daily load of sediment modeled by HSPF followed flow peaks and available observed sediment data points.

Keywords: HSPF, CANWET, Watershed modelling, Source Water Protection.

INTRODUCTION

The Source Water Protection Act has been passed by Ontario Ministry of Environment (MOE) and received the royal assent for implementation in Ontario, Canada (MOE, 2006). The conservation authorities and other government agencies are currently involved in assessment phase of drinking water sources and their focus is on assessing water budget at watershed scale. Two systems, the surface water system and groundwater system, are being worked upon and different tools researched for quantifying elements of both the systems individually and in integration. The surface water budgeting demands that how well the components of surface water system, evapotranspiration, surface runoff, interflow, baseflow, and deep percolation, can be simulated to get an understanding of the hydrology of an area. The MOE has described the components of water budget that play a key role in source water protection and suggests to follow watershed based approach for evaluation of these components (MOE, 2006). The MOE guidelines also suggest number of available watershed modeling tools which could be implemented based upon their suitability for the area of application. The two models, Hydrologic Simulation Program – FORTRAN (HSPF) (Bicknell et al., 2001) and Canadian ArcView Nutrient and Water Evaluation Tool (CANWET) (Anonymous, 2008) were selected for comparison and suitability of use for watersheds in southern Ontario. Both the models operate under different complexities and are currently being used by various agencies and consultants in Ontario to address source water protection objectives.

The CANWET model is the Canadian version of Generalized Watershed Loading Function model (GWLF) developed at Cornell University, NY, USA by Haith et al. (1992). The model uses the concept of USEP in simplified form (Haith, 2006) and also uses land use based approach for hydrologic simulations but with limited parameters, which makes the model application simple. The CANWET/GWLF models have been widely used for hydrology and non-point source pollution simulations from watersheds (Shrestha et al, 2006; Stedinon et al., 2005). Similarly, the HSPF model has also been extensively used for hydrological and total maximum daily load (TMDL) modeling (Singh et al., 2005; Al-Abed and Whiteley, 2002). The HSPF model is more comprehensive compared to CANWET, involves large number of variables, and uses complex approaches in simulating watershed hydrology and pollutants. A theoretical comparison of number of watershed models including HSPF and GWLF was done by Borah and Bera (2003). Now with the availability of models with varied complexities in use and approach, question arises that how much complexity do we need for water budgeting and total maximum daily load (TMDL) assessment? Therefore, the presented study was conducted with the objectives to compare the components of the two models for water budgeting and sediment simulation. The evaluation will give users a feeling of the strengths and weakness of the two models.

Example 'U of G' Published CANWET Manuscripts

CANWET's "U.S. Cousin"

PENNSTATE

MapShed

MapShed Overview
MapShed Downloads
MapShed Registration
Report a Bug

As of August 2011, the AVGWLF watershed modeling software that has been available since 1999 (including GWLF-E and PRedICT) will no longer be supported. It is being replaced by MapShed, which essentially duplicates the functionality of AVGWLF within a non-commercial GIS software environment called MapWindow. Both the MapWindow software, as well as the customized interface and related modeling tools associated with MapShed, are available for download via this site. As described elsewhere, the core watershed model (GWLF) has also been considerably enhanced to provide additional capabilities not included in the older version of the model used in AVGWLF.

psiee penn state institutes of energy & the environment

If you have any questions about **MapShed**, please contact one of the following individuals:

For general distribution, use questions, or technical support issues contact contact:

Dr. Barry M. Evans
Director: GIS Support Center
Penn State Institutes of the Environment
The Pennsylvania State University
128 Land and Water Research Building
University Park, PA 16802
(814) 865-3357

For program installation questions or errors, or technical support issues contact:

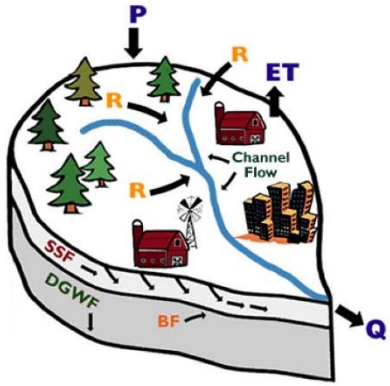
Kenneth J. Corradini
Penn State Institutes of the Environment
The Pennsylvania State University
1 Land and Water Research Building
University Park, PA 16802
(014) 865-6966

MapShed
VERSION 1.1

USERS GUIDE

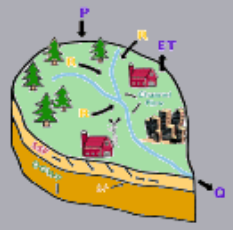
Barry M. Evans and Kenneth J. Corradini

Penn State Institutes of Energy and the Environment
The Pennsylvania State University
University Park, PA 16802



April 2012
(Updated June 2014)

ArcView GWLF Interface for Windows
Version 3.2



Created by
David W. Lehning
Barry M. Evans

PENNSTATE

http://www.avgwlf.psu.edu/

RedICT

PRedICT

Pollution Reduction Impact Comparison Tool

Version 1.0

Create Scenario | View Output

- (•) Mean Annual Load Analysis
- ( ) Flow-Based Load Analysis

Exit PRedICT

PENNSTATE Environmental Resources Research Institute

Greenland International Consulting Ltd.

Canadian
ArcView
Nutrient and
Water
Evaluation
Tool

CANWET

Windows
Version 1.0

GREENLAND

INNOVATIONS IN WATER MANAGEMENT

Conservation ONTARIO
Natural Champions

Nutrient Management Pilot Project

Summary Report

THE CONSERVATION AUTHORITIES OF ONTARIO

AUSABLE BAYFIELD • CATARAQUI REGION • CATFISH CREEK • CENTRAL LAKE ONTARIO • CREDIT VALLEY
CROWE VALLEY • ESSEX REGION • GANARASKA REGION • GRAND RIVER • GREY SAUBLE • HALTON REGION
HAMILTON REGION • KAWARTHA REGION • KETTLE CREEK • LAKEHEAD REGION • LAKE SIMCOE
LONG POINT REGION • LOWER THAMES VALLEY • LOWER TRENT VALLEY • MAITLAND VALLEY • MATTAGAMI REGION
MISSISSIPPI VALLEY • NIAGARA PENINSULA • NICKEL DISTRICT • NORTH BAY MATTAWA • NOTTAWASAGA VALLEY
OTONABEE REGION • QUITE CONSERVATION • RAISIN RIVER • RIDEAU VALLEY • SAUGEEN VALLEY
AULT STE. MARIE REGION • SOUTH NATION • ST. CLAIR REGION • TORONTO REGION • UPPER THAMES RIVER

PROJECT PARTNERS

Conservation ONTARIO · Ontario · Lake Simcoe Region Conservation Authority · Nottawasaga Valley Conservation Authority · Kawartha Conservation

This guide was made possible by the **Government of Ontario** and **Conservation Ontario** in partnership with the **Lake Simcoe Region Conservation Authority**, **Nottawasaga Valley Conservation Authority**, and the **Kawartha Conservation**

LAKE SIMCOE REGION CONSERVATION AUTHORITY · NOTTAWASAGA VALLEY CONSERVATION AUTHORITY · KAWARTHA CONSERVATION

The Project at a Glance...

Resource management agencies need to comprehend the complex inter-relationship between environmental health, local economy, and social conditions. The application of computer models has been widely accepted as the standard tool used by resource managers to predict the change in water quality associated with human activities and altered landscapes.

The *Nutrient Management Pilot Project Summary Report* and *CANWET Users Guide* describe the use of a leading edge initiative for modeling surface water budgets and nutrient loading.

In 2003, the Lake Simcoe Region Conservation Authority (LSRCA) retained Greenland International Consulting Ltd. to develop a surface water quality model for the management of nutrients, sediments and other contaminants in Ontario watersheds. The first phase involved the selection of an appropriate computer model that could be adapted for Southern Ontario conditions to:

- accurately determine the concentration of sediments and nutrients resulting from point and non-point source pollutants within a watershed, and
- predict potential reductions from the implementation of Best Management Practices (BMPs).

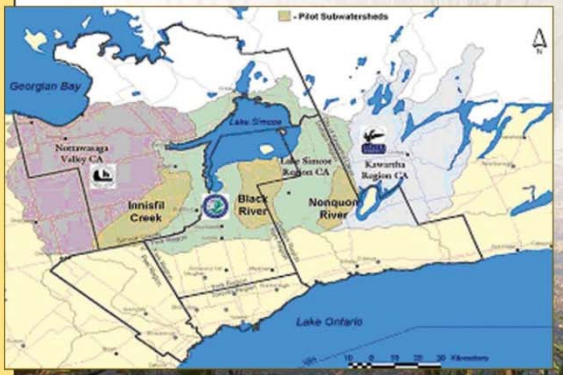
CANWET Model

The pilot project was completed using the first Canadian version of a modeling tool known as CANWET - **C**anadian **A**rcView **N**utrient and **W**ater **E**valuation **T**ool - based on the ArcView Generalized Watershed Loading Function (AVGWLF) model developed at Penn State University. CANWET incorporates modules for assessing nutrient and sediment loading and water balance within a GIS environment, and features a predictive modeling component for evaluating the implementation of both agricultural and non-agricultural pollution reduction strategies.

The model was pilot-tested in three Subwatersheds in southern Ontario with mixed urban/rural land uses, water use needs, and headwaters in the Oak Ridges Moraine: Innisfil Creek, Nonquon and Black Rivers.

The CANWET software is designed to assist the user to:

- Identify priority areas for restoration and remediation efforts;
- Calculate nutrient loading from rural areas within a subwatershed to the receiving waters;
- Evaluate the effectiveness of various watershed management practices; and
- Evaluate the impacts of future development and/or land use scenarios with respect to loading of nutrients to receiving waters.



Greenland International Consulting Ltd.

Canadian ArcView Nutrient and Water Evaluation Tool

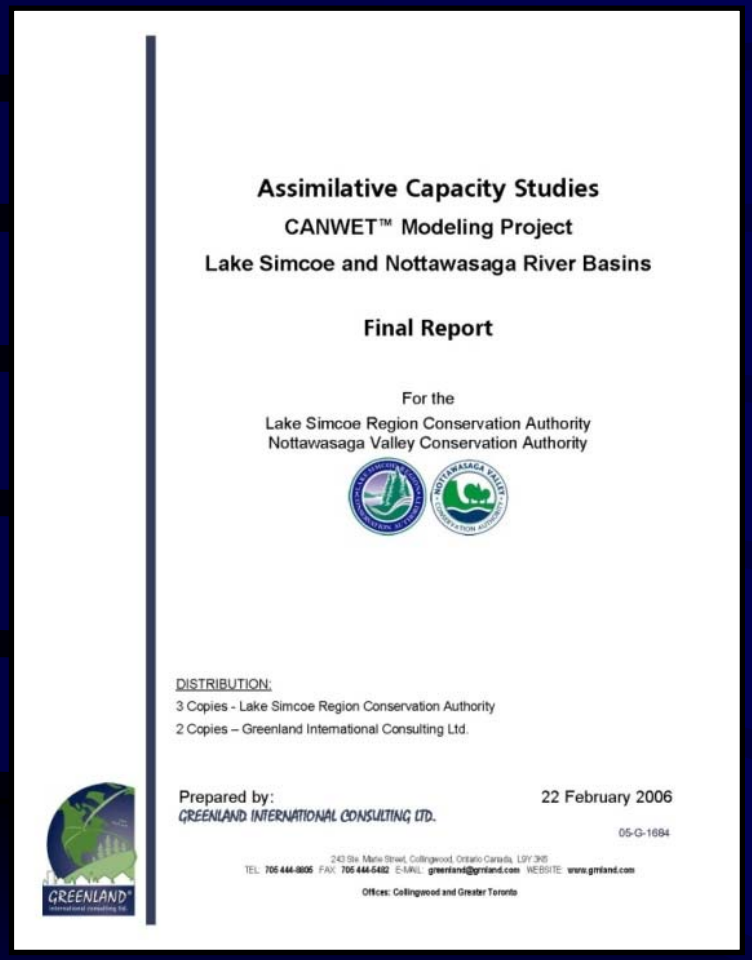
CANWET

Windows Version 1.0

Copyright

GREENLAND

CANWET Version '1' (2004)



Assimilative Capacity Studies

CANWET™ Modeling Project

Lake Simcoe and Nottawasaga River Basins

Final Report

For the
Lake Simcoe Region Conservation Authority
Nottawasaga Valley Conservation Authority

DISTRIBUTION:
3 Copies - Lake Simcoe Region Conservation Authority
2 Copies – Greenland International Consulting Ltd.

Prepared by:
GREENLAND INTERNATIONAL CONSULTING LTD.

22 February 2006

05-G-1684

243 Ste. Marie Street, Collingwood, Ontario Canada, L9Y 3K6
TEL: 705 444-8805 FAX: 705 444-5402 E-MAIL: greenland@grnland.com WEBSITE: www.grnland.com

Offices: Collingwood and Greater Toronto

CANWET Version '2' (2006)

Tel: 905 -895-1281
1-800-465-0437
Fax: 905-853-5881
E-Mail: info@lsrca.on.ca
Web: www.lsrca.on.ca

120 Bayview Parkway
Box 282
Newmarket, Ontario
L3Y 4X1

A Watershed For Life

Conservation ONTARIO
Natural Champions

July 27th , 2006

Mr. Mark Palmer, President
Greenland International Consulting Ltd.
243 Ste. Marie Street
Collingwood, ON L9Y 3K6

Dear Mr. Palmer:

Re: Completion of the Assimilative Capacity Study

On behalf of the Lake Simcoe Region Conservation Authority (LSRCA) I would personally like to thank you for your significant contribution to the Assimilative Capacity Study (ACS). The completion ACS represents a significant milestone in developing the tools and targets required to ensure the long-term sustainable management and protection of the Lake Simcoe and Nottawasaga River basins.

Your participation in and dedication to completing the ACS is appreciated. You will be pleased to know that the Province has provided the LSRCA formal acceptance of the submitted reports and project deliverables and as such the final reports will be made available on the public ACS website in the immediate future. With the formal Provincial acceptance of the deliverables the LSRCA will be able to release any outstanding holdbacks and formally conclude the terms of the Professional Services Agreement.

Once again I thank you for participation and effort in make the Assimilative Capacity Study a successful undertaking.

Yours truly,

D. Gayle Wood, CMM III
Chief Administrative Officer

CANWET Version '3'

WATER RESOURCES

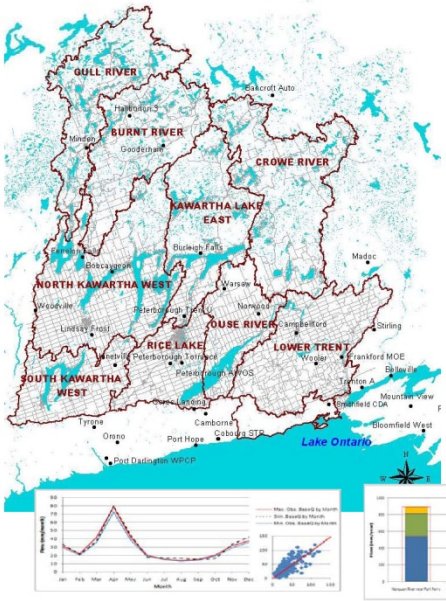
Source Water Protection

Water Budget and Stress Assessment Modeling

Client: Trent Conservation Coalition (TCC), Ontario

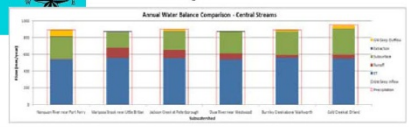
The Trent Conservation Coalition needed to develop a detailed water budget and stress assessment in order to better manage water within the Trent River system, Bay of Quinte and a portion of the Lake Ontario basin. The water budget was to be used in determining vulnerable areas susceptible to future water shortage. The project brought together data and information from a large number of sources collected over many years to develop a continuous hydrologic model, with groundwater consideration, capable of quantifying watershed processes and assisting in future decision support.

Greenland International Consulting Ltd. and XCG Consultants Ltd. were contracted to develop sub-watershed water balances and carry out a water stress assessment for a 15,000 km^2 drainage area. This was accomplished using CANWET™ v.3 with an array of spatial data layers and temporal databases. Sub-watersheds were delineated using topographic data and stream networks. Continuous water balance models were setup, calibrated and validated to represent all inputs and outputs into each sub-system and the larger system.



This process involved:

- quantifying the impacts of vertical and lateral groundwater flows across catchment boundaries due to complex geological formations
- working with limited or incomplete data
- estimating evapotranspiration on a monthly time step from land, lake and reservoir sources
- accounting for agricultural and municipal water takings and other human impacts
- accounting for more that 100 hydraulic control structures and dams within the river system
- determining areas with potential for water quantity stress
- evaluating future conditions and likely stresses in the watershed due to human development and climate change



Greenland International Consulting Ltd.

DRINKING WATER SOURCE PROTECTION
ACT FOR CLEAN WATER

TRENT CONSERVATION COALITION
SOURCE PROTECTION REGION

To Whom it May Concern:

Greenland was retained by the Trent Conservation Coalition (TCC) – Source Protection Region to undertake a water budget and water quantity stress assessment using the CANWET v.3 software package developed by Greenland. A model of the Trent River Basin was developed and calibrated using CANWET v.3. Subsequent to the completion of this project, the technical staff from the TCC – member conservation authorities received training on the use of the software and the Trent River Basin model.

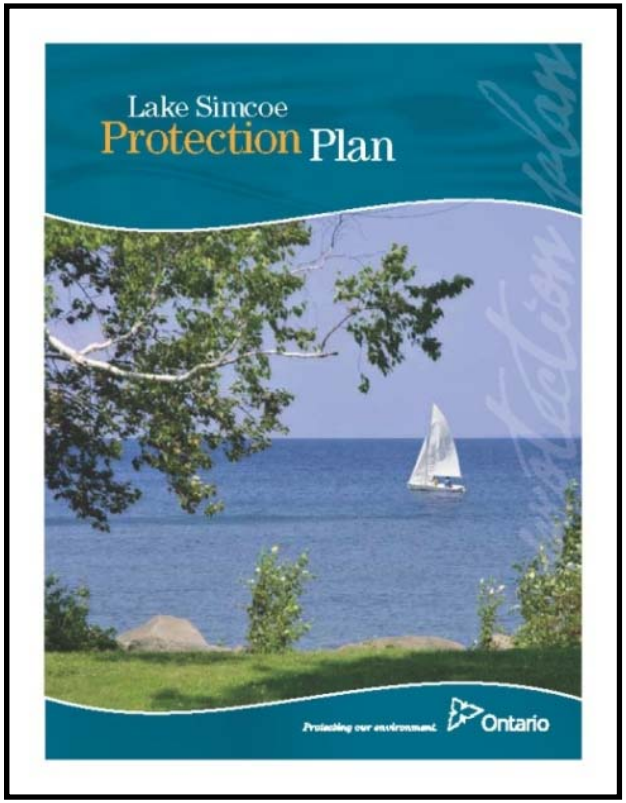
Since then, Kawartha Region Conservation Authority – a conservation authority within the TCC coalition, has used this software and the Trent River model to investigate phosphorus issues within the Scugog sub-watershed. Furthermore, the datasets that are provided with the Trent River Basin model is being used by TCC to pre-screen areas to identify the presence of activities that are likely to generate significant amount of nutrients and source materials, as prescribed by the Province's "Clean Water Act (2006)" and associated "Assessment Report: Technical Rules (2008)".

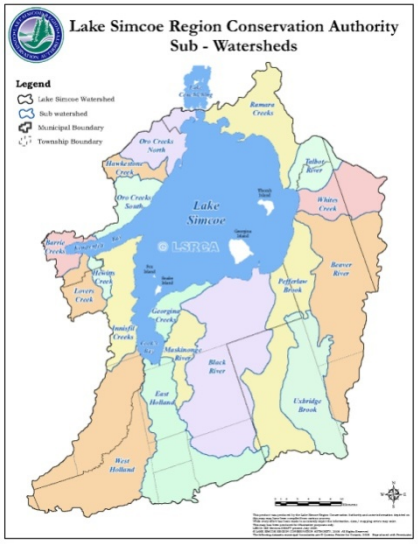
We are pleased with the performance of the CANWET v.3 software and supportive of the upcoming CANWET v.4 software and its utility for our source protection region.

Sincerely,

Shan Mugalingam PhD, P.Eng.
Engineer, Water Resources & Spatial Information Systems
Drinking Water Source Protection
Trent Conservation Coalition Source Protection Region
Phone: 613-394-3915 (x.247)
Fax: 613-394-5226
URL: http://www.trentsourceprotection.on.ca/

Lower Trent Conservation
714 Murray Street, R. R. #1
Trenton, ON K8V 5P4





CANWET (V.3) Used by Ontario To Help Prepare the Award-winning *'Lake Simcoe Protection Plan"*

Tel: 905•895•1281
1•800•465•0437
Fax: 905•853•5881
E-Mail: info@lsrca.on.ca
Web: www.lsrca.on.ca

120 Bayview Parkway
Box 282
Newmarket, Ontario
L3Y 4X1

February 26, 2010

R. Mark Palmer, P.Eng.
President
Greenland Consulting Engineers
120 Hume Street
Collingwood, ON L9Y 1V5

Dear Mr. Palmer:

Re: CANWET™ Model and Application

Please accept this letter as the Lake Simcoe Region Conservation Authority's endorsement of the CANWET™ (v.3) model. The Conservation Authority is extremely satisfied with the model's performance and accuracy and supports the continued use of this product in our watershed and others.

CANWET™ was initially developed and tested to deal with nutrient loading issues within the Lake Simcoe basin. Since this time the model has become an invaluable tool in the development of growth plans, as was demonstrated in the Lake Simcoe and Nottawassaga River Assimilative Capacity studies to support the Inter Governmental Action Plan (IGAP) process within Simcoe County. The model has also been extensively used and tested as part of the Lake Simcoe Basin's Source Water Protection program to develop Tier 1 water budgets and, most recently, the development and implementation of the provincial Lake Simcoe Protection Plan (LSPP). The tool has allowed the Authority to develop water quality and quantity targets at a sub-catchment level and is being evaluated for use under a Phosphorus Trading program being considered by the Ministry of the Environment.

Please do not hesitate to contact me should you require any further information or assistance.

Sincerely,

Michael Walters, CMM III
General Manager, Watershed Management

MW/lmc

A

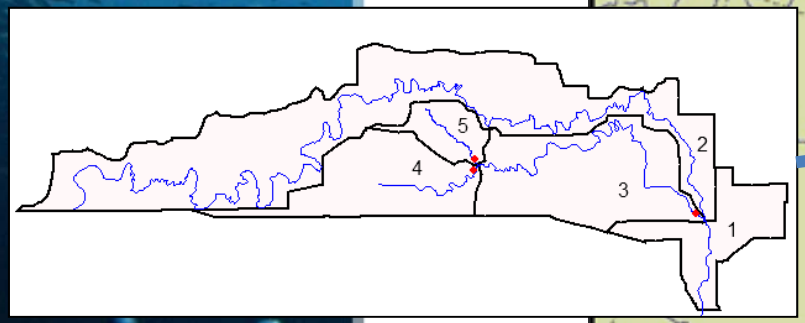
Watershed

For

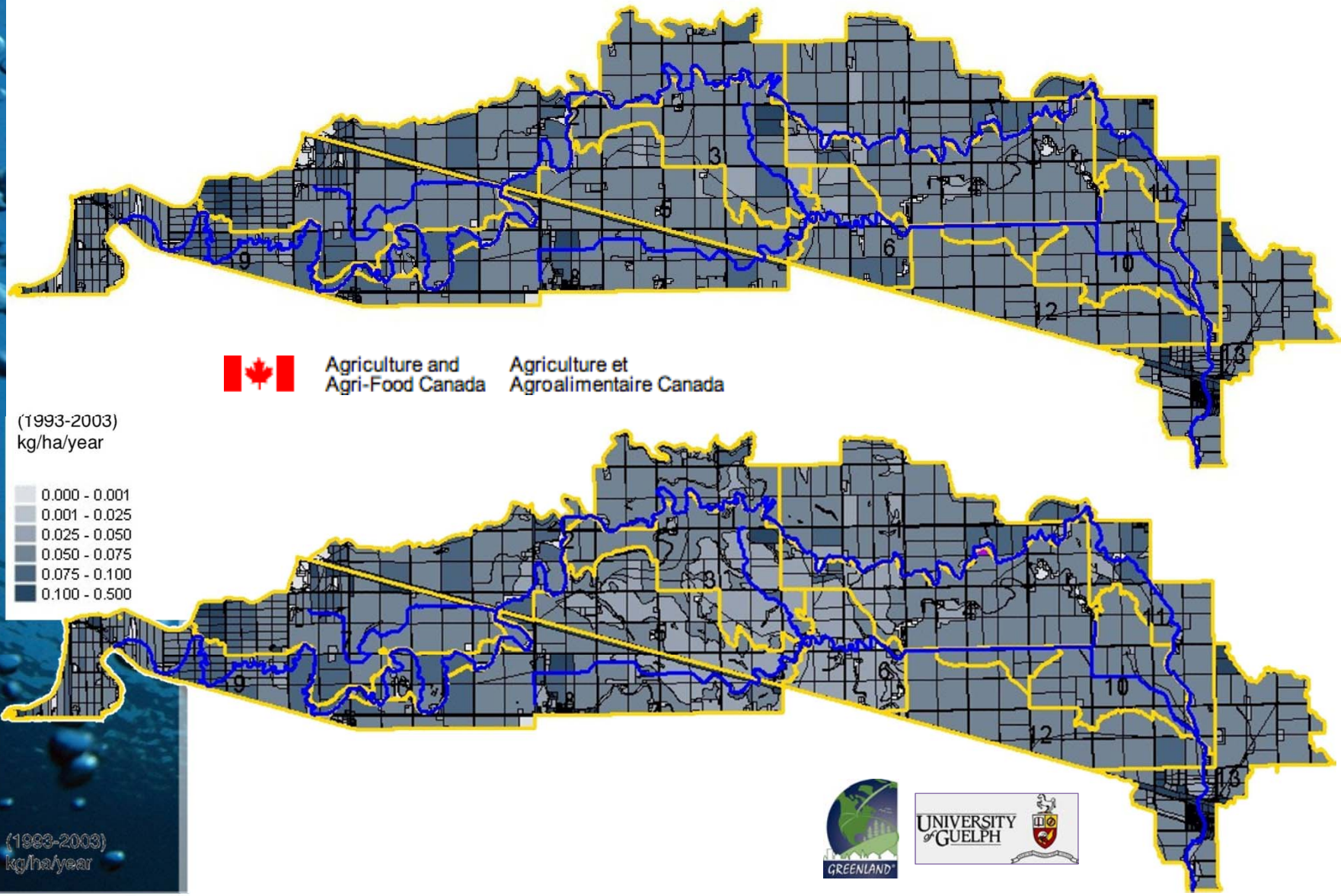
Life

CANWET-4 Tested Successfully for Use in the Lake Winnipeg Basin

LaSalle River Watershed

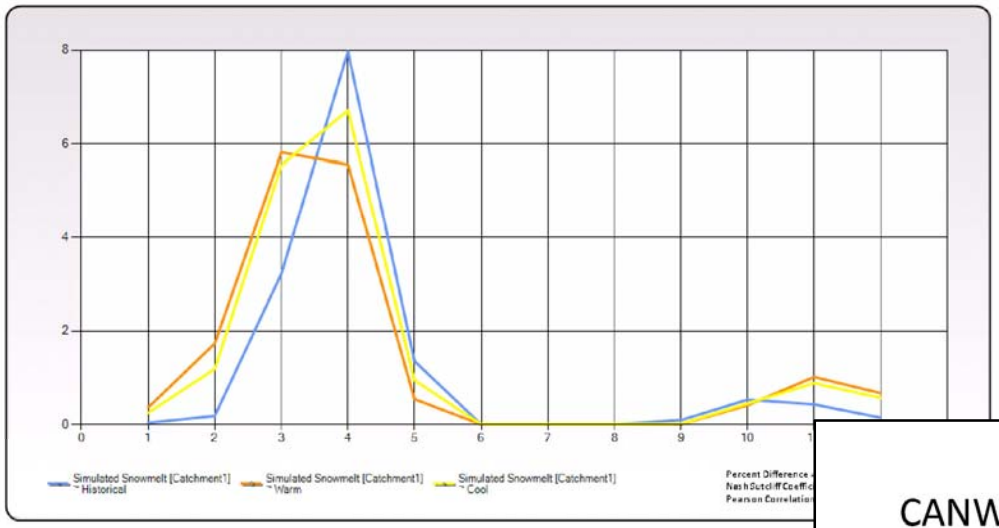


Land Use Change Response: Phosphorus Load in LaSalle River Watershed



CANWET™ - 4 Simulated Climate Change Response

Snow Melt Response under Historical, Warm, and Cool Climate Change Scenarios

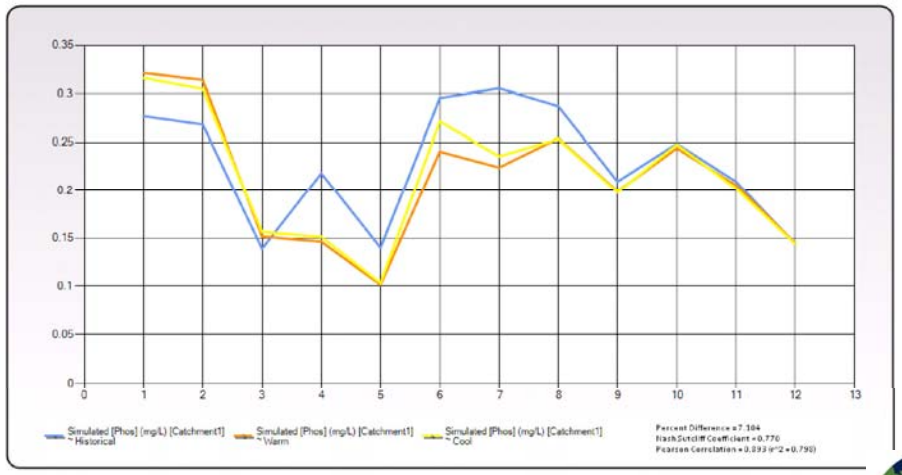


CANWET Version '4'

Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

CANWET™ - 4 Simulated Climate Change Response

Phosphorus Concentration (mg/L) Response under Historical, Warm, and Cool Climate Change Scenarios



UNIVERSITY of GUELPH

GREENLAND

CANWET Version '4'
Government of Canada Letters of Support

National Research Council Canada | Conseil national de recherches Canada
Industrial Research Assistance Program | Programme d'aide à la recherche industrielle

NRC·CNRC

July 8, 2011

Mr. R. Mark Palmer
Greenland International Consulting Ltd.
120 Hume Street
Collingwood, ON
L9Y 1V5

Re: Acknowledgement of Successful NRC-IRAP Funded Project

Dear Mark,

I am writing to acknowledge the completion of a successful R&D project funded by the National Research Council's Industrial Research Assistance Program (NRC-IRAP).

Your firm completed the project titled "Web Based GIS Driven Watershed Management Tool" in January, 2011. NRC-IRAP contributed $300,000 towards the cost of the project, as well as technical advice from our team of Industrial Technology Advisors. Your firm's performance on the project was excellent, and your team was a pleasure to work with. In particular, Trevor Boston demonstrated a strong ability to manage the project to completion.

The CANWET product that you have commercialized since the end of the project represents a strong step forward in your field, and you should be proud.

We wish you well in the successful commercialization of the technology, and the continued growth of your firm which will contribute to the Canadian economy.

Sincerely,

Doug Reed
Industrial Technology Advisor
NRC-IRAP
c/o Seneca College
8 The Seneca Way
Suite 911
Markham, ON
L3R 5Y1

Canada

Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

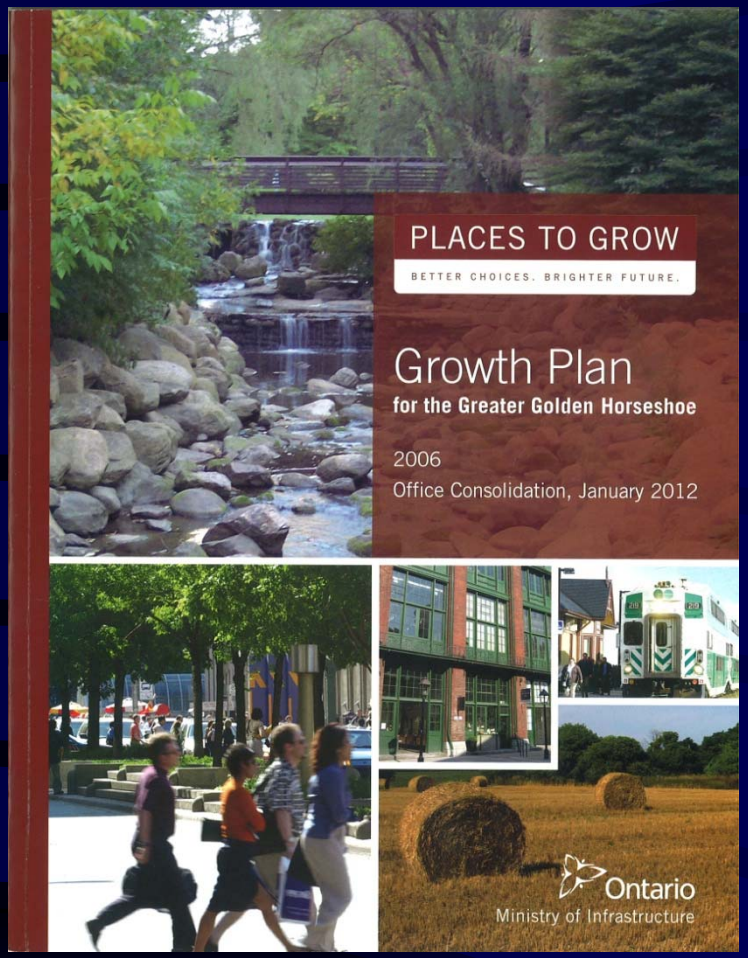
To whom it may concern,

In March of 2013, Greenland International Consulting Ltd. completed a study for Agriculture and Agri-Food Canada to estimate nutrient loading in a small catchment of about 177 square kilometers in the La Salle River watershed in southern Manitoba using the CanWET 4 model. Given uncertainties in some input data and model parameters, the preliminary results using the CanWET 4 model for baseline conditions of stream discharge, nutrient concentrations and loads were satisfactory to our project team as simulated values were within the range of observed values during the validation period. The CanWET 4 model was also used to simulate the outcomes of land use change scenarios incorporating varying degrees of wetland restoration and cropland conversion to forage in this catchment. This study suggests that with the use of improved input data and through verification of key model parameters that the CanWET 4 modeling approach could be used to predict changes to nutrient loads from changing land use scenarios in watersheds of this region.

Sincerely,

Jason Vanrobaeys
Senior Land Resource Specialist
Agriculture and Agri-Food Canada
101 Route 100, Morden, Manitoba R6M 1Y5
Email Jason.Vanrobaeys@agr.gc.ca
Phone: 204-823-0609

Canada



January 19, 2012

Simcoe County Water & Wastewater Visioning Strategy

The Study

Map of Simcoe County

- ✓ Simcoe County identified as a key area for planned employment and population growth opportunities.
- ✓ Simcoe County Council adopted a resolution to complete a Water and Wastewater Visioning Strategy.
- ✓ Greenland retained to complete an infrastructure planning and water-shed impact assessment study including GIS-based modeling of all County watersheds using CANWET™ (v.4).

Study Objectives

In-kind Project Contributions by the Greenland Group (CANWET™- 4 and Concurrent International Initiative)

CANWET™ - 4 (CANadian Watershed Evaluation Tool)

ASSESS

Assess all existing water & wastewater system capacities with respect to servicing existing and proposed population growth in the County of Simcoe.

IDENTIFY

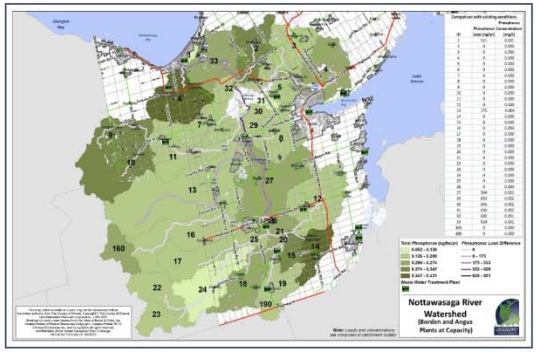
Identify opportunities for all municipalities that are found to have a servicing gap.

COMPILE

Compile general review of existing environmental (natural, socio-economic) conditions for the County of Simcoe, including wastewater servicing opportunities and constraints using CANWET™- 4.

SAMPLE SOLUTION

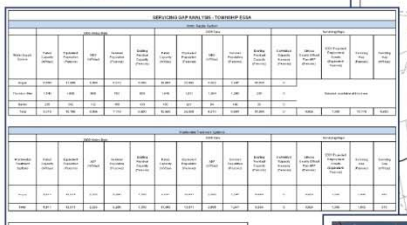
Sample Solution

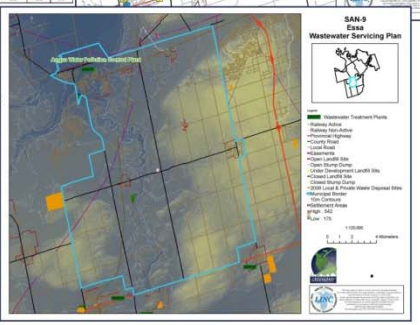


By connecting and treating 2031 wastewater flows from neighbouring municipalities (Clearview and Adjala-Tosorontio) at the Angus and C.F.B. Borden Wastewater Treatment Plants, there is a negligible increase in downstream phosphorus concentrations in the Nottawasaga River.

Sample Problem

Township of Essa (Angus Wastewater Treatment Plant) has residential wastewater capacity. Neighbouring municipalities (Clearview and Adjala-Tosorontio) have a negative deficit wastewater servicing gap.





Consulting Engineers of Ontario

2012 Ontario Consulting Engineering Awards

COUNTY OF SIMCOE
For Greater Opportunities

GREENLAND consulting engineers

Submitted By:

- Greenland Consulting Engineers
  - Jim Hartman, P. Eng.
  - Trevor Boston, M.Sc., P. Eng.
  - Neil Marsden, B. Sc.
  - R. Mark Palmer, P. Eng.
- County of Simcoe
  - Rick Newlove, P. Eng.—General Manager of Engineering, Planning & Environment
  - Grant Hudolin—Geographical Information Systems Manager
  - Matt Murray—Geographical Information Systems

Acknowledgments:

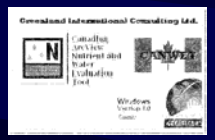
- Mark Aitken, CAO – County of Simcoe
- Staff from the County of Simcoe
- Staffs from the Study Municipalities, First Nations & C.F.B. Borden
- Elected Officials from the County of Simcoe & Study Area Municipalities
- District Municipality of Muskoka
- Regional Municipality of York
- Regional Municipality of Durham
- Nottawasaga Valley Conservation Authority
- Severn - Sound Association
- Lake Simcoe Region Conservation Authority

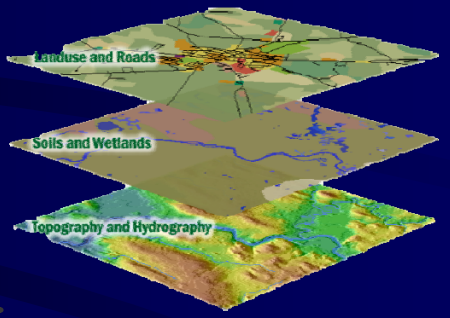
Evolution of Watershed Decision Support Systems

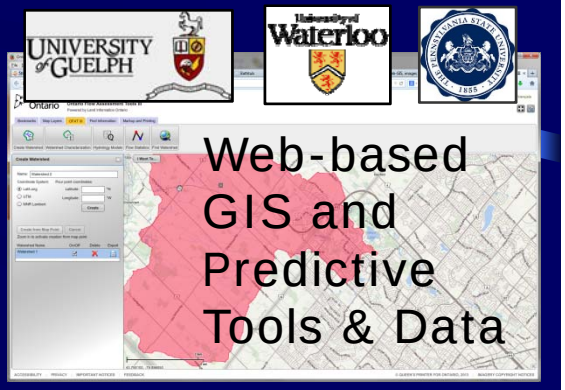
Since 2013
Intelligence Information Age

Integrated GIS and Geo-processing that incorporates best-available science

Cloud Computing & Storage







Web-based GIS and Predictive Tools & Data

Mobile Devices and Sharing

1980-90's

Since 2000
Information Technology Age

GREENLAND Group of Companies

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COMMUNITECH

University of Waterloo Partnership (Since 2013)

COMMUNITECH

We help tech companies start, grow and succeed

R. Mark Palmer, P. Eng., President and CEO
Greenland Group of Companies
c/o Greenland International Consulting Ltd.
Head Office: 120 Hume Street
Collingwood, Ontario
L9Y 1V5

February 19, 2015

RE: Acknowledgment of Information Technology Development Partnerships and Collaborations

Dear Mr. Palmer:

The Greenland Group (Greenland) was introduced to Communitech in 2013 along with business partners affiliated with the University of Waterloo and Centre for Community Mapping (COMAP). This letter is to acknowledge the importance of this proactive joint venture and to indicate our strong interest in future project partnerships with Greenland and other network members.

Founded by a group of entrepreneurs in 1997, Communitech is an industry-led innovation center in Waterloo Region, supporting a tech cluster of nearly 1,000 companies employing 30,000 people. Communitech supports tech companies at all stages of their growth and development – from startups to rapidly growing mid-sized companies and large global players. Communitech supports companies in commercializing innovation and technology, with the goal of creating a greater number of successful global businesses. This support includes Greenland, which has been a Canadian leader for over 20 years in the development of water resources decision support systems and other engineering software.

Communitech worked with Greenland and project partners from the University of Waterloo and COMAP to build "CANWET-5" – a web-based platform for simulation of watershed processes. The new platform will be pivotal in enabling Canadian watershed management through engagement of stakeholder groups and agencies using a common system. This achievement represents the first piece in a much larger and integrated decision support system to address cumulative stresses and regional impacts from climate change factors. CANWET-5 will be important to identify open/transparent and sustainable solutions too.

Greenland is now supporting other joint initiatives with Communitech. These leading-edge information technology projects will include other private sector members with the Communitech network, as well as Ontario government agencies and First Nation communities. These projects are intended to develop commercialized products and services involving the Greenland Group and other Communitech partners and to enable new Canada-wide related collaborations.

Communitech 151 Charles Street West, Suite 100, Kitchener Ontario Canada N2G 1H6
T: 519-888-9944 F: 519-888-7007 info@communitech.ca www.communitech.ca

Mark, if any of your prospective clients or contacts have questions regarding our collaborative efforts to date, ongoing discussions and project leveraging capabilities, the Communitech team would be more than happy to help.

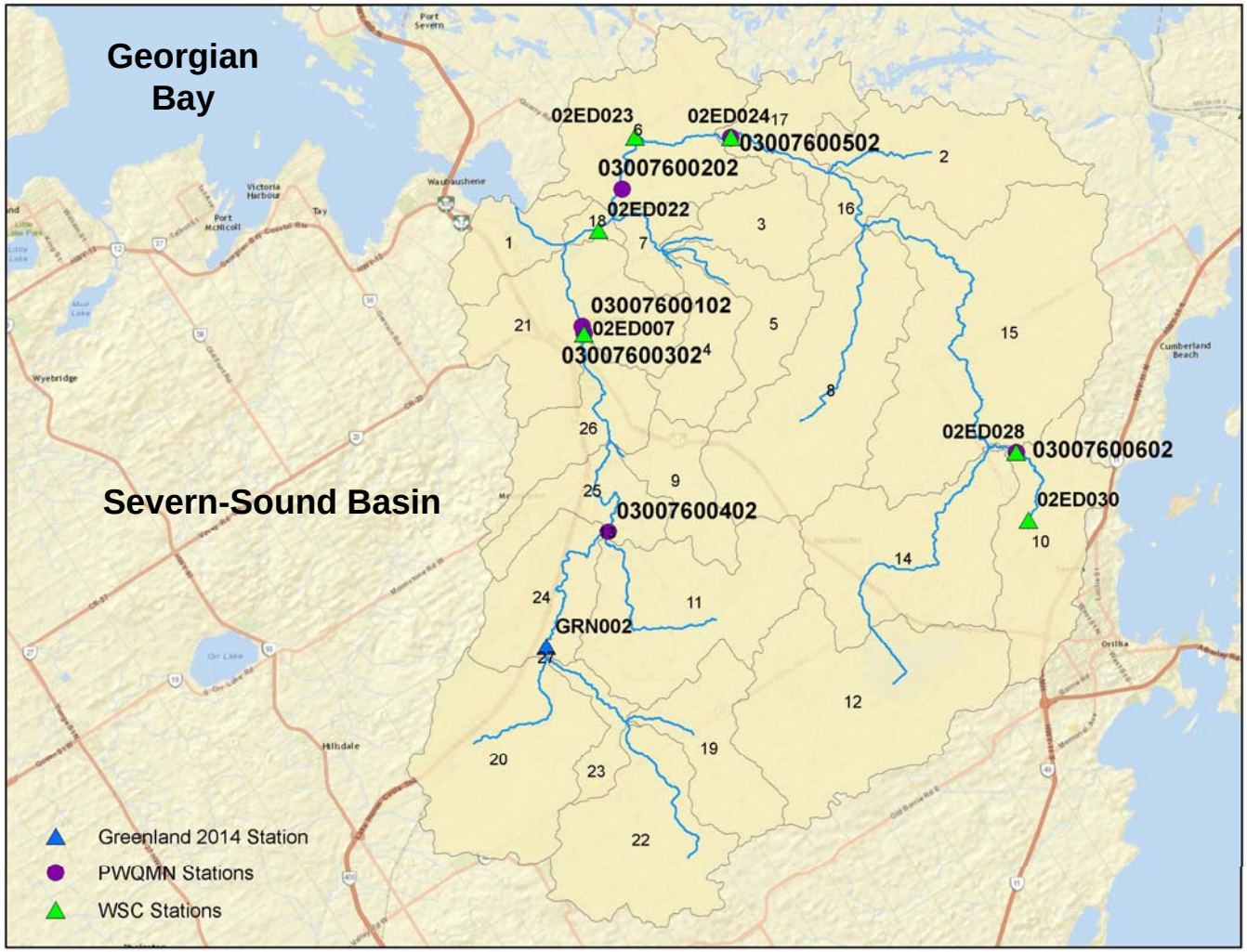
Inquiries can be directed to Geoff Bellew, who is our senior strategic advisor and resident expert in supporting collaborative projects amongst industry and academic partners. Please contact Geoff directly at 519.888.9944 ext. 1063.

We look forward to our continued strong collaboration with Greenland.

Sincerely,

Iain Klugman
CEO

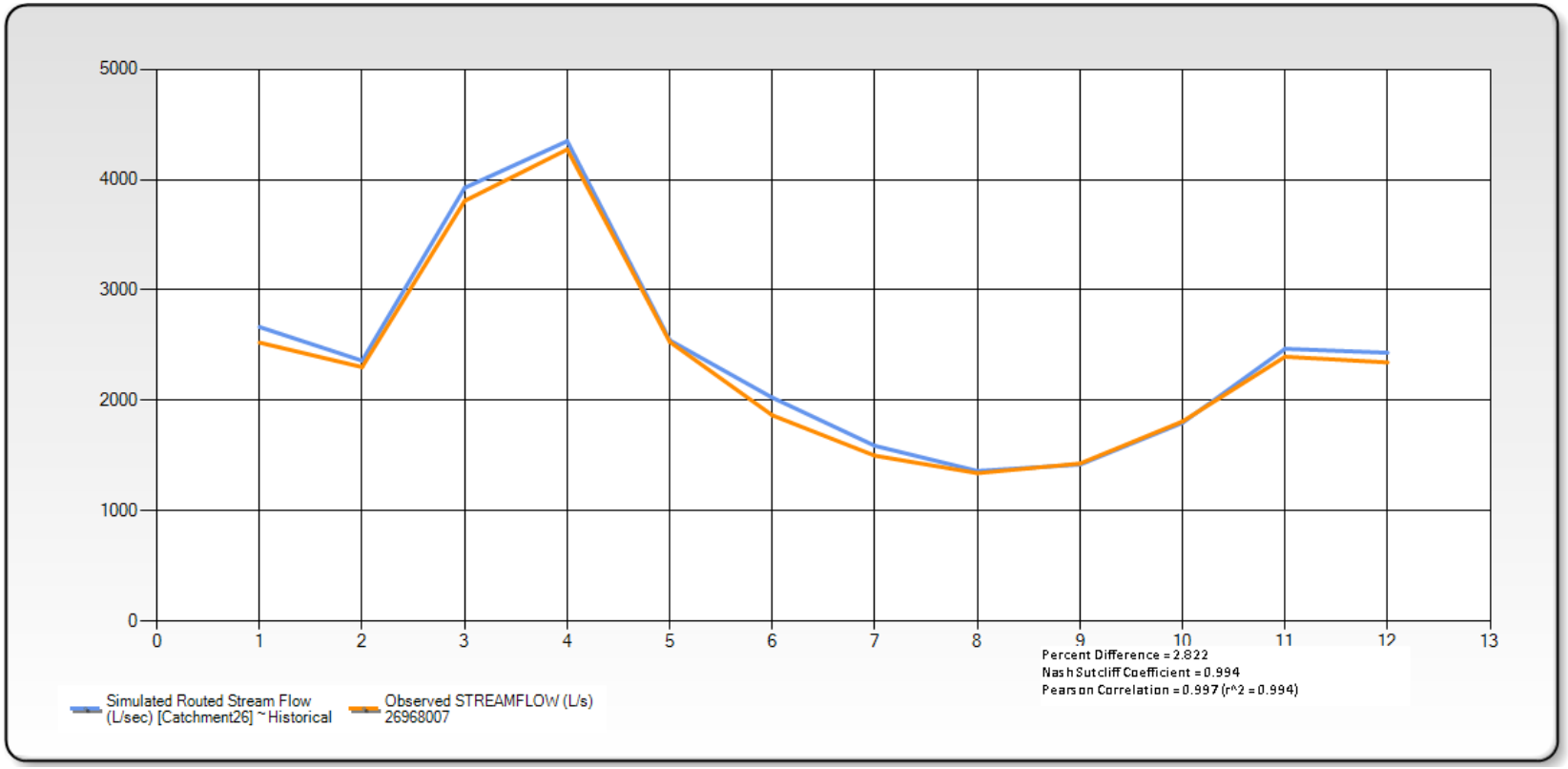
CANWET Status (2015) for the Severn-Sound "Development Basin" to Assess Cumulative Impacts from WWTPs and SWM Facilities Upon P, N, BOD, Pathogens , Bacteria, Sediments, In-stream DO & Temperature



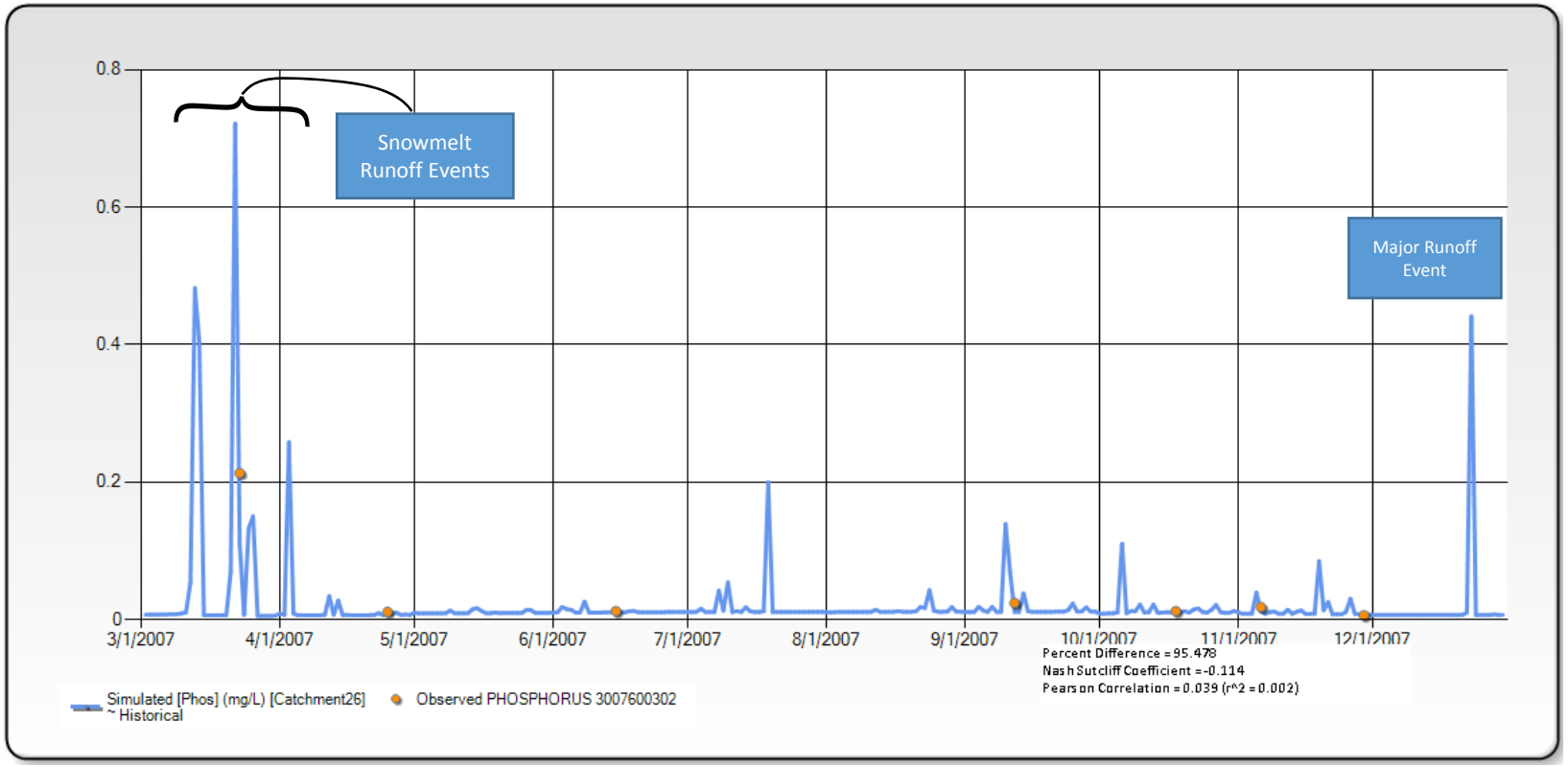
E.g. Coldwater River Watershed

(Part-of the Severn-Sound CANWET-5 "Development Basin")

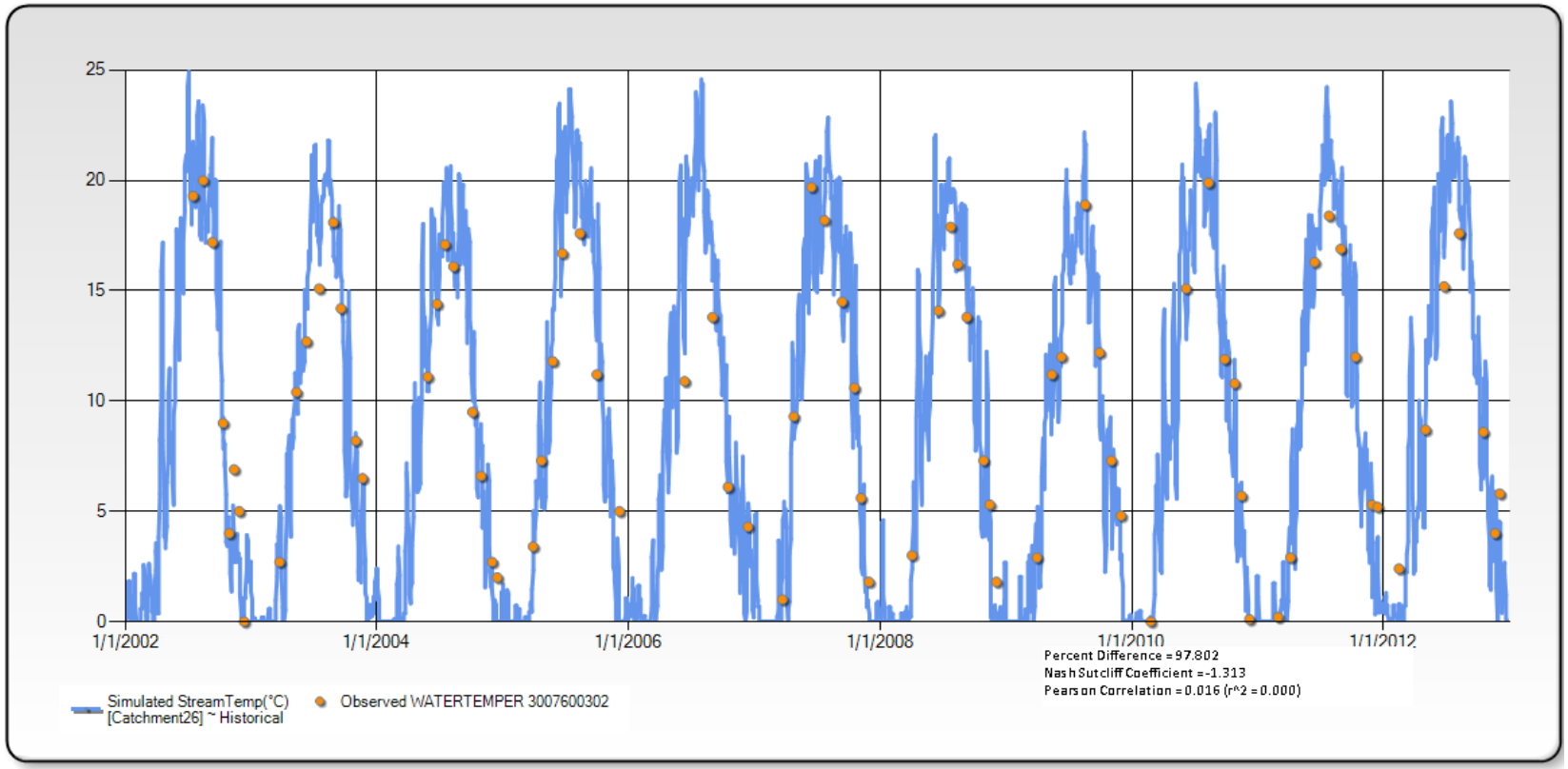
E.g.: Coldwater River Watershed Calibration Hydrology, Long Term Monthly, 02ED007



E.g.: Coldwater River Watershed Calibration Phosphorus, Daily, 033007600302

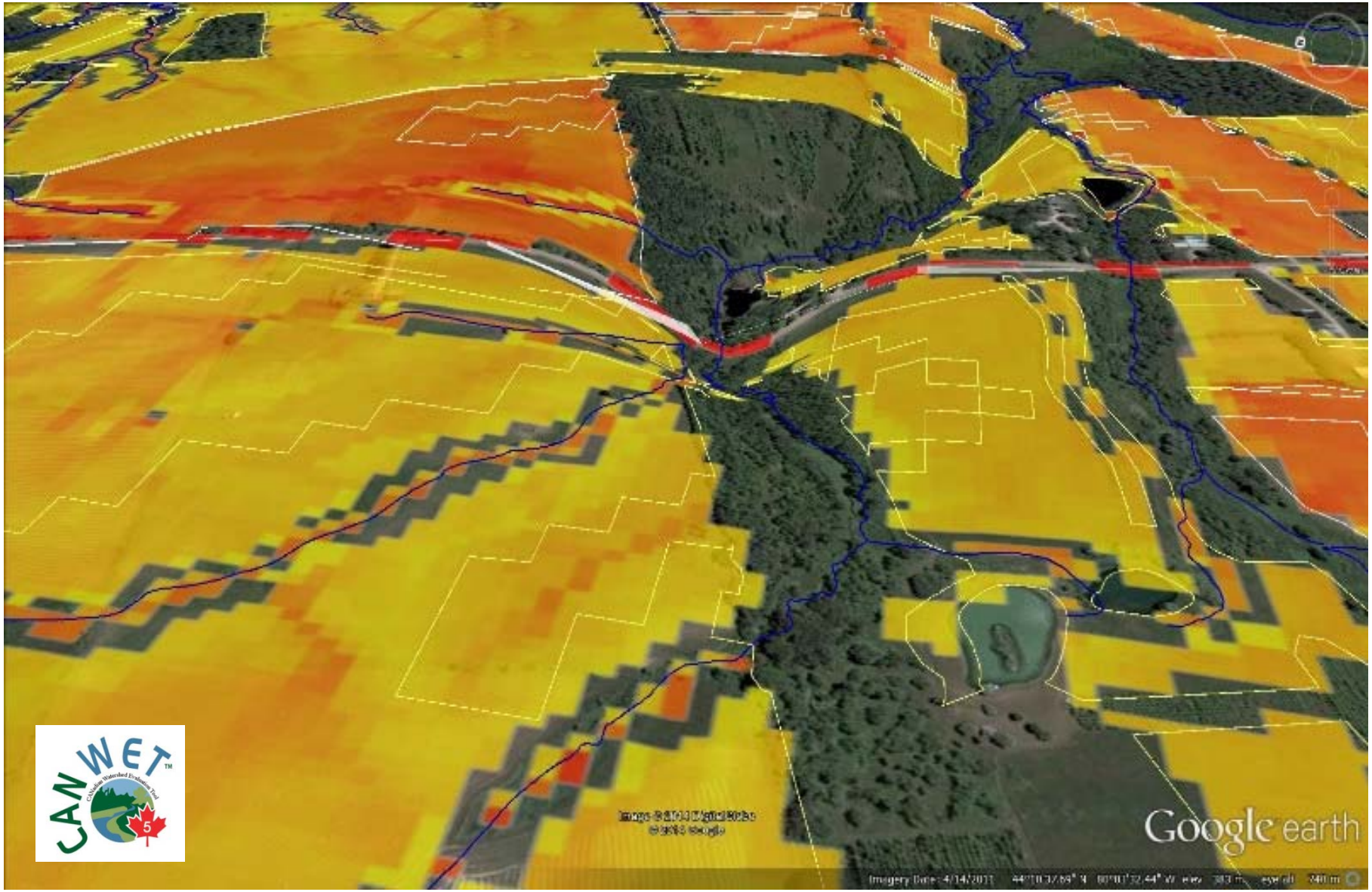


E.g.: Coldwater River Watershed Calibration Stream Temperature, Daily, 033007600302

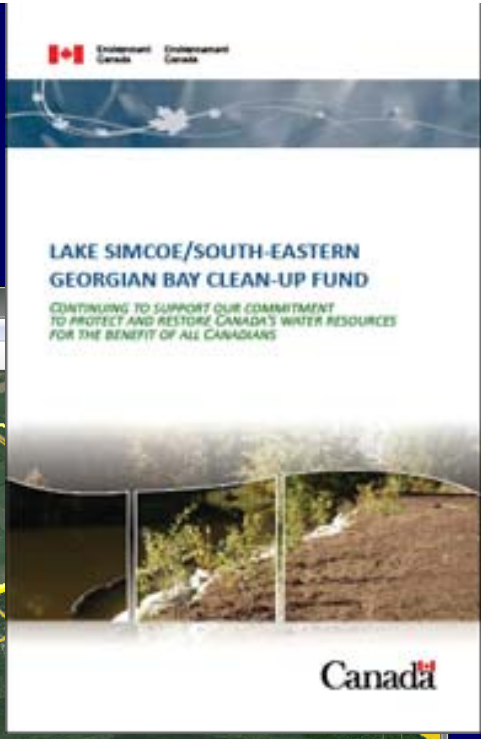


CANWET Status (2015) for the Nottawasaga River "Development Basin" to Assess Cumulative Impacts from WWTPs and SWM Facilities Upon P, N, BOD, Pathogens , Bacteria, Sediments, In-stream DO & Temperature

E.g.: Identification of Catchment Nutrient Source ‘Hot Spots’ with CANWET and LiDAR Map Data



CANWET Now Used to Identify How to Cost - Effectively Implement Phosphorus Reduction and Mitigation Plans



Township of Adjala-Tosorontio

CANWET-5 APPLICATION (2014)

Municipal Class E.A. Sewage Treatment Master Plan and Total Phosphorus Management Plan for the Pine River Watershed

Nottawasaga River
CANWET - 5
"Development Basin"

For Greater Opportunities

"An Engineering and Technologies Enterprise"
www.grnland.com

EA Process title

Everett Wastewater Treatment Plant Schedule "C" Class Environmental Assessment

This Schedule "C" Environmental Assessment is being prepared in accordance with the requirements of the Municipal Class Environmental Assessment (Class EA) process.

As part of this Schedule "C" Environmental Assessment, Design Concepts will be evaluated, selected, and recommended for implementation.

Schedule "A/A+" Projects

- Considered minor operation and maintenance activities and are selected for pre-approval without requirements for further assessment.
- These projects are typically limited in scale and present minimal impacts to the surrounding environment.
- Schedule A+ projects require that the public be advised prior to project implementation.

Schedule "B" Projects

- Generally include improvements and minor expansions to existing facilities where there is potential for some environmental impacts.
- These projects require screening of alternatives for their environmental impacts and completion of Phases 1 and 2 of the Class EA planning process.
- Provided no significant impacts are identified, Schedule "B" projects are approved and may proceed directly to Phase 5.

Schedule "C" Projects

- **These projects have the potential for significant environmental effects and therefore must proceed under full planning and documentation procedures.**
- **Requires that an Environmental Study Report be prepared and filed for review by the public and review agencies.**
- **Generally consist of construction of new facilities and major expansions to existing facilities (e.g. new Wastewater Treatment Plant with surface water discharge).**

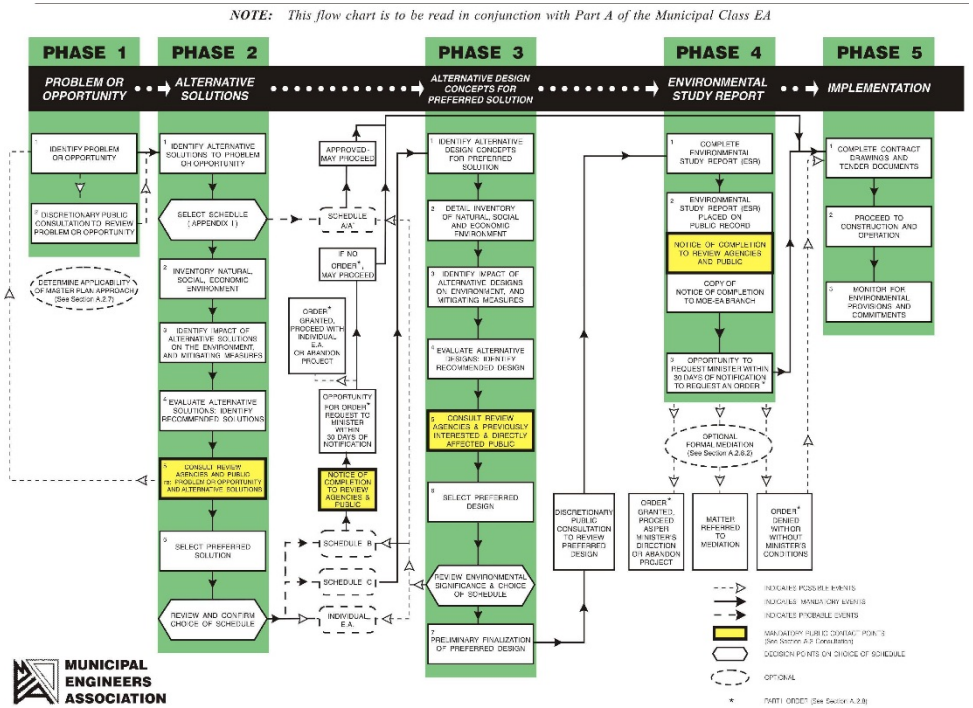


Figure 1- Municipal Class EA Planning and Design Process

Everett Community WWTP EA

This study fulfilled Phases 3 and 4 of the Class EA Process and satisfied the requirements for Schedule 'C' projects

Assimilative Capacity, Effluent Requirements & Phasing

Pine River Assimilative Capacity Study

- **An Assimilative Capacity Study was completed for the Pine River Watershed to determine if capacity to accept treated wastewater effluent for the proposed ultimate build-out population of Everett exists within the receiving river system.**
- **The Study found that a Wastewater Treatment Plant (WWTP) with treatment capacity for a population of approximately10,000 will not cause conditions downstream to exceed Provincial Water Quality Objectives under the conditions evaluated.**
- **In spite of the apparent capacity within the Pine River for additional nutrient loading, it was recommended through the MSP that additional measures be taken to ensure effluent quality is as high as possible. As such, a phosphorous concentration objective of 0.05 mg/L for treated WWTP effluent has been used in assessment of design concepts for the proposed Surface Water Outfall WWTP.**
- **Recommended Effluent Quality Parameters for The Everett WWTP were developed as part of this EA and are presented below:**

Effluent Requirements		
Parameter	Compliance Limit	Design Objective
TP (mg/L)	0.1	0.05[1]
Total Ammonia (mg/L)	1.8	1.8[2]
TSS (mg/L)	10	5[3]
BOD (mg/L)	10	5[3]
Total Fecal Coliform (CFU/100 mL)	200	200[4]

Note:
1) Recommended by the Everett Secondary Plan Master Servicing Plan (November 2012)
2) Used by the Pine River Assimilative Capacity Study (December 2012)
3) Proposed by the R&M for the in-process R&M WWTP
4) ECA limit at the nearby Angus WWTP.

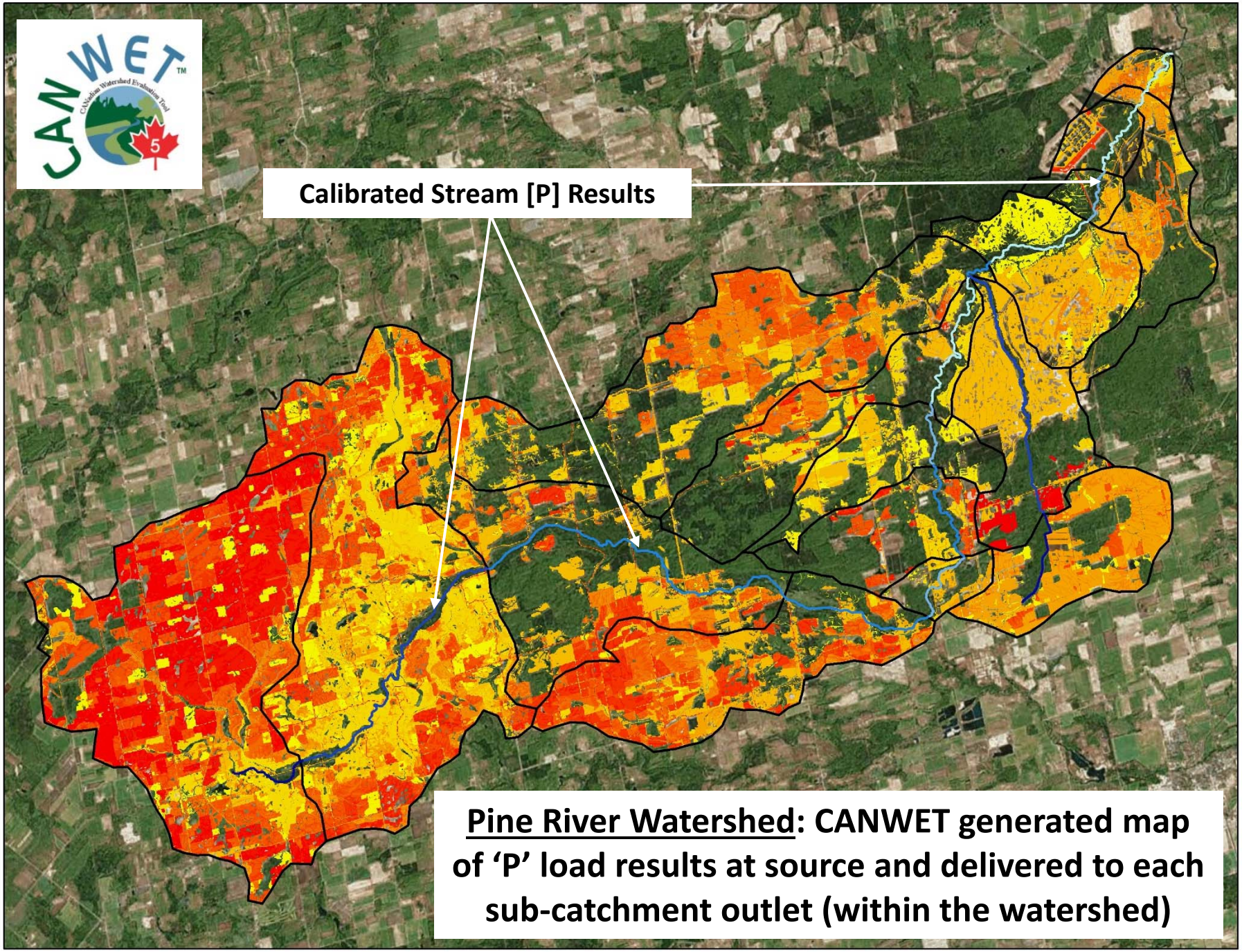
WWTP Class EA Development Phasing

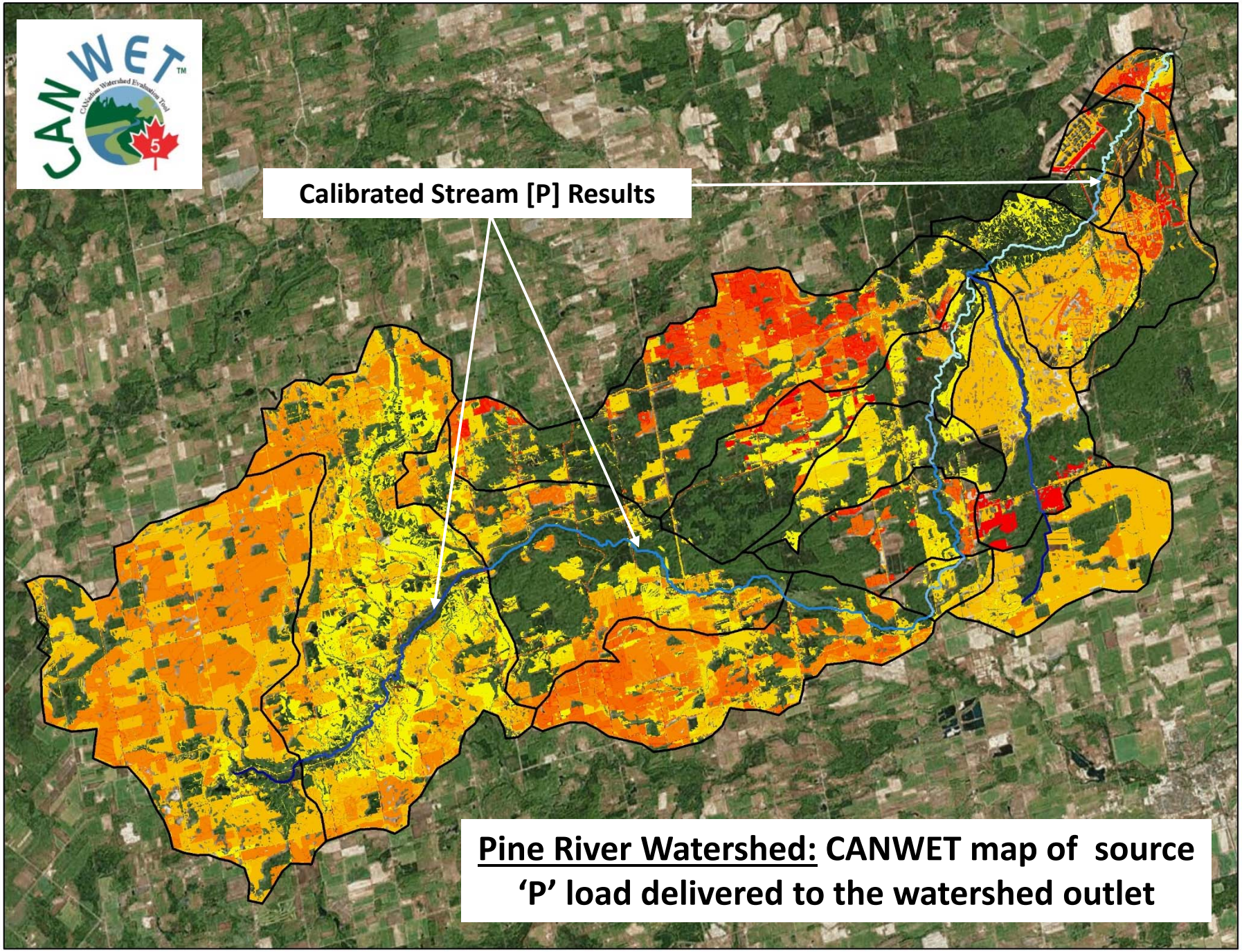
- WWTP to be Constructed in Four (4) Phases.
- Ultimate Servicing Capacity for an Equivalent Population of 10,669 persons.

Other Relevant Background Information

- Hydrogeological Report.
- Archaeological Report.
- Natural Environment Study.
- Existing Conditions Water & Wastewater Servicing Studies.
- Natural Hazards Study.
- Pre-Development Drainage Study.
- Traffic and Transportation Study.
- Existing Draft Plans.
- Township of Adjala-Tosorontio & County of Simcoe "As-Constructed" Drawings.
- The Community of Everett Master Servicing Plan (MSP) Class EA.

This value-added / science-based information was used by Greenland® to develop and evaluate WWTP Design Concepts and to select a "Preferred Partnership Solution"


CANWET
Calibrated Stream [P] Results
Pine River Watershed: CANWET generated map of 'P' load results at source and delivered to each sub-catchment outlet (within the watershed)

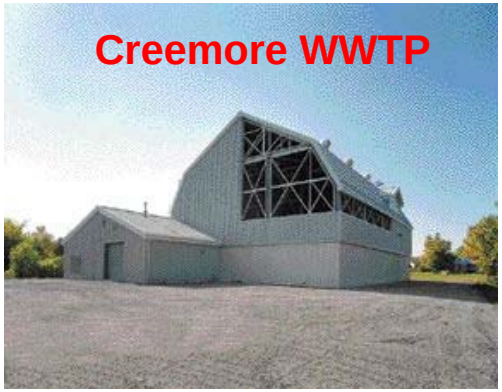

CANWET
Calibrated Stream [P] Results
Pine River Watershed: CANWET map of source 'P' load delivered to the watershed outlet

Long Term Mitigation Measures

Potential Impact	Mitigation Strategy
Surface Water Quality & Monitoring of Effluent From WWTP	• Investigation of Concept FM-3B - Discharge treated effluent to a rehabilitated gravel pit west of County Road 13. • **Nutrient offsetting and downstream monitoring of nutrient loading are proposed and Phase 1 recommended from an Environment Canada program.** • **Proposed WWTP effluent objective is 0.05mg/L for Total Phosphorus, approximately half of the allowable discharge within the Pine River Assimilative capacity.** • The Certificate of Approval for the WWTP will require, that effluent quality is monitored and effluent limits and objectives are achieved.
Infringement on Environmental Protection and Hazard Setback Areas	• Outlet pipe alignment to be located within existing road right of way until pipe reaches northern boundary of natural areas west of County Road 13 • Outlet to go through former quarry lands to minimize impacts to environmental/hazard areas.
Stormwater Management & Drainage	• Engineering & Landscape design for WWTP Site and FM Alignment to be designed to match existing drainage patterns and in accordance with Township and NVCA Requirements.
Removal of Trees & Vegetation	• Recommended Solution minimizes impacts to existing vegetation • Restore Construction areas with native species.
Residential Impacts (Noise, Odour & Visual Impacts)	• WWTP Architectural Design should compliment surrounding community (e.g. Creemore "Barn" WWTP). • Detailed WWTP Landscape design should include screening (i.e. berms, trees and other plantings). • Detailed WWTP Site Plan design should include adequate buffers for noise and odour.

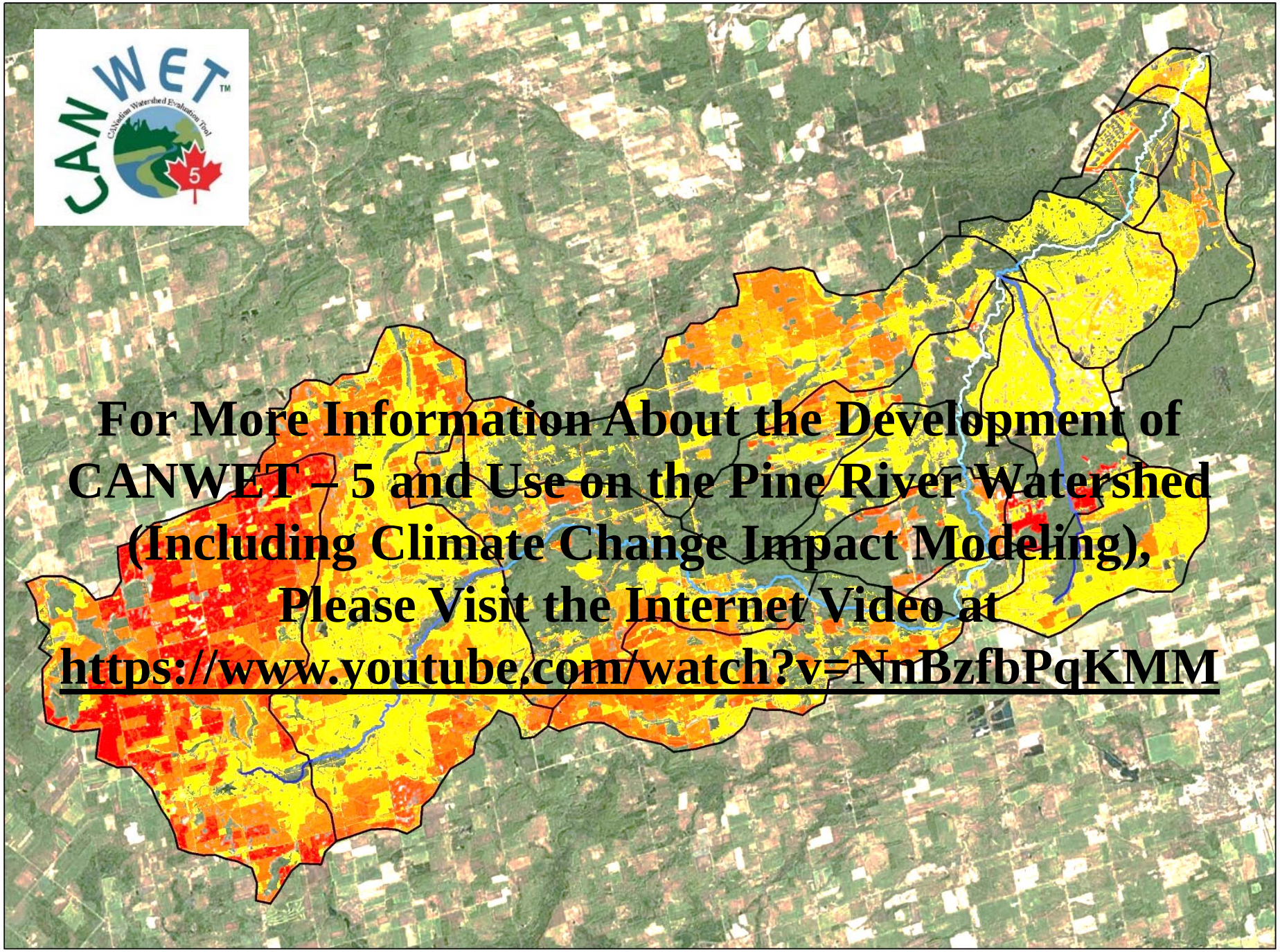
What is Mitigation?

- Additional considerations which help to further reduce environmental impacts.
- Example: Architectural design for the Creemore WWTP was made to blend into the rural landscape.



Source:
www.canadianconsultingengineer.com

**A Final Design Concept was Prepared by Greenland®
Following Public and Agency Consultations**


CANWET™
CANadian Watershed Evaluation Tool
5
For More Information About the Development of
CANWET – 5 and Use on the Pine River Watershed
(Including Climate Change Impact Modeling),
Please Visit the Internet Video at
https://www.youtube.com/watch?v=NnBzfbPqKMM

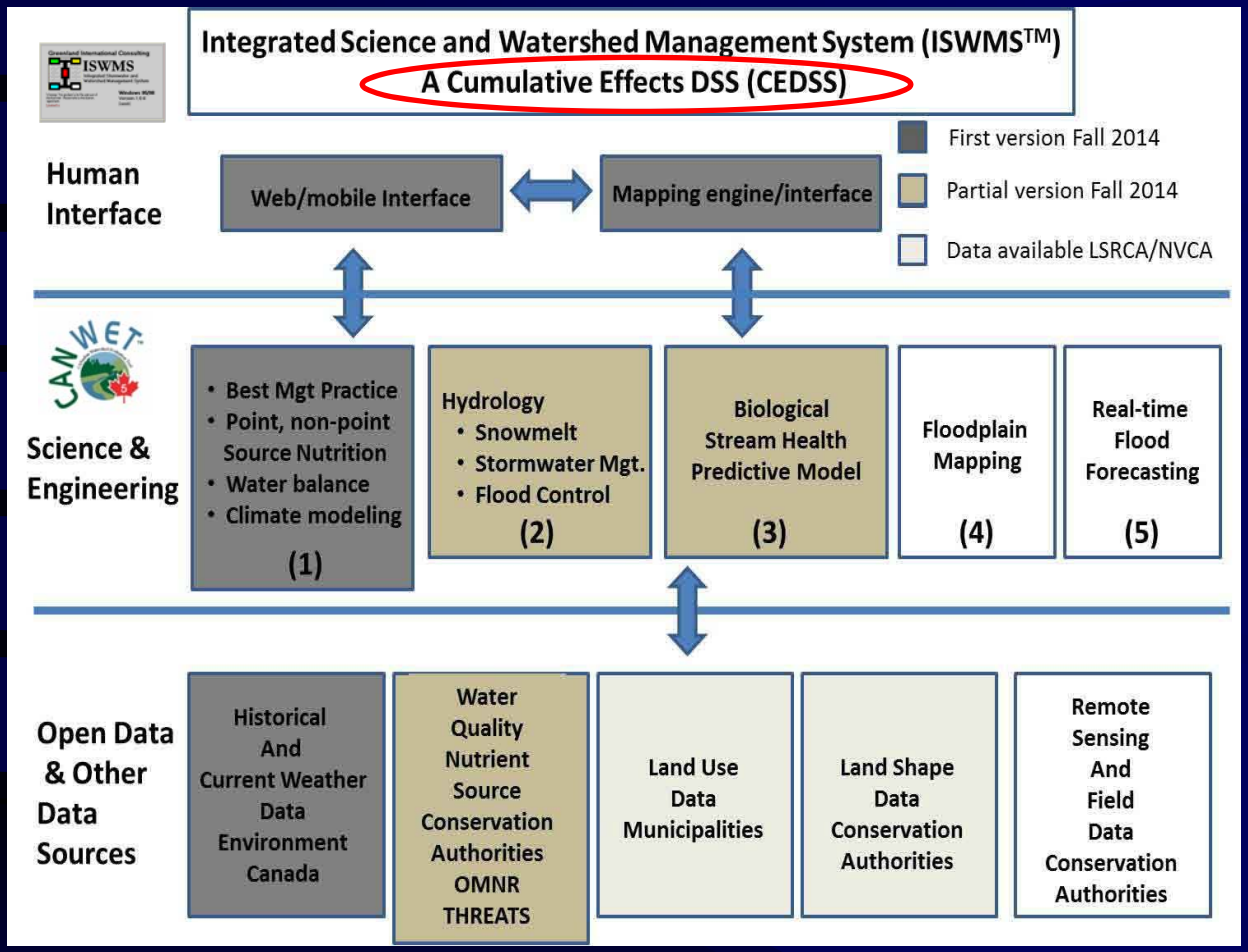
Integrated Science and Watershed Management System (ISWMS)

What is ISWMS?

The **I**ntegrated **S**cience and **W**atershed **M**anagement **S**ystem (**ISWMS**) was originally developed (1998 – 2005) by the Greenland® Group as a windows-based Decision Support System (DSS) for stormwater management; hydrological modelling; floodplain mapping and flood forecasting. The system was developed for the Nottawasaga Valley Conservation Authority. **At the time, the long-term DSS 'vision' was (but depending upon the availability of certified open data and timely evolution of cost-effective operational platforms) other science-based tools + GIS and Internet integrations.**

The ISWMS (Version '2') goal with the University of Waterloo and COMAP includes multi-functional stormwater management; hydrologic; water quality; nutrient trading; hydraulic and contaminant transport; flood forecasting; climate change impact; instream (biological) health assessment; and, Best Management Practice (BMP) analysis capabilities for river system and lake basin management programs. It will also be used for drinking water supply, wastewater treatment and flood control infrastructure planning and design initiatives. **The DSS will include CANWET-5** and other new tools. **The project also includes a renowned science team from the University of Guelph.**

ISWMS (Version 2): Architectural Layers & Components *(On-going)*



Six Nations (ON)

Pilot Source Water Protection Region

GREENLAND Group of Companies "An Engineering and Technologies Enterprise" www.grnland.com

UNIVERSITY of GUELPH

COMMUNITECH

comap.ca

University of Waterloo

THE PENNSYLVANIA STATE UNIVERSITY 1855

A Blueprint for Cumulative Effects Management

- Results from a combination of past, present and future activities.

- Requires consideration of effects across a variety of decision-making processes from strategic (i.e. policy and planning) to operational and regulatory (i.e. compliance, impact assessments, approvals) to monitoring.

- Decision makers different branches within government, different departments or different levels of government. Yet, share common information needs (e.g. current environmental baseline).

- While the concept of cumulative effects is understood, the components and process of implementation is less understood.

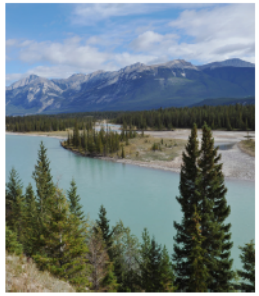
National Research & Development
Canadian Water Network

ASSESSING CUMULATIVE EFFECTS OF CANADIAN WATERS

DR. MONIQUE DUBÉ; CANADIAN RIVERS INSTITUTE, UNIVERSITY OF NEW BRUNSWICK

KEY MESSAGES FOR DECISION MAKERS

- Cumulative effects assessment (CEA) is the process of understanding changes in the environment that are accumulating over time and space and how those changes may affect the public, land use planning decisions and future development.
- This research recommends improved methodology for CEA, tests the methodology in several watersheds across Canada, and develops decision support software to conduct CEA.



WHO IS THIS INFORMATION RELEVANT FOR?

Groups interested in the state of the environment now and in the future:

- the general public
- regulatory agencies (at all levels)
- industry
- First Nations and Métis
- watershed groups
- consultants
- academia

WHAT WAS THE RESEARCH FOCUS?

How should we be monitoring our "environmental bank account"? Will we know when we've reached our limit? Collecting environmental data is of no value unless it is compared to some form of benchmark. Existing one-off approaches have not given Canadians confidence that we truly know the health of our environment. CEA holistically tracks and predicts environmental change over time and space. By setting limits, decision makers can track change and mitigate effects before extreme action is required.

WHAT WAS THE RESEARCH METHOD?

Development of a Common Framework for CEA: A national team of researchers and practitioners was assembled to align terminology and agree on key components required for CEA.

Testing the Framework: Different components of the CEA framework were tested in seven watersheds of four provinces and two territories in Canada including a transboundary river crossing into Alaska, USA.

CEA Software: The Healthy River Ecosystem AssessmenTSystem (THREATS) was developed to support the implementation of the CEA.

WHAT WERE THE RESEARCH RESULTS?

The critical components needed for CEA and issues affecting its implementation were identified.

These components are not currently being practiced in an integrated manner by those required to conduct or support CEA under regulation.

The THREATS decision support software to support CEA was developed and now serves as a foundation for ongoing development in partnership with the private and academic sectors.

WHAT ARE THE IMPLICATIONS FOR DECISION MAKERS?

CEA methodology must be improved to better manage and protect our environment from cumulative effects.

Five years of research involving CEA scientists and practitioners from a variety of backgrounds and viewpoints successfully developed and tested an improved methodology and decision support software for implementation.

The absence of a designated responsible authority accountable for CEA and decision support software remains the single greatest challenge to improved implementation.

MORE INFORMATION AVAILABLE AT: DR. MONIQUE DUBÉ, CANADIAN RIVERS INSTITUTE, UNIVERSITY OF NEW BRUNSWICK, EMAIL C/O: MONIQUE.DUBE@AER.CA

ASSESSING CUMULATIVE EFFECTS OF CANADIAN WATERS

DR. MONIQUE DUBÉ; CANADIAN RIVERS INSTITUTE, UNIVERSITY OF NEW BRUNSWICK

CANADIAN WATER NETWORK
RÉSEAU CANADIEN DE L'EAU

Integrated Environmental Assessment and Management — Volume 9, Number 3—pp. 363–369

A Framework for Assessing Cumulative Effects in Watersheds: An Introduction to Canadian Case Studies

Monique Dubé, Peter Duinker, Lorne Greig, Martin Carver, Mark Servos, Mark McMaster, Bram Noble, Hans Schreier, Lee Jackson, and Kelly R Munkittrick*

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‡School for Resource and Environmental Studies, Dalhousie University, Halifax, Nova Scotia, Canada
§ESSA Technologies, Richmond Hill, Ontario, Canada
‖Aqua Environmental Associates, Nelson, British Columbia, Canada
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(Submitted 19 November 2012; Returned for Revision 31 December 2012; Accepted 19 March 2013)

Special Series

EDITOR'S NOTE

This article is 1 of 9 articles in the special *IEAM* series entitled "Watershed Cumulative Effects Assessment (CEA)." The research program emanated from a 4-year Canadian Water Network initiative, "Development of The Healthy River Ecosystem Assessment System (THREATS) for Assessing and Adaptively Managing the Cumulative Effects of Manmade Developments on Canadian Freshwaters." The objectives were to develop a framework for watershed CEA, implement portions of the framework in multiple river basins across Canada, and to develop legacy tools (i.e., THREATS decision support software) for ongoing development, use, and uptake by water stakeholders.

ABSTRACT

From 2008 to 2013, a series of studies supported by the Canadian Water Network were conducted in Canadian watersheds in an effort to improve methods to assess cumulative effects. These studies fit under a common framework for watershed cumulative effects assessment (CEA). This article presents an introduction to the Special Series on Watershed CEA in *IEAM* including the framework and its impetus, a brief introduction to each of the articles in the series, challenges, and a path forward. The framework includes a regional water monitoring program that produces 3 core outputs: an accumulated state assessment, stressor–response relationships, and development of predictive cumulative effects scenario models. The framework considers core values, indicators, thresholds, and use of consistent terminology. It emphasizes that CEA requires 2 components, accumulated state quantification and predictive scenario forecasting. It recognizes both of these components must be supported by a regional, multiscale monitoring program. *Integr Environ Assess Manag* 2013;9:363–369. © 2013 SETAC

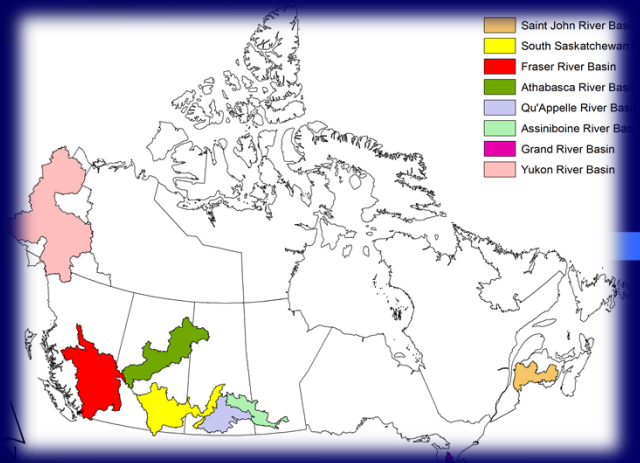
Keywords: Canada Cumulative effects assessment Environmental impact assessment Watershed

INTRODUCTION

Cumulative effects assessment (CEA) is defined as the assessment of the accumulation of change on the landscape due to multiple stressors (natural and manmade) over scales of time and space and from both a priori (predictive) and a posteriori (retrospective) perspectives (Dubé 2003). In Canada, CEA began in the 1980s as part of the environmental impact assessment (EIA) process. It was recognized by Hegmann et al. (1999) that approval of individual development projects in the absence of consideration of the impacts of past and future developments could result in unintended cumulative effects that expressed themselves at more regional scales. Although there have been some applications of CEA in the forestry sector (Nitschke 2008; Yamasaki et al. 2008; Greig and Duinker 2011) in broader Canadian EIA practice, CEA has not been effective (Duinker and Greig 2006). The scope of CEA has been limited to local development projects seeking regulatory approval.

EIAs are stressor-based in which stressors associated with development activities are identified and their effects on valued ecosystem components (VECs) are predicted based on known pathways of interaction (Beanlands and Duinker 1984). The risk of potential impacts is assessed independently for each environmental component and the approach incorrectly assumes all stressors and stressor interactions are known

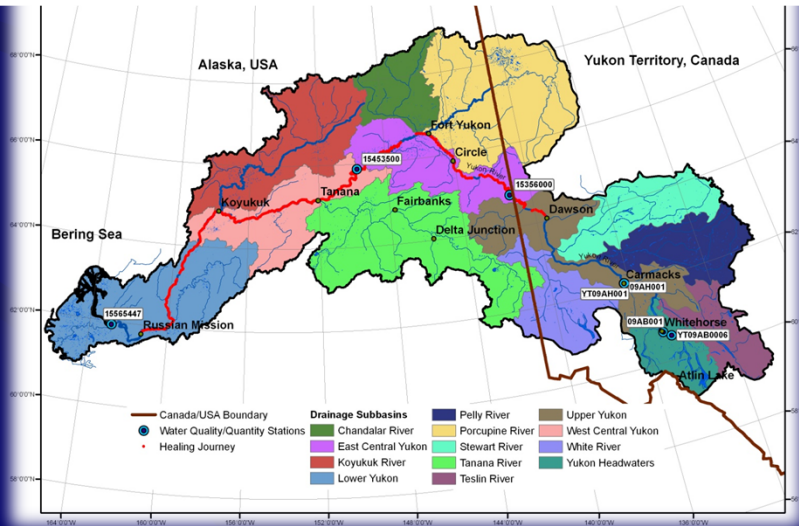
A podcast discussing the contents of this artide can be found at www.wiley.com/go/IEAMpod
* To whom correspondence may be addressed: dub
Published online 2 April 2013 in Wiley Online Libra
(wileyonlinelibrary.com).
DOI: 10.1002/ieam.1418



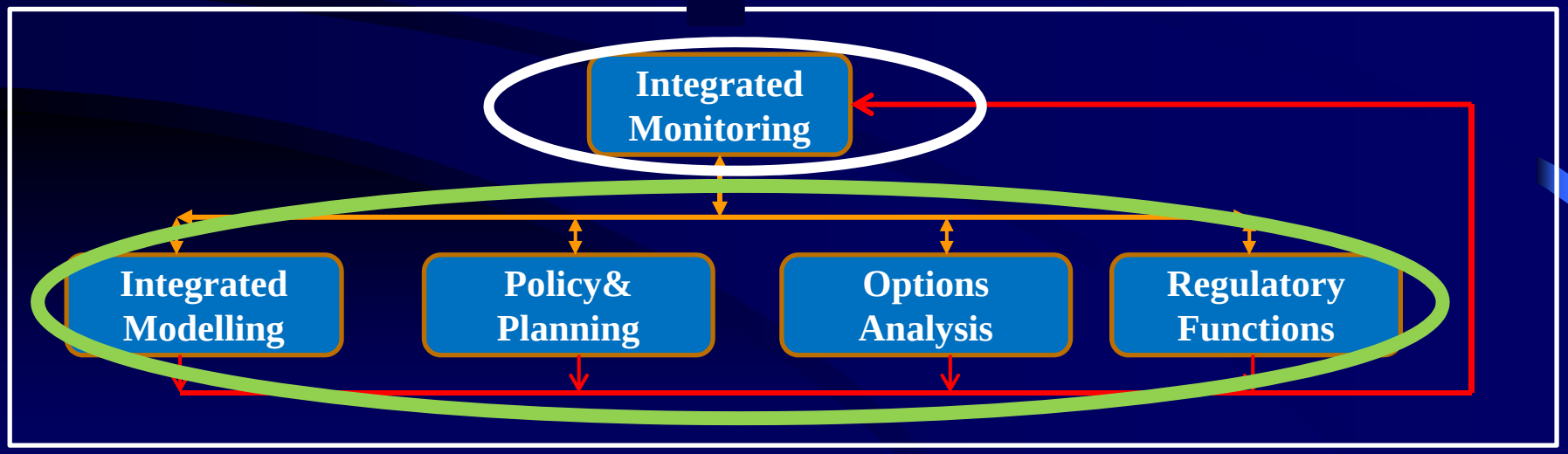
Accumulated State of the Yukon River Watershed: Part I Critical Review of Literature

Monique Dubé,† Breda Muldoon,† Julie Wilson,† and Karonhiakta'tie Bryan Maracle‡*

†Canadian Rivers Institute, University of New Brunswick, Alberta, Canada
‡Director of Natural Resources, Council of Athabascan Tribal Governments, Fort Yukon, Alaska, USA



Five Fundamental Components of Cumulative Effects Management



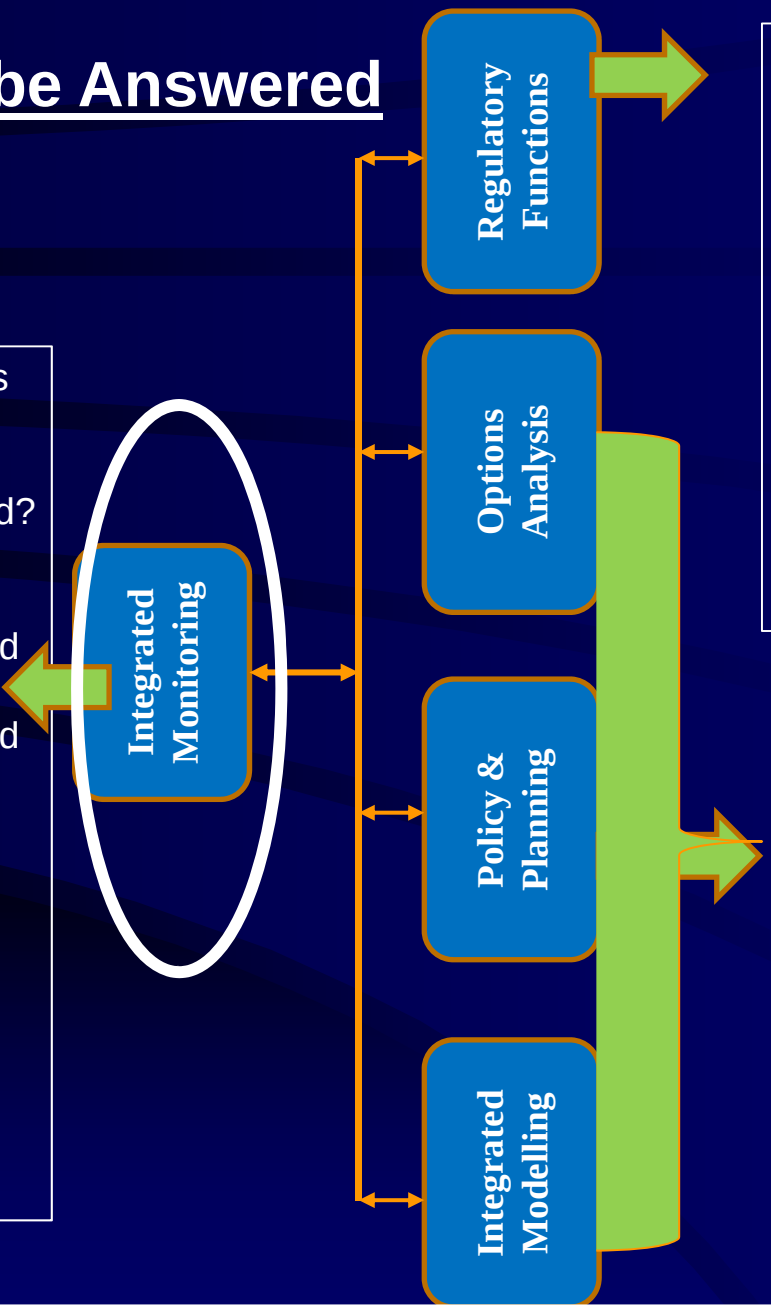
Questions to be Answered

- What development has occurred? (stress)
- What environmental changes have occurred? (response)

- Do the changes exceed a sector trigger?
- Do the changes exceed a regional plan threshold?

- Are the changes trending towards a trigger?

- Are the environmental changes caused by a sector?



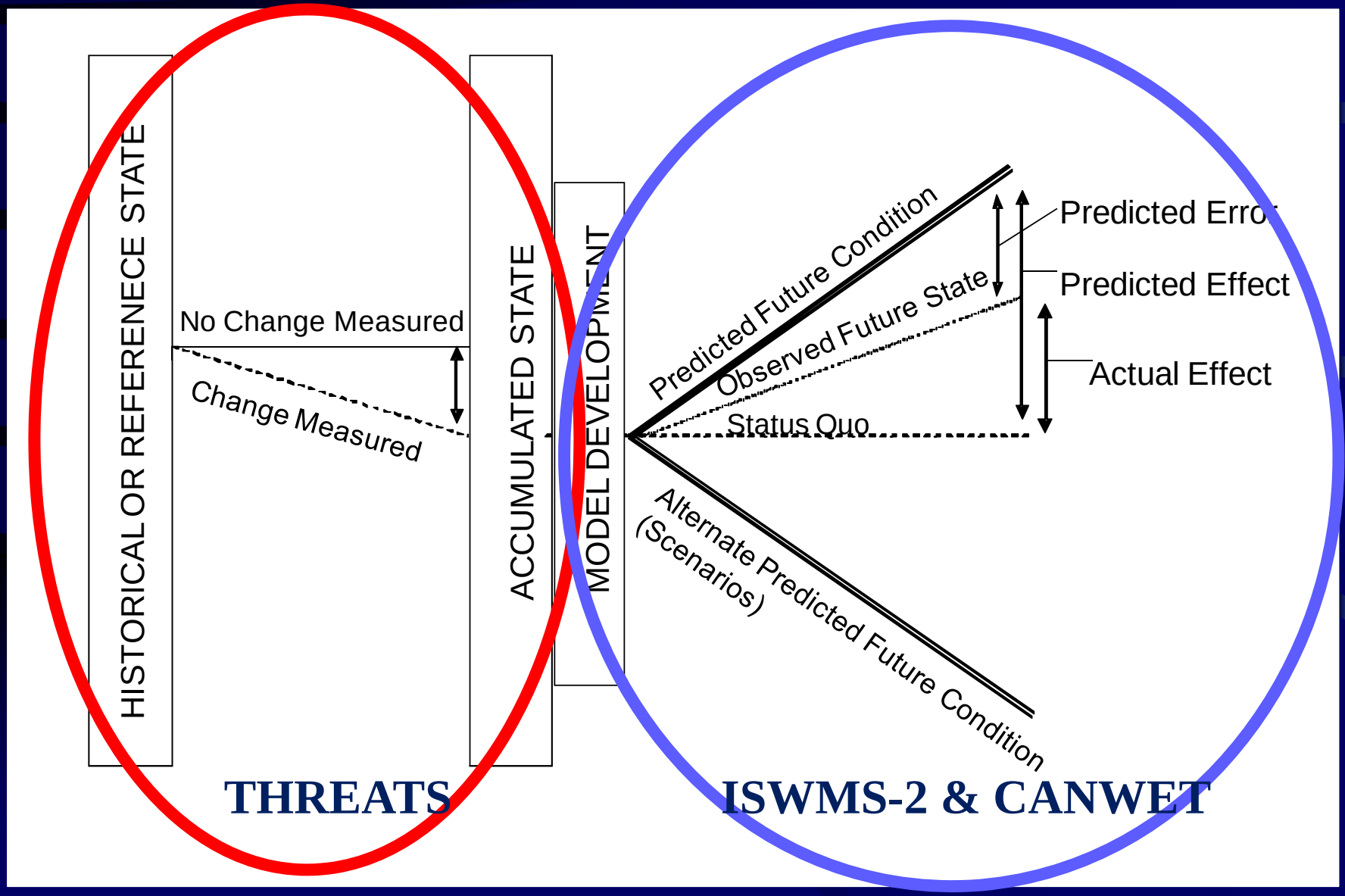
- What exists on the land? How close are we to limits? Will this project application put us over?
- Can we fast-track a development and illustrate no harm?
- Are there areas where resource development can be accelerated as environmental risk is low and the environment is stable?
- What are the environmental changes that have occurred? Are regulations protective?

- Given the resource distribution, probability and economics of resource development, and existing state of the environment, what is the predicted environmental response to development?

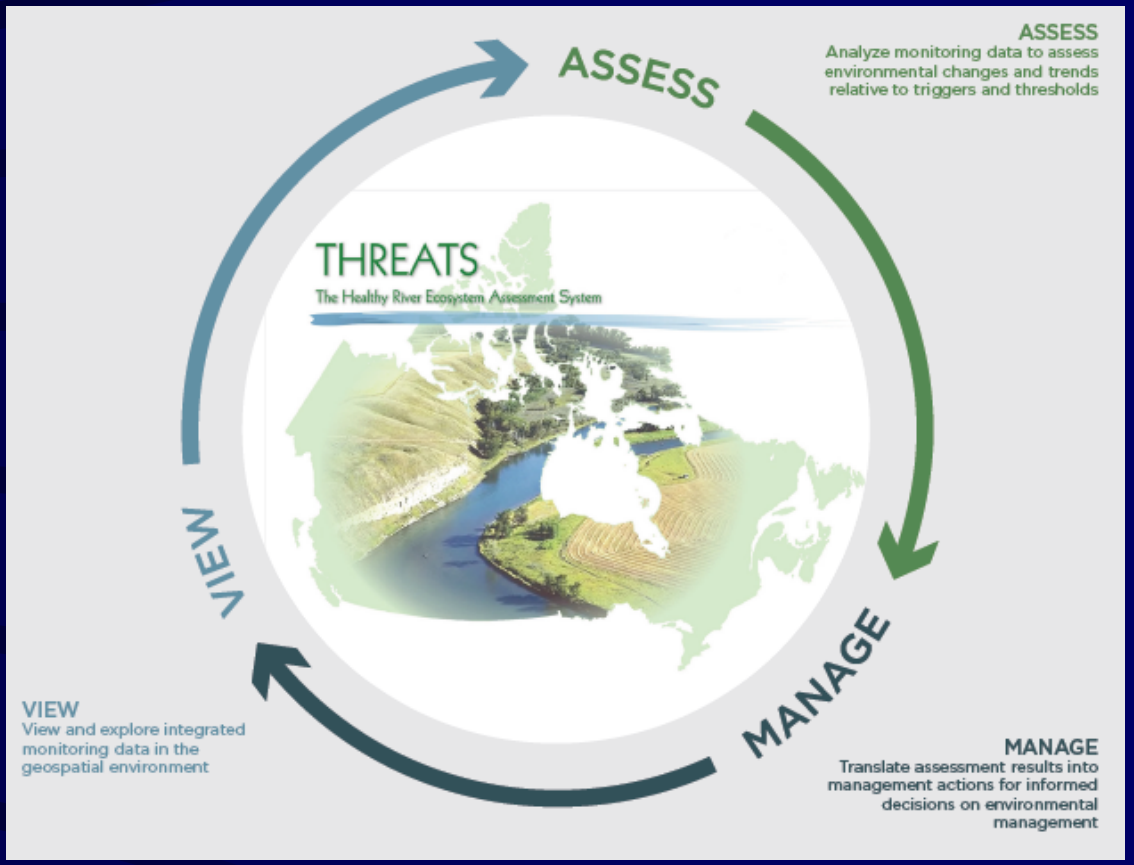
- Is there an alternate scenario?

- Will the predicted state result in exceedances of a trigger and/or thresholds?

Monitoring + Modelling = Cumulative Effects Assessment

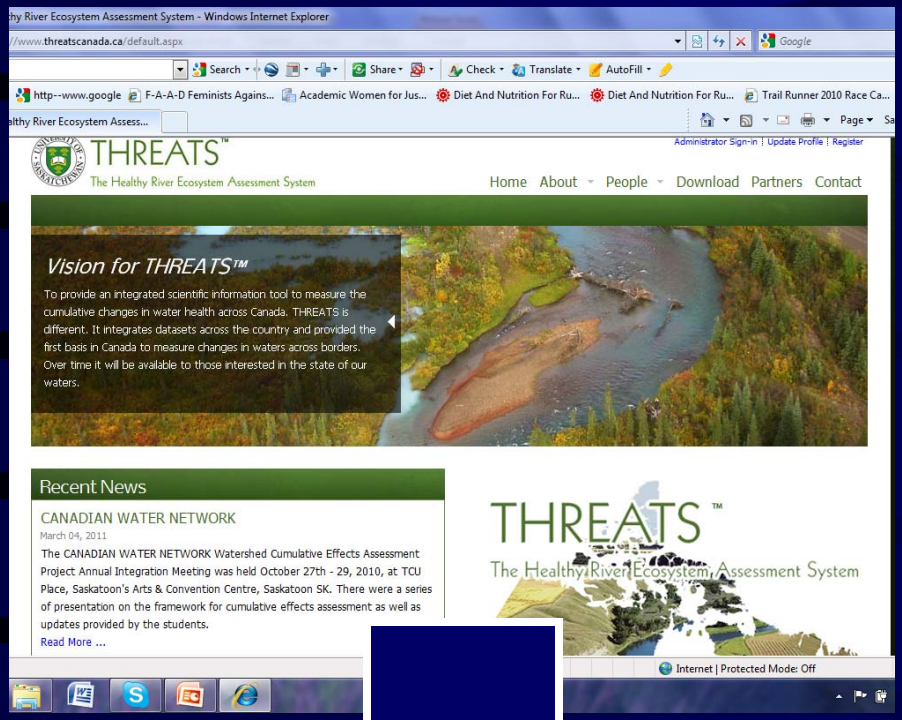


Three Core Functions of the Monitoring Tool



HOW SHOULD WE BE TRACKING OUR "ENVIRONMENTAL BANK ACCOUNT"?

Every year, people keep billions of dollars of their hard-earned income in bank accounts. They have confidence in the process banks have established to track their money, show changes in their balances, and to identify when their funds have reached a critical deficit. Cumulative effects assessment ***(CEA) is the process of tracking the environmental bank account.*** CEA is the process of holistically tracking and predicting environmental change over time and space and relative to limits. Existing approaches have not given Canadians confidence that we know the health of our environment. Are there risks that need to be better managed and mitigated? This research developed an improved framework for conducting CEA and the software needed to support it. The framework was then tested in watersheds across Canada.

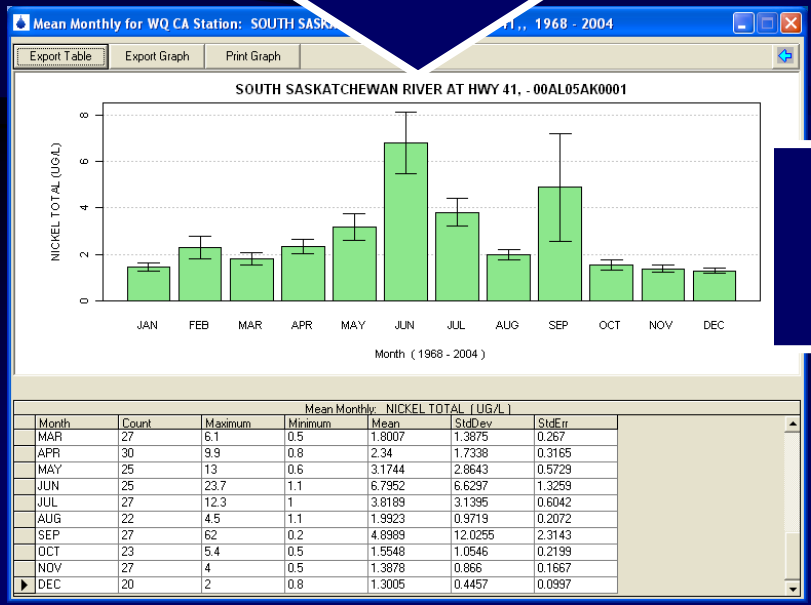


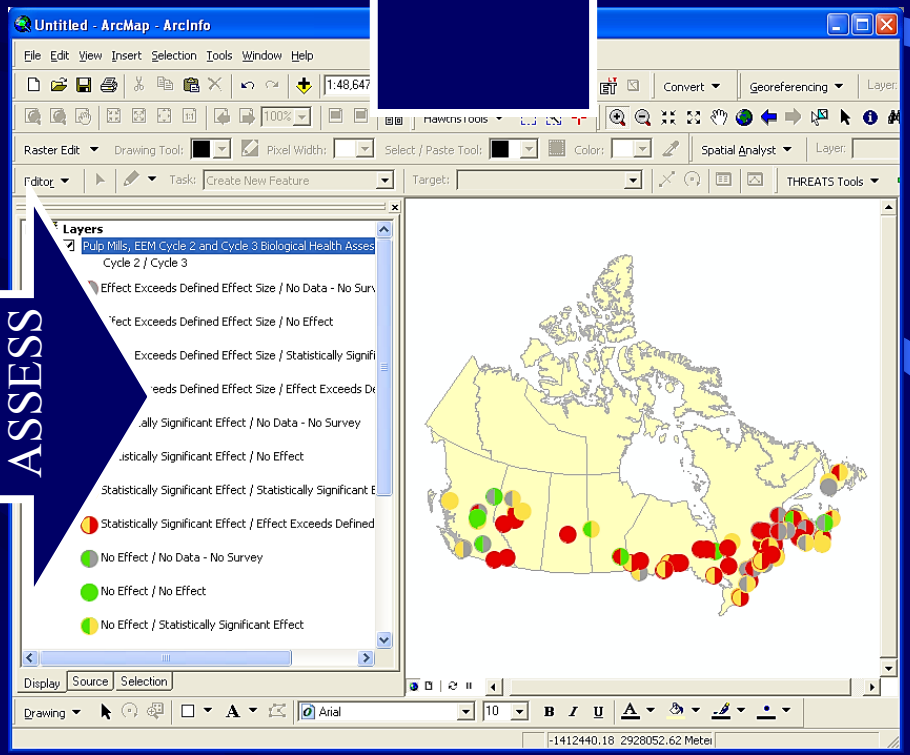
Station	Season	Exceedance	Trend	Action
1	W	No	No	No Action
1	W	Yes (L, M, H)	No	Explore
1	W	No	Yes (better/worse)	Explore
1	w	Yes (L, M, H)	Yes (better/worse)	Act

VIEW

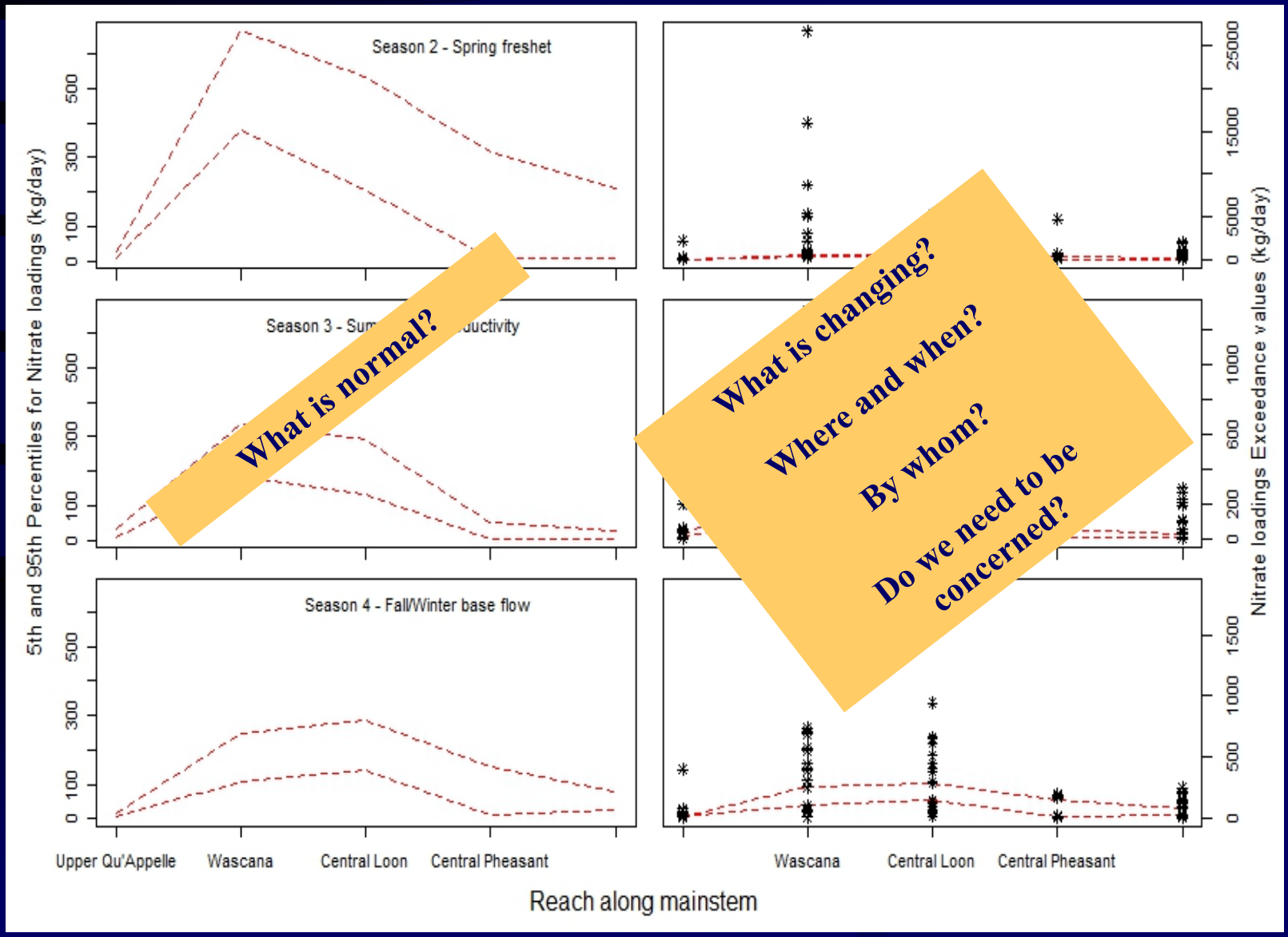
MANAGE

ASSESS

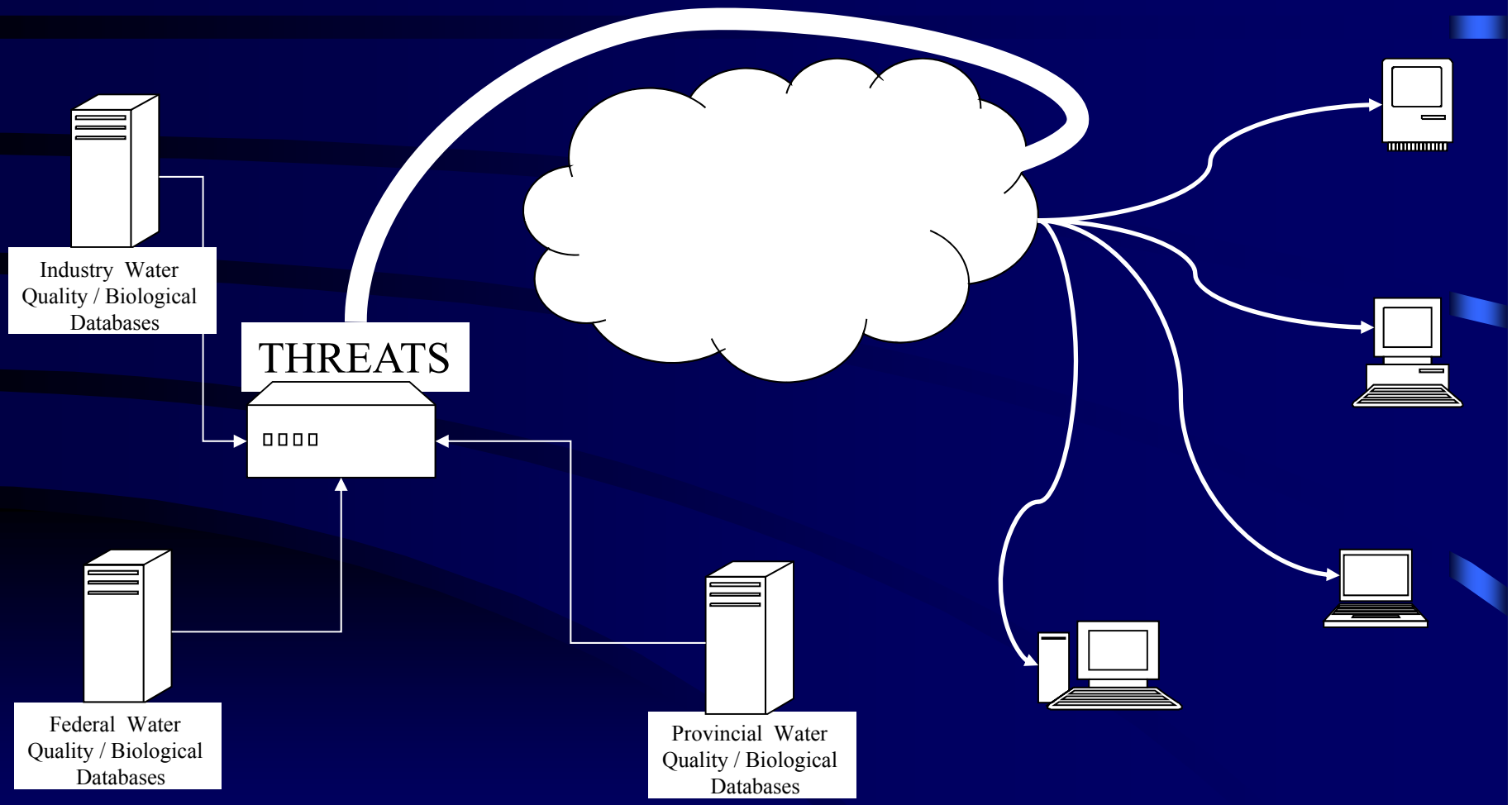




Key Outcomes of Monitoring



The “water weather network” accessible to every person, manager, industry, First Nation, student, researcher, farmer across Canada.



ISWMS-2 + THREATS (On-going)

RESEARCH / SCIENCE DEVELOPMENT SIDE

1) Monitoring focused; Accumulated state assessment.
2) Monitoring assessment linked to modelling baseline and validation.
3) Extension to biological data sets in pilot watersheds (e.g., OBBN).
4) Landscape Change Assessment.
5) Cumulative Effects Assessment.

TECHNICAL SIDE

1) Integration with **ISWMS and CANWET – 5.**
2) Accommodate increased data clouds, on-the-fly data entry, web-based access for public users.

Relevant Lake Erie Watershed and CANWET Team Experience

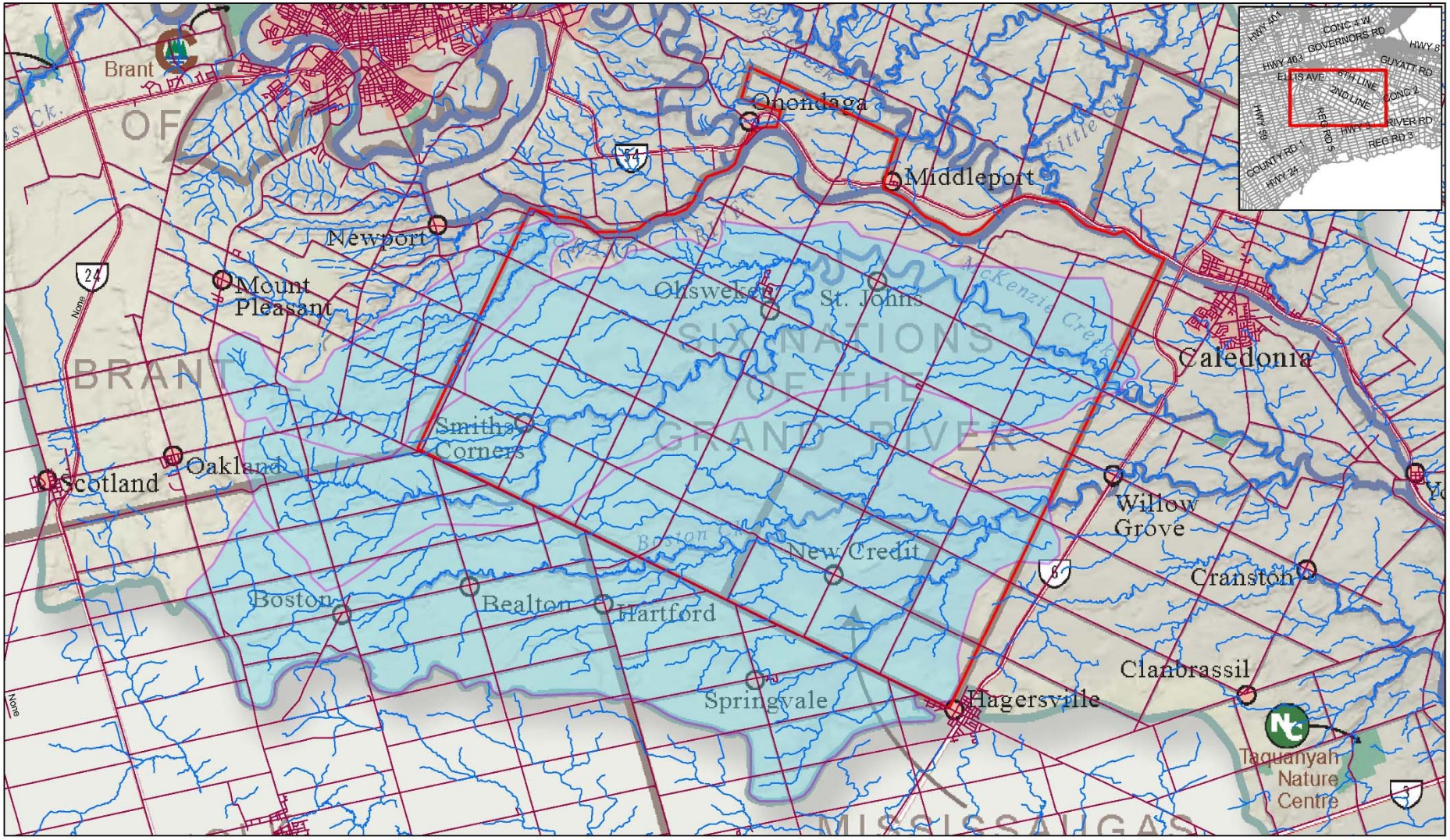
1) Ontario's First Nations (*On-going*)

2) Government of Ontario (OMAFRA, 2011)

3) Dr. Barry Evans (Use of MapShed on U.S. Projects)

4) Environment Canada Project (*On-going*)

#1: Six Nations (Grand River Watershed): *On-going*



GENERAL NOTES	BENCH MARKS TEMPORARY BENCHMARK	NO	REVISIONS	DATE	APPROVED	TRCA ENGINEER DATE	Legend Drainage Area Study_Area	Six Nations DRAINAGE AREA	GREENLAND® Consulting Engineers 120 Hume Street Collingwood, Ontario, L9Y 1V5 Tel: (705) 444-8805 Fax: (705) 444-5182 E-mail: greenland@grnland.com Website: www.grnland.com	STRAGIS Environmental Services Inc. SCALE HOR 1:100,000 VERT DESIGN G. YANG DRAWN G. YANG REVIEWED D. MOSS DATE MARCH 2014 FIGURE NO Figure 2 SHEET NO 3273

Issues of Concern and Other Considerations

- Current research about water taking concerns about all creeks. For example, McKenzie Creek has been identified as an area of concern under the Ontario Low Water Response Plan;
- 1975 Drainage Study (last one completed);
- 2004 GRCA Groundwater Study and GIS hydrogeological database;
- 2007 (Draft) Source Water Protection Plan;
- 2010 LiDAR – GIS mapping database;
- 2014 Grand River Watershed Management Plan;
- Consideration of climate change impact constraints (or opportunities);
- Cumulative watershed impacts from all water takings;
- Prior work program support from the Environmental Commissioner;
- Assessment of riparian drainage effects from the Master Drainage Plan upon downstream and upstream areas, including, New Credit, Brant, Haldimand and Norfolk Counties;
- Consideration of Federal Acts and Regulations that only apply; and,
- Regard for as-required off-reserve legislations and regulations.

Proposed Science-based MEP Approach

- Prepare CANWET™ Study Area model to first identify:
  - Watershed boundaries;
  - Land uses;
  - Soils;
  - Stream network parameters; and,
  - Overland flow drainage paths.
- Import model data into other modelling tools that have also been developed by the Greenland Group.
- Field check inventory (e.g. ditch systems and culverts), including, training of and assistance by CO-OP students.

  - Training/data collection: (Fall/14 through Spring/15)
  - Collect streamflow data (Spring – Fall/15:TBC)

Study Field Activities with Assistance from Community Members

- Inventory and surveying of culvert crossings.
- Survey typical watercourse cross sections “under water” to augment available LiDAR database.
- Assist Greenland Group with stream flow and weather gauge installations for required model calibrations.
- Download monitoring data for the Greenland Group.

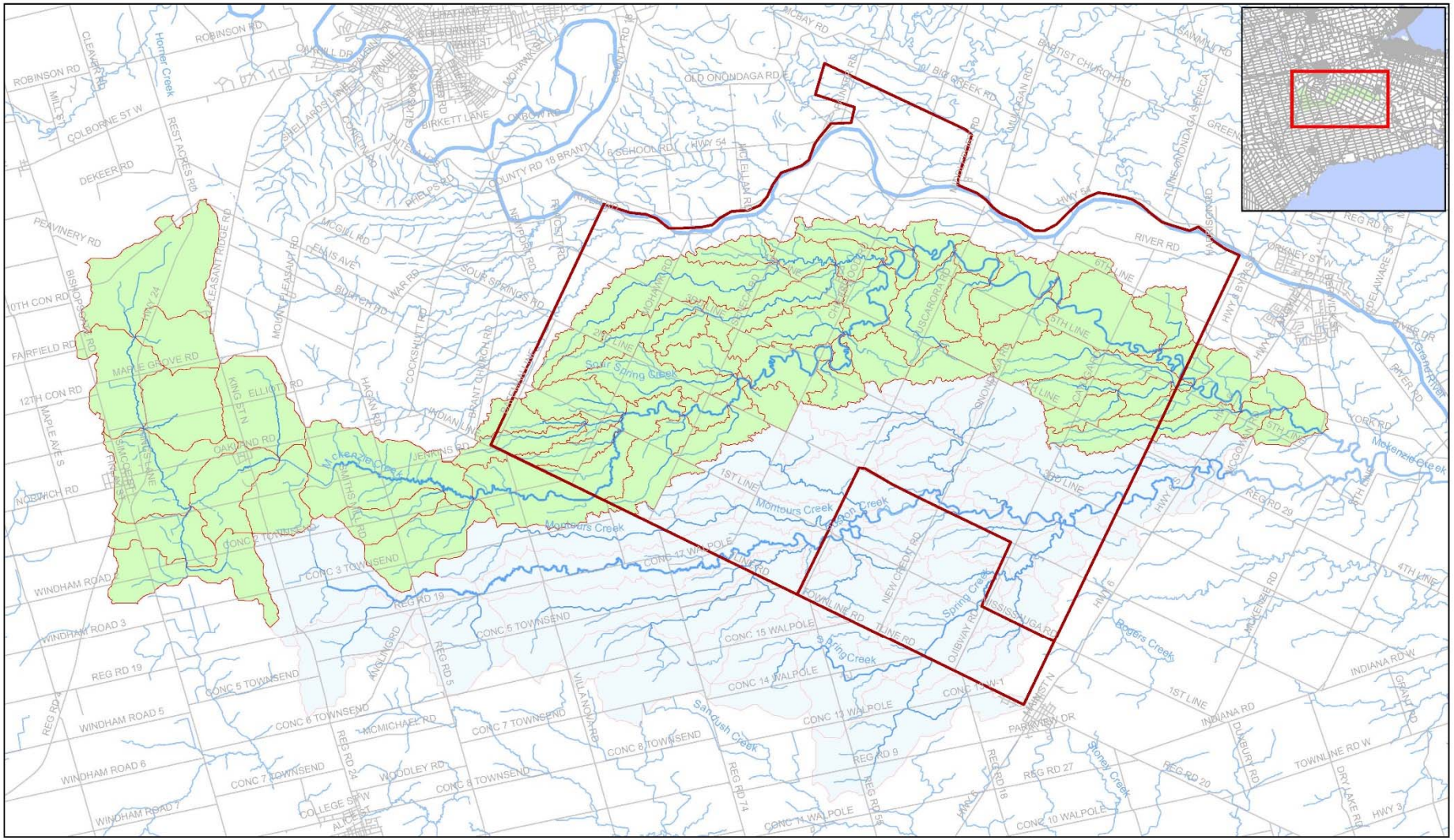
Proposed Sixth Nations MEP Deliverables

- Integrated Plan similar to a Source Water Protection Plan **and** effective strategies for water quality improvements.
- Flood Impact Strategy:
  - Extent of flood inundated areas.
  - Mitigation strategy - which culverts or channels need to be improved to receive the best benefit?
  - Other improvements for the most flood vulnerable areas?
- Regard for climate change Impacts (quantity and quality)
- Low flow condition analysis with identification of impacts to agriculture, water quality, and water takings.
- Seasonal water storage strategy during high flow periods to augment low flow conditions and consideration of evaporation (and any other water budget) impacts.
- All alternatives examined using Cost/Benefit decision matrix.

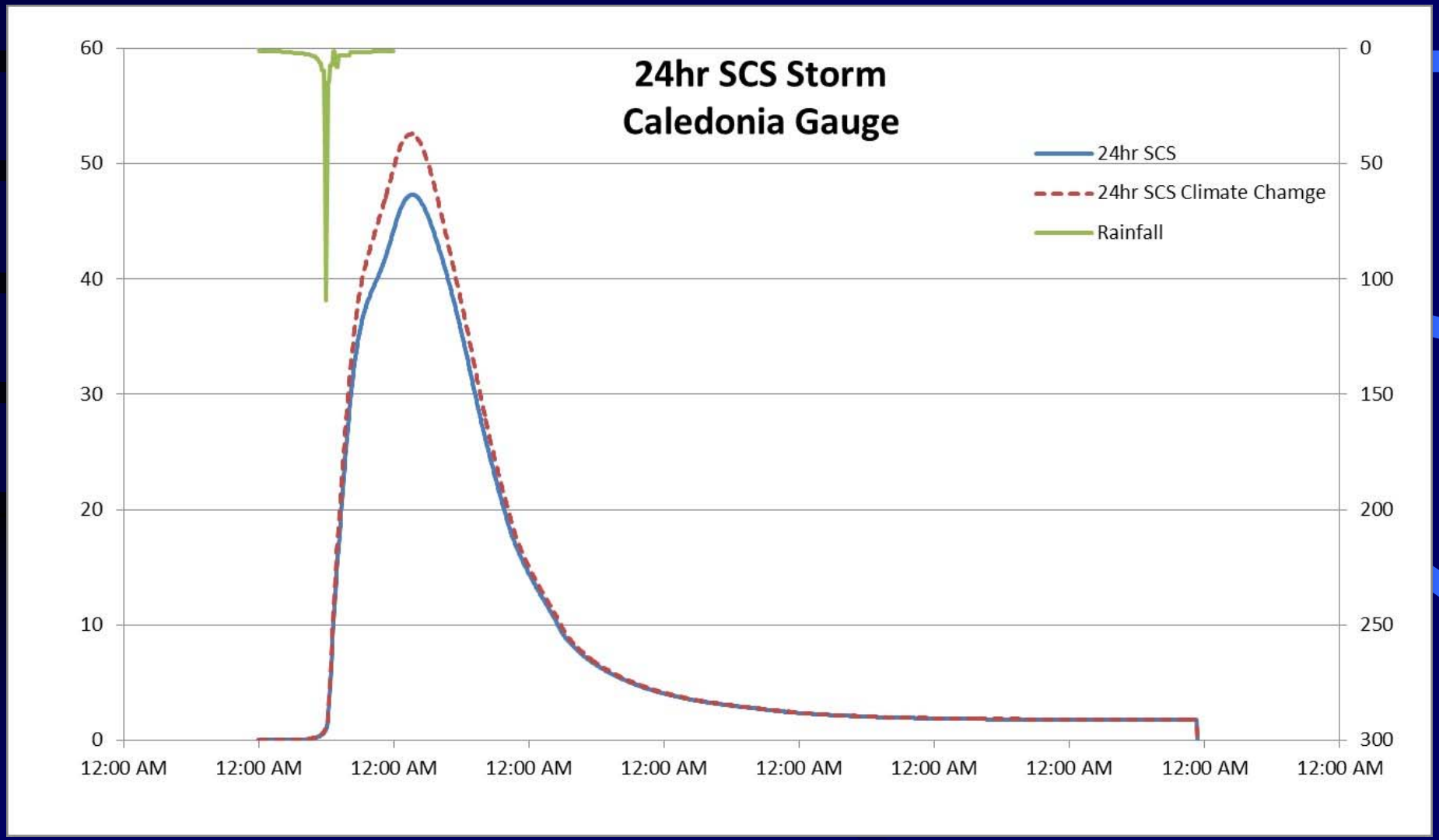
Proposed MEP Deliverables (cont'd)

- Training and hiring of Six Nations community members (CO-OP students) to assist with collecting field information, flow gauge data, weather data and water sampling data.
- Development of an 'Adaptive Management Strategy' to be implemented long-term by the Six Nations Council with as-required technical support by the Greenland Group.
- Assist in developing a comprehensive Business Case to help identify new funding sources for identified capital remedial works and drainage infrastructure. The document format can also be presented by the Six Nations Council to other communities in Canada and as-part of a post-study overview, education and information transfer forum.

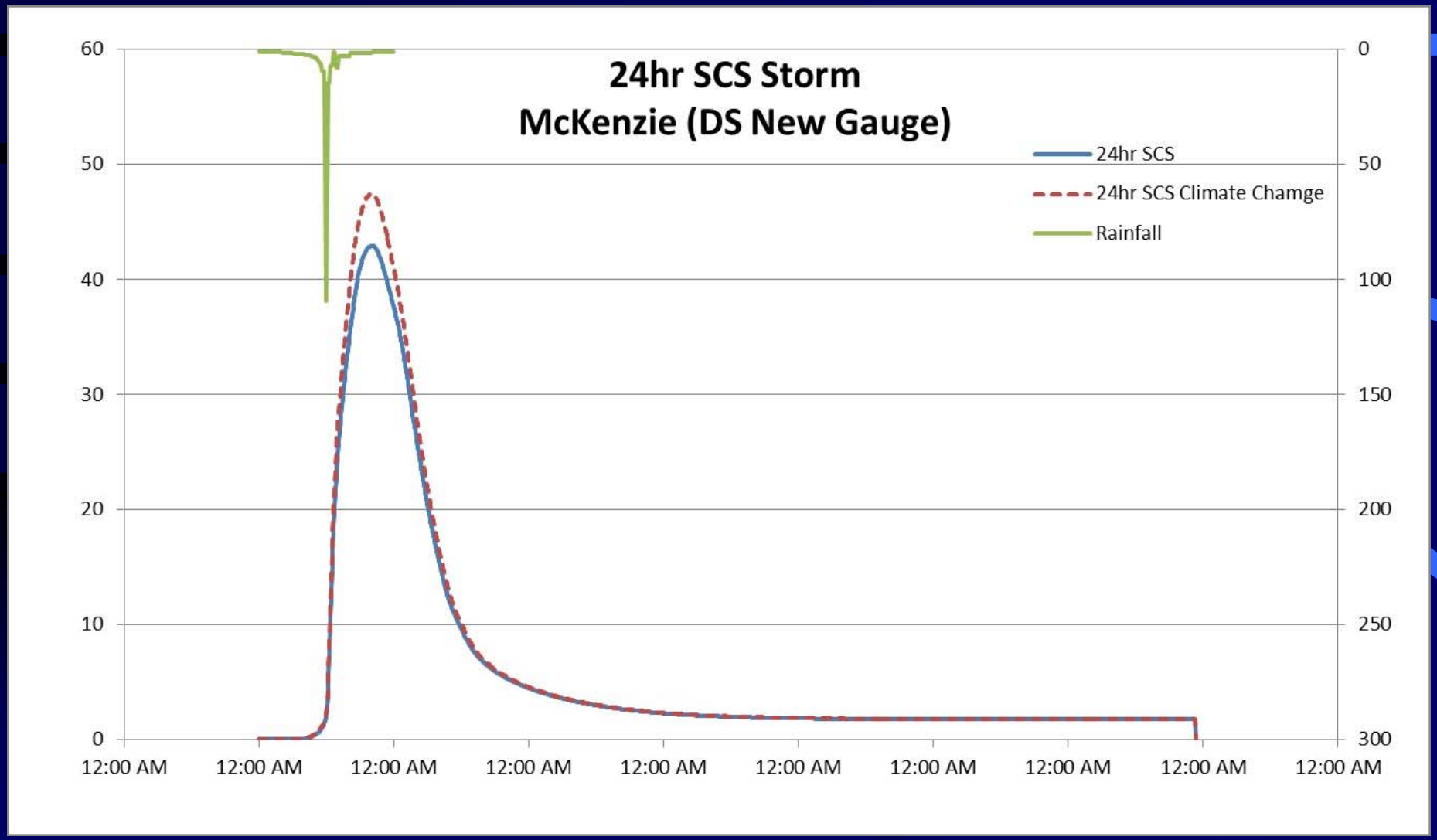
Master Drainage Model Catchment Delineation (McKenzie Creek Watershed)



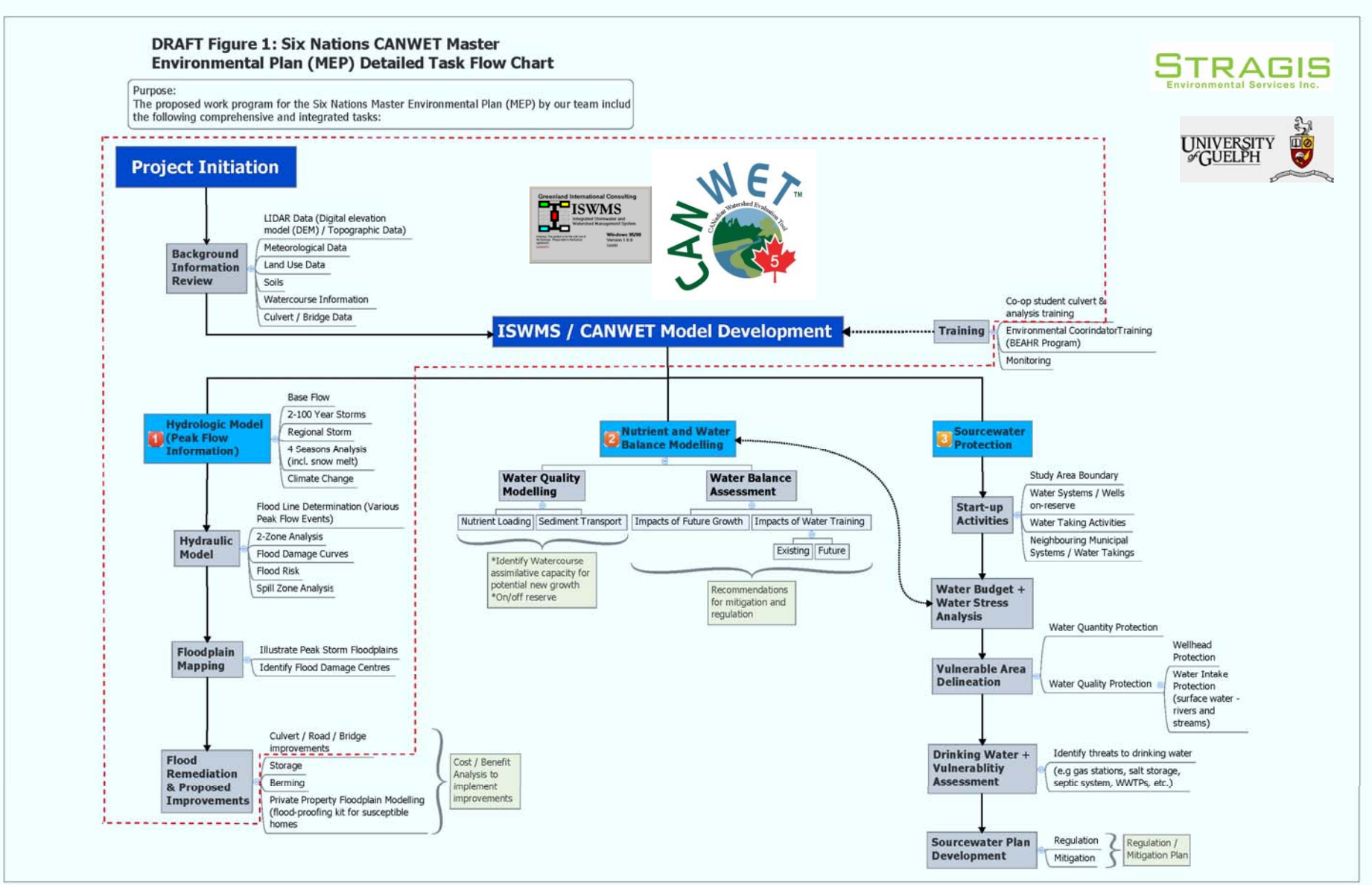
Sample: 100 Year Master Drainage Model Simulation and Comparison with Climate Change Scenario



Sample: 100 Year Master Drainage Model Simulation and Comparison with Climate Change Scenario (Cont'd)



#1: Six Nations (Grand River Watershed): *On-going*



#1 (Cont'd): Mitacs Aboriginal Communities Engagement Pilot Project

(Approved: Start-up Fall 2015)

<u>Project Title:</u> Development of a "Clean Water Plan" by Ontario First Nations Communities (Using CANWET – 5) and in Response to Bill S-8 (Safe Drinking Water for Canada's First Nations Act)

#2: Great Lakes Basin Decision Support Framework (For OMAFRA, 2011)

A. Jurisdictional scan;
B. Development of a decision support framework;
C. Scope refinement and decision criteria development;
D. Weighting of criteria and selection of indicators; and,
E. Multi-criteria decision support analysis using geo-processed data.

#2: Great Lakes Basin Decision Support Framework (For OMAFRA, 2011)

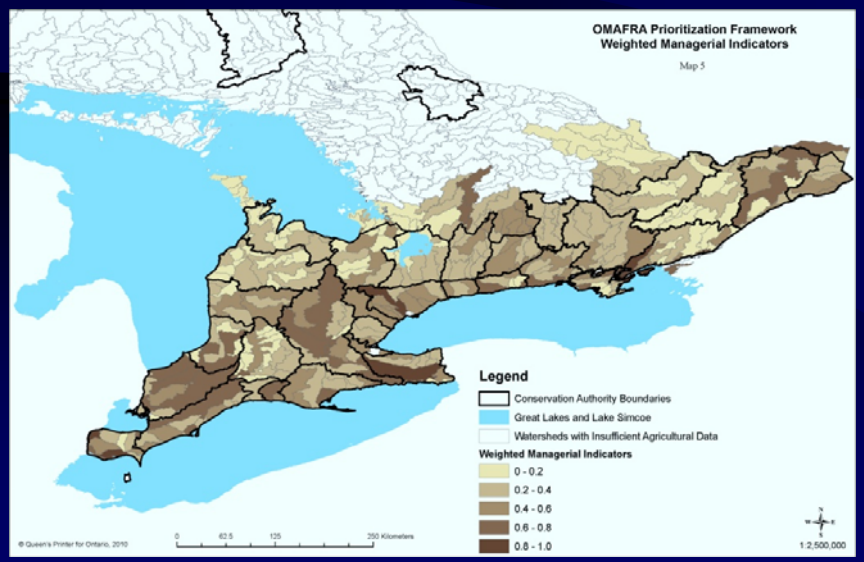
Project Objectives:

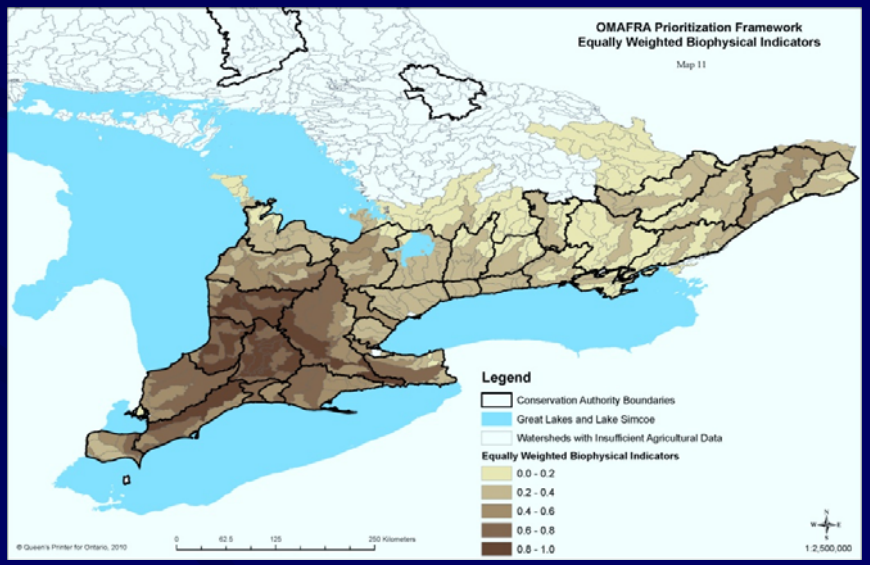
- High level approach for prioritizing agri-environmental program resources (people or funds);
- Transparent, defensible, credible, repeatable, adaptable, objective, information based, easily communicated to and understood by stakeholders, with input from Key Informants;
- Geographic and issues basis; and,
- Intended for Great Lakes Basin water quality programming but applicable to other programs.

Final Report Maps Presented:

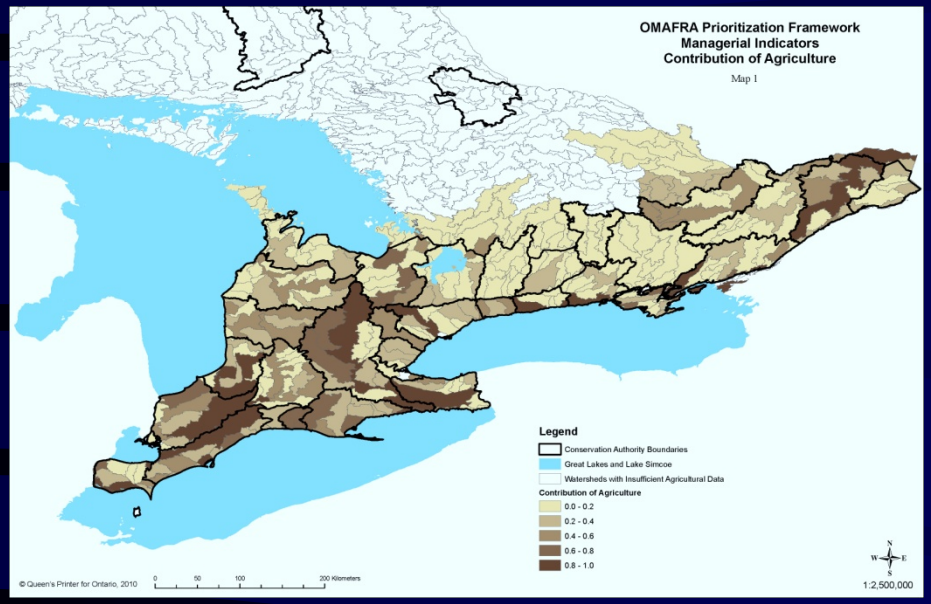
- Concerns at a high level (sum of products of criteria weight and indicators);
- Showed sensitivity, pressure, current impacts; and,
- Did not show practice / program specific improvements or implementation that would be needed to change water quality.

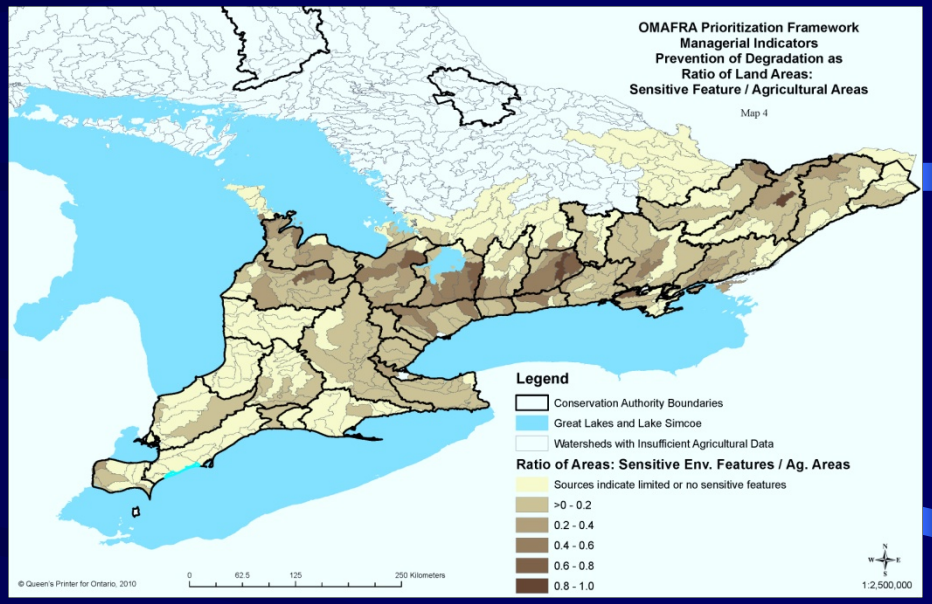
Aggregated Indicators Maps (Final Report: 2011)

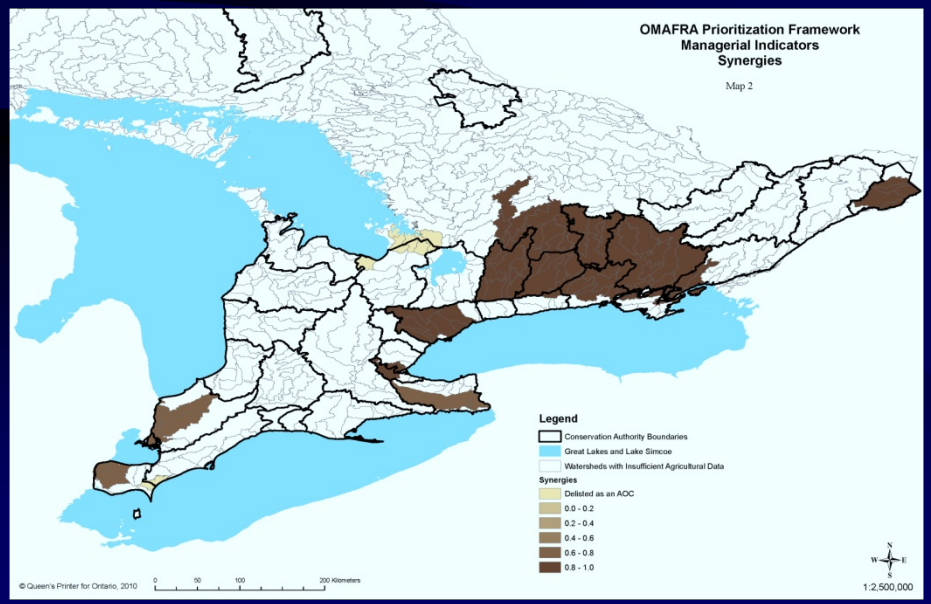


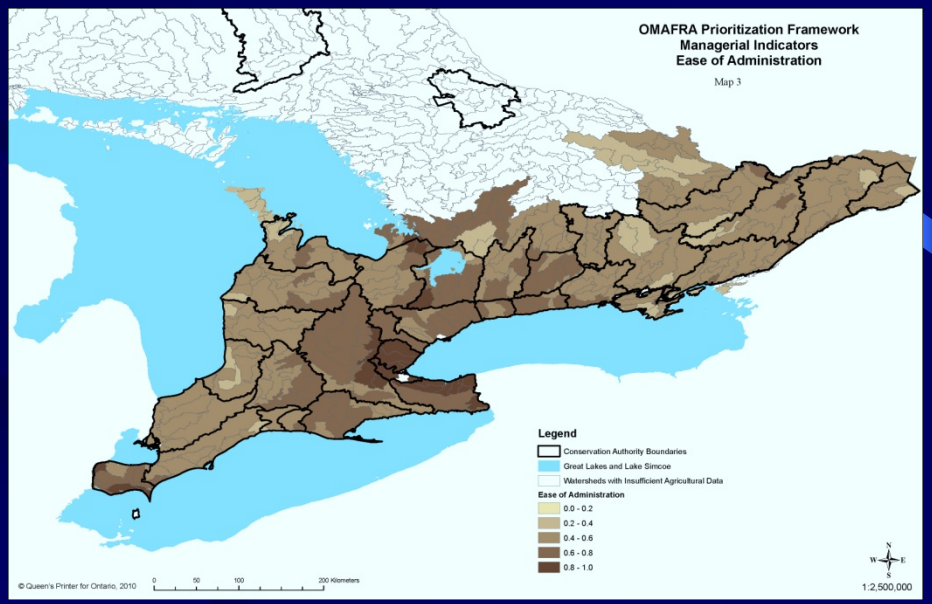


Managerial Indicators

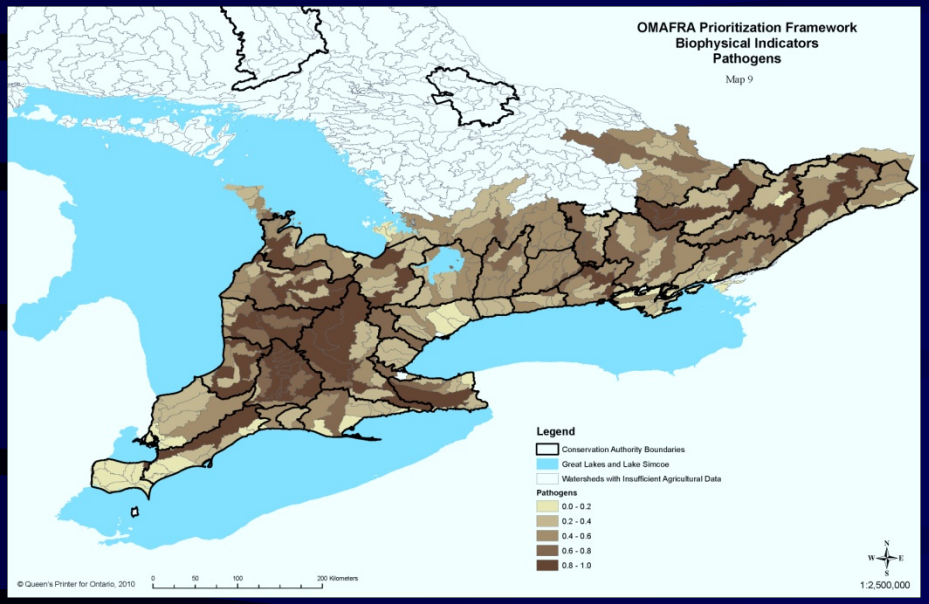


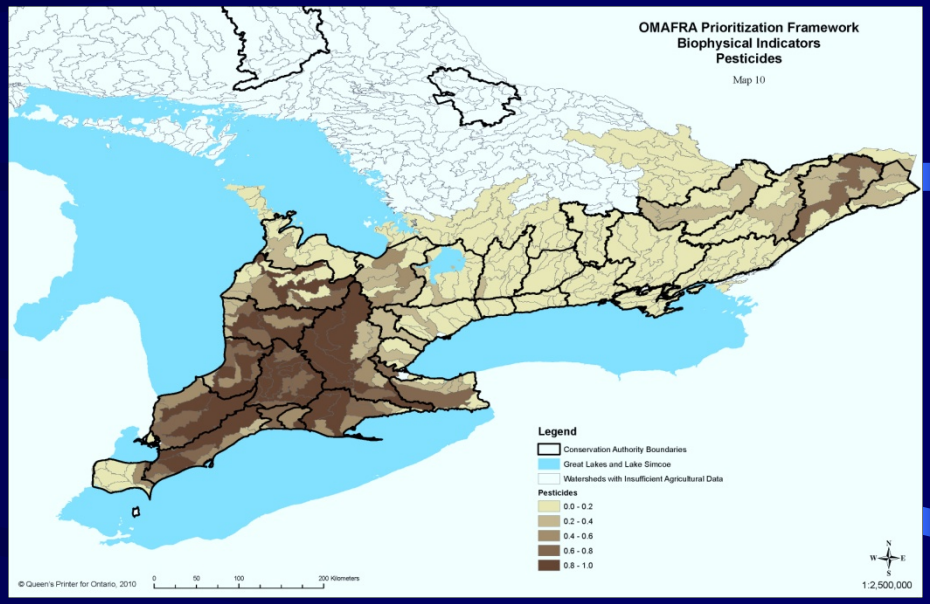


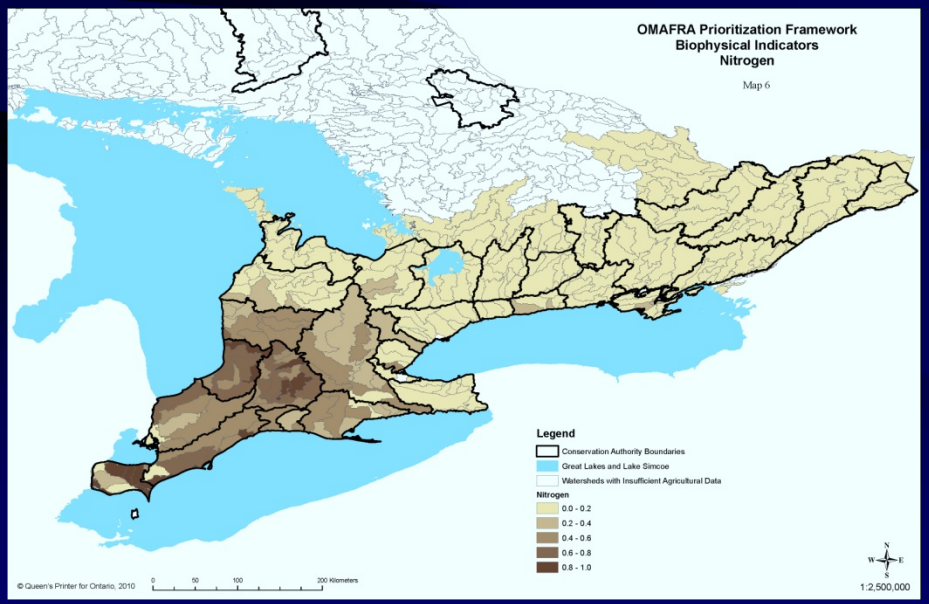


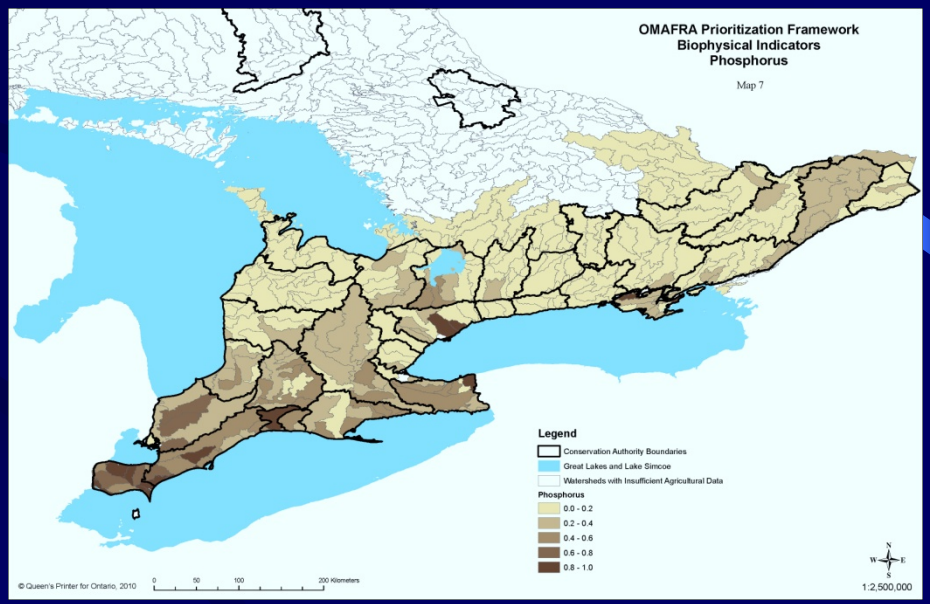


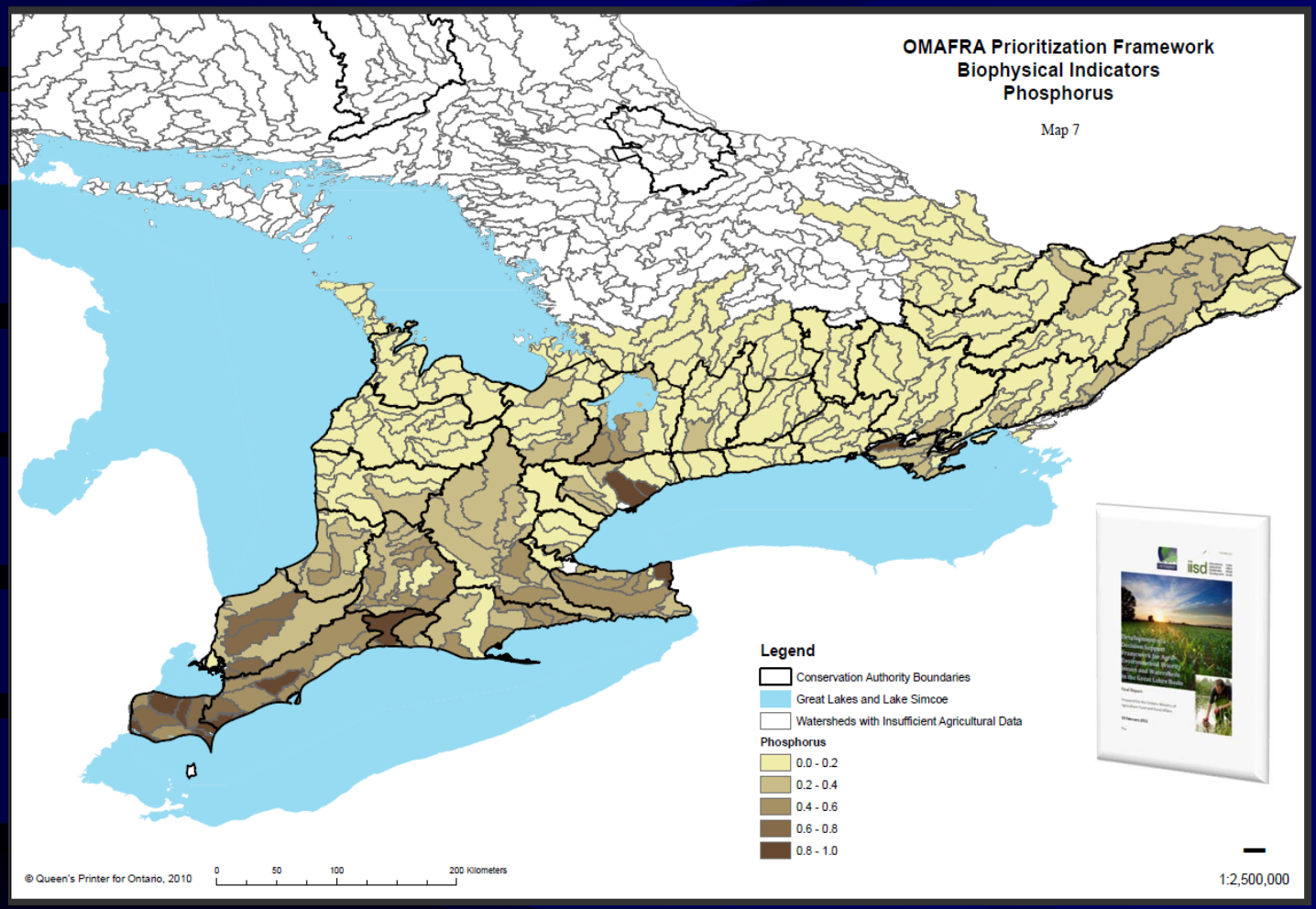
Bio-physical Indicators







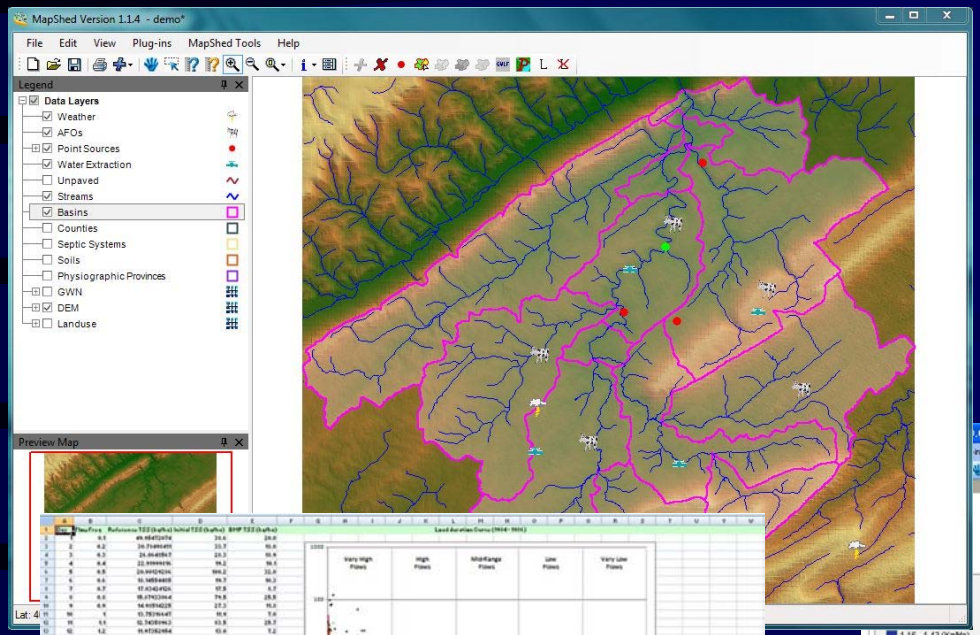


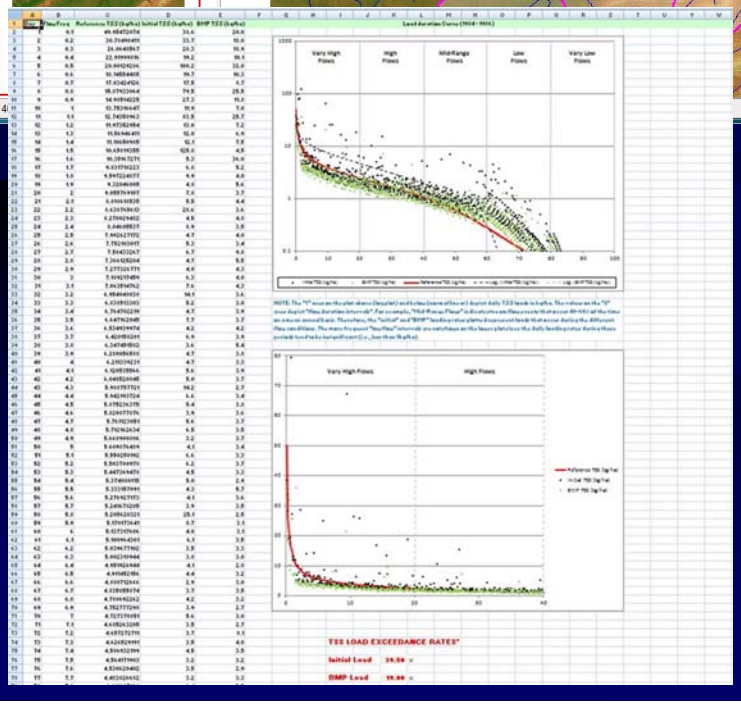


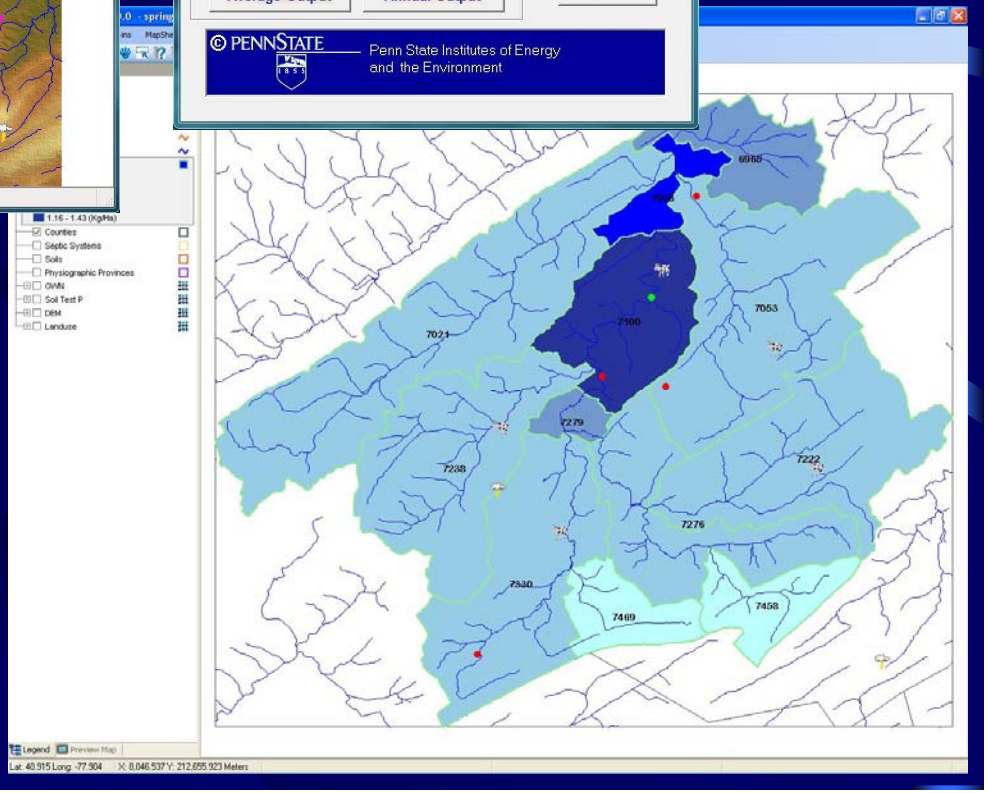
Relative potential impact of phosphorus from agricultural practices on Great Lakes Basin water quality (Source: OMAFRA – Greenland, 2011)

This type of indicator is now being used for Greenland's on-going Environment Canada project with the University of Guelph to determine the relative contribution of non-point source phosphorus loading and therefore the relative economic implications by watershed that might be expected for stakeholders operating within each watershed area. However, it should be noted that these indicators do not directly consider loads delivered to the Great Lakes. However, the pattern sets up a basis to conduct further modelling and analysis to estimate baseline loads, load reductions by BMPs, and associated economic costs.

#3: Examples of MapShed ("CANWET's Cousin") Use for Lake Erie and Other U.S. Watersheds







CANWET's "U.S. Cousin"

PENNSTATE

MapShed

MapShed Overview
MapShed Downloads
MapShed Registration
Report a Bug

As of August 2011, the AVGWLF watershed modeling software that has been available since 1999 (including GWLF-E and PRedICT) will no longer be supported. It is being replaced by MapShed, which essentially duplicates the functionality of AVGWLF within a non-commercial GIS software environment called MapWindow. Both the MapWindow software, as well as the customized interface and related modeling tools associated with MapShed, are available for download via this site. As described elsewhere, the core watershed model (GWLF) has also been considerably enhanced to provide additional capabilities not included in the older version of the model used in AVGWLF.

psiee penn state institutes of energy & the environment

If you have any questions about **MapShed**, please contact one of the following individuals:

For general distribution, use questions, or technical support issues contact contact:

Dr. Barry M. Evans
Director: GIS Support Center
Penn State Institutes of the Environment
The Pennsylvania State University
128 Land and Water Research Building
University Park, PA 16802
(814) 865-3357

For program installation questions or errors, or technical support issues contact:

Kenneth J. Corradini
Penn State Institutes of the Environment
The Pennsylvania State University
1 Land and Water Research Building
University Park, PA 16802
(014) 865-6966

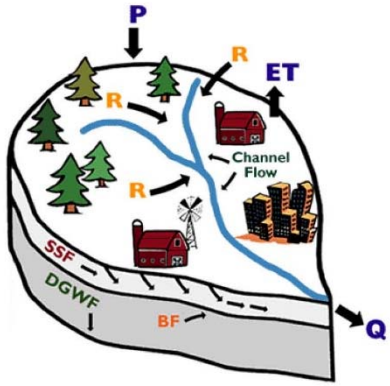
MapShed

VERSION 1.1

USERS GUIDE

Barry M. Evans and Kenneth J. Corradini

Penn State Institutes of Energy and the Environment
The Pennsylvania State University
University Park, PA 16802



April 2012
(Updated June 2014)

Brief History

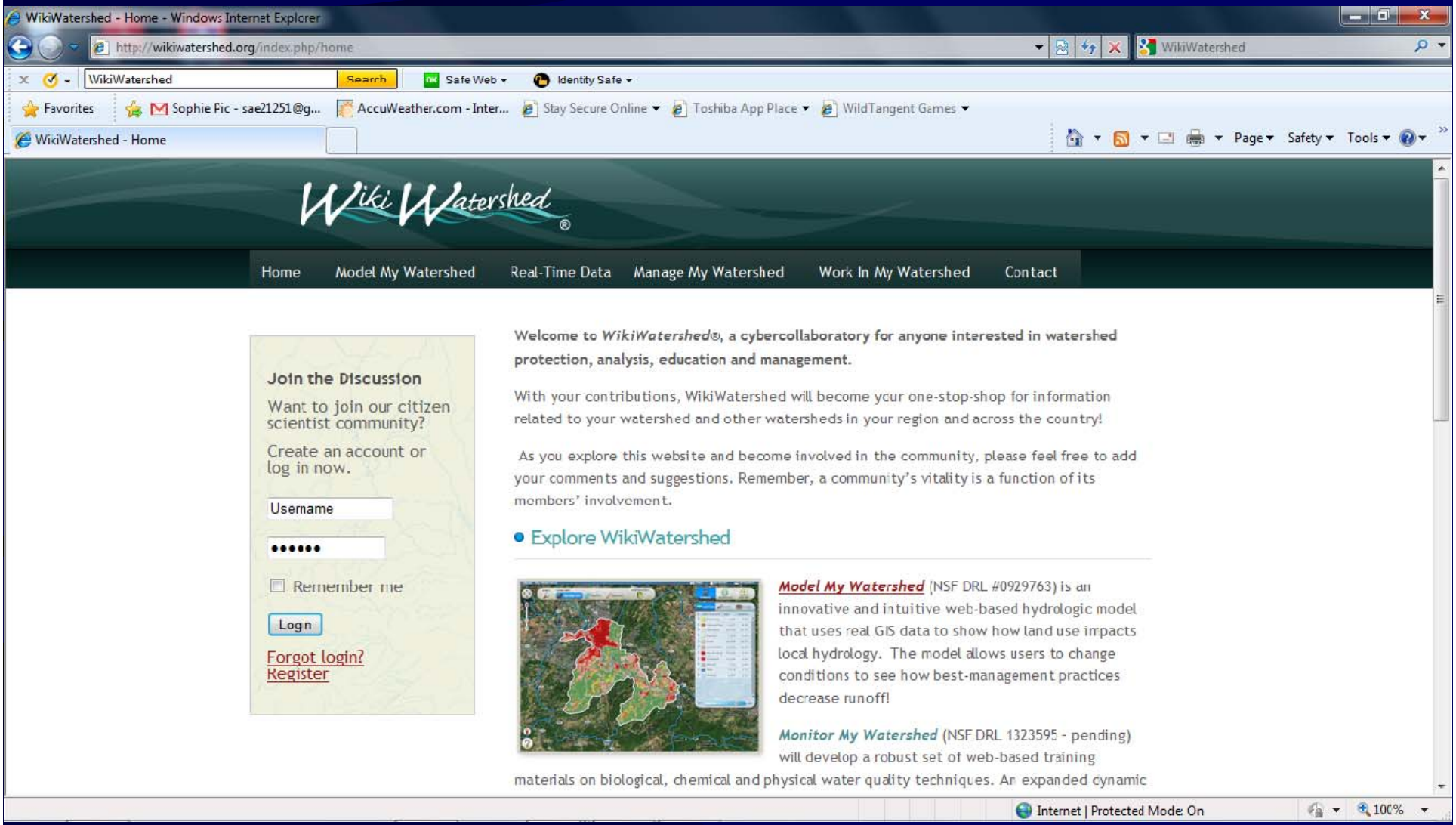
- Core simulation model used is GWLF, which has been substantially enhanced over last 15 years (now GWLF-E).
- Initial modeling application developed using ArcView 3.x GIS software (AVGWLF).
- AVGWLF has been used by PaDEP and a number of other government and research organizations since 1999.
- Efforts to re-configure application to work in non-commercial GIS platform (MapWindow) began in 2010.
- First “non-beta” version of MapShed released to public by end of May 2012.

Brief History / Highlights

- AVGWLF and MapShed are also used extensively in New York and New England to support TMDL/watershed assessments (funding from USEPA and NEIWPCC).
- AVGWLF and MapShed are used by consultants and other groups throughout US and other countries (e.g., Mexico, Spain, Israel, India, eastern Europe, etc.).
- State environmental agencies in Michigan and Ohio are considering use of MapShed to support TMDL projects.
- Efforts are now underway to incorporate MapShed into a web-based platform.

Other Major Projects

- EPA-funded project to customize AVGWLF for EPA Region 6 (most of southwest U.S.).
- EPA-funded project to evaluate nitrogen loads generated within Connecticut River Basin and delivered to Long Island Sound as part of TMDL project.
- Evaluation of non-point source loads in 428 sub-watersheds of the Delaware River Basin as part of basin-wide restoration project funded by the William Penn Foundation.
- Since 2003, on-going collaboration with the Greenland Group (and its Canadian university partners) in the continuing development of CANWET.



STROUD WATER RESEARCH CENTER

wikiwatershed.org

#4: Development of Policy Options & Lake Erie Demonstration Use of the CANWET Decision Support System (*On-going)*

2015
January
25

Evaluation of Policy Options to Achieve Nutrient Reductions from Canadian Sources to Lake Erie

Prepared for:
Environment Canada

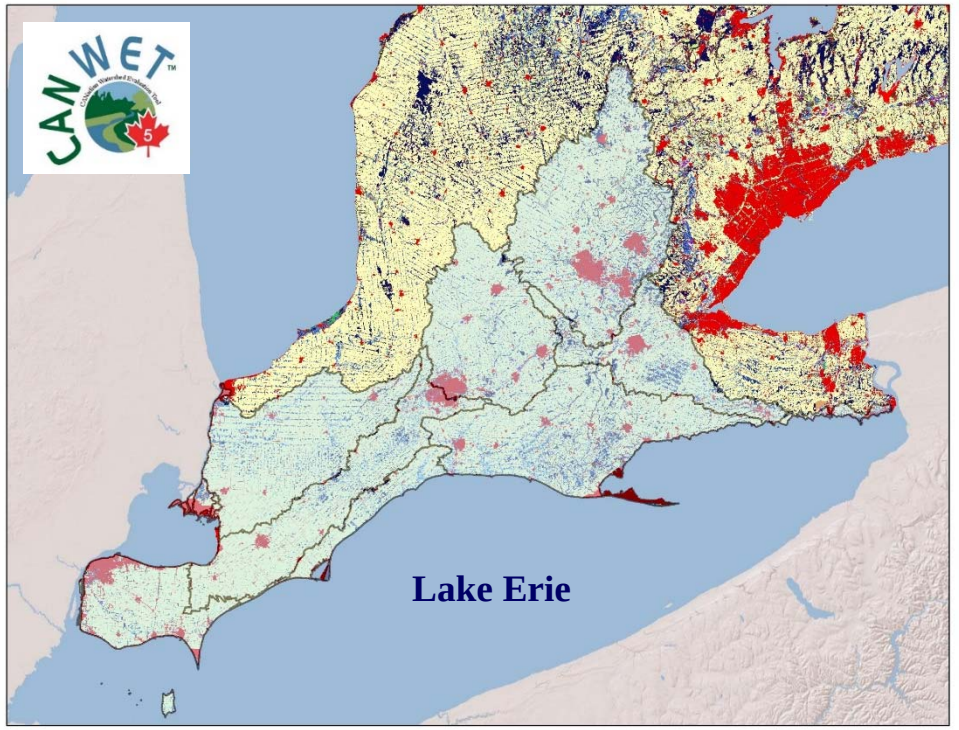
Submitted By:

Greenland
International Consulting Ltd.

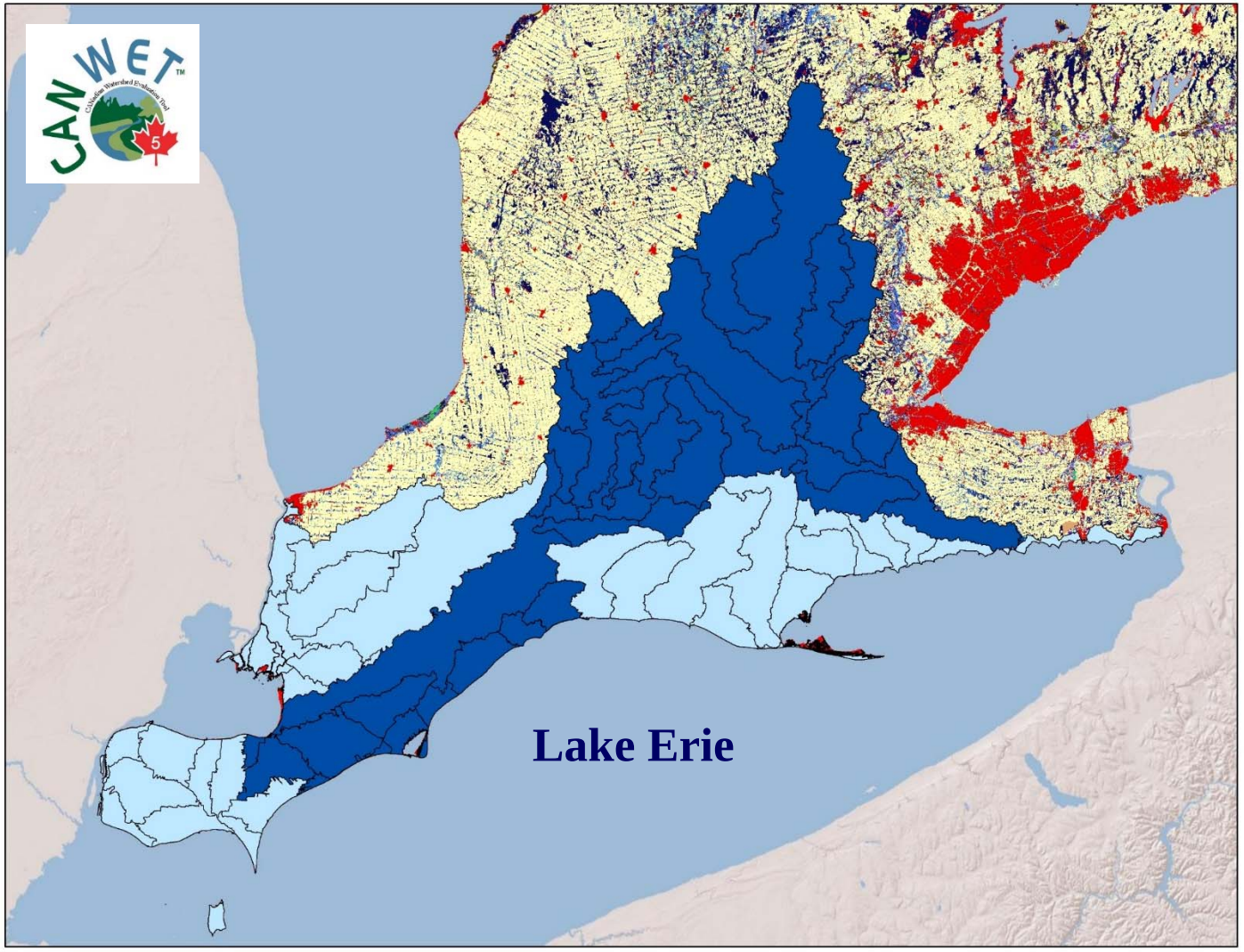
In Association With:

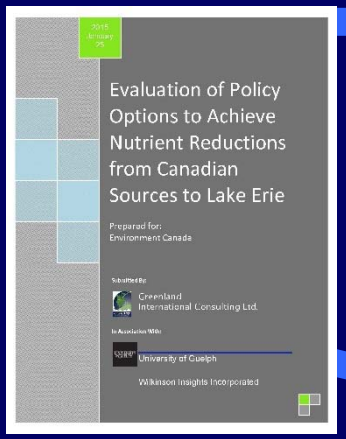
University of Guelph

Wilkinson Insights Incorporated



Lake Erie Quaternary Drainage Areas (NOTE: 'Dark Blue' Catchments Within Grand River and Thames River Watersheds) Preliminary Modeling Completed with CANWET (*On-going*)





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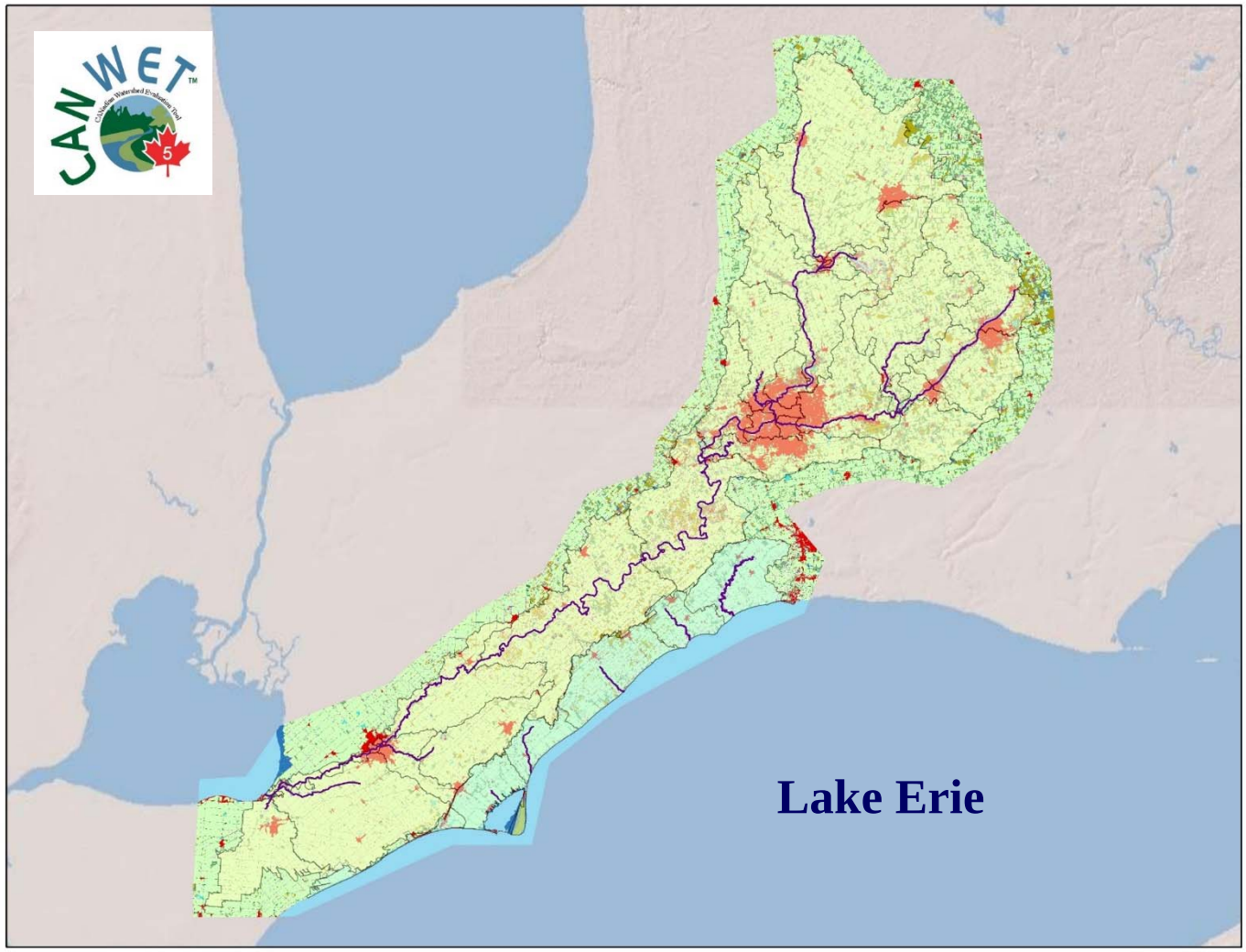
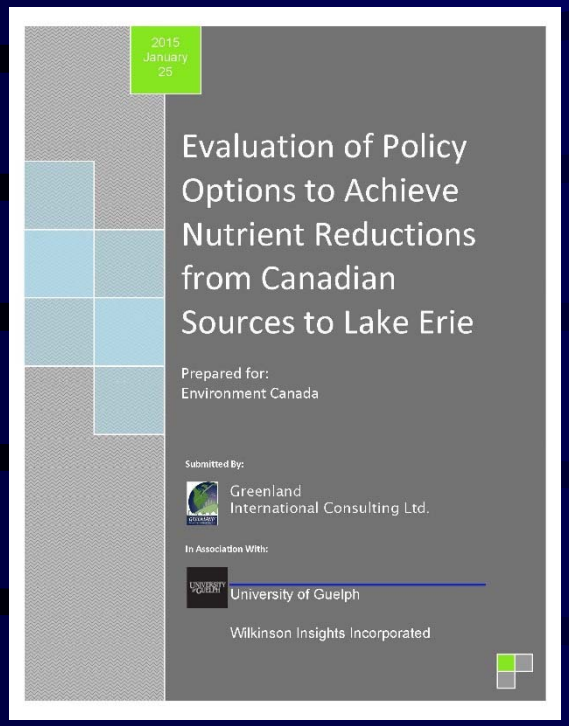
Example: Development of CANWET Model for the Thames River Watershed (*On-going*)



- Map shown to the left includes integration of OMNR and AAFC land use layers (also @ 15m resolution)

- Annual crop types and urban development details derived using Landsat-8 satellite imagery

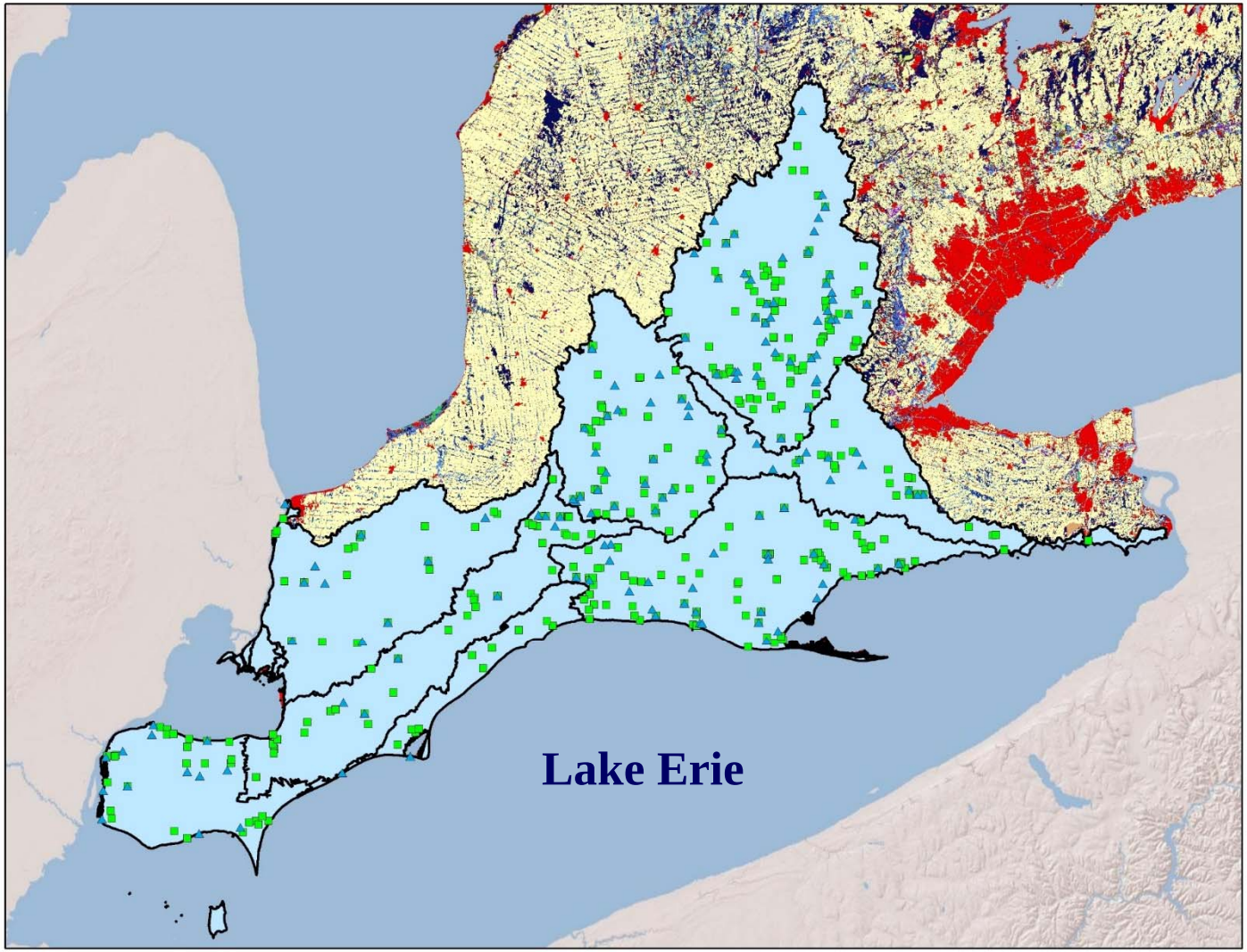


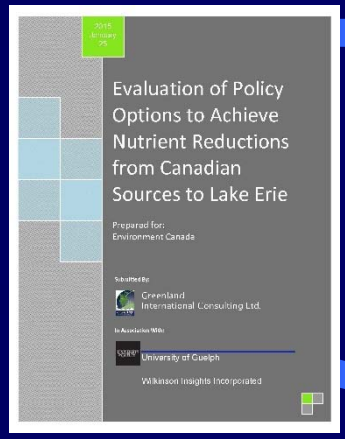
#4: Development of Policy Options & Lake Erie Demonstration Use of Latest CANWET Decision Support System

(Completed CANWET Processed Data To-date)

- Land Use (Integration of OMNR and AAFC data)
  - 15m resolution, annual crop types, annual urban development areas;
- Detailed Soil Types;
- Agricultural Tile Drainage;
- Sewage Treatment Plants & Other Point Sources;
- MOECC Permit to Water Taking Records;
- Revised Universal Soil Loss Equation (RUSLE)
  - Regional parameterization; and,
- Animal Population Estimates
  (NOTE: Derived from Federal Agriculture Census)

Final Comments: Present (and Past) Monitoring Network
(Includes: 146 Flow Stations and 358 Water Quality Stations)





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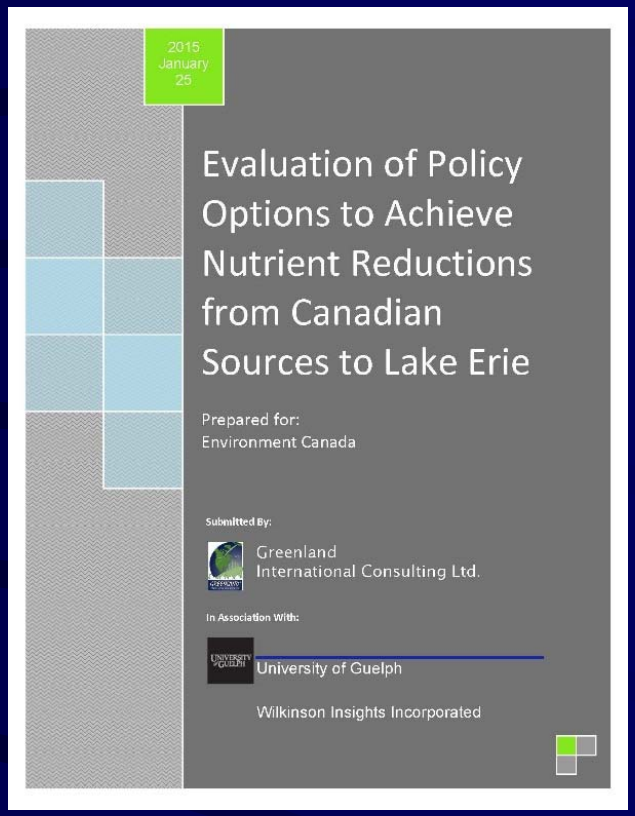

CANWET Video (+/- 1 Minute) About Latest GIS Interface with Automatic Calibration Routines

(NOTE: Current Lake Erie Project Focus)

Teleconference and Webinar Information Meeting Hosted by the International Joint Commission (IJC)

Ottawa, Canada
(May 20, 2015)

Presentation by the University of Guelph and Greenland® Group About the CANWET Model

Thank-you!