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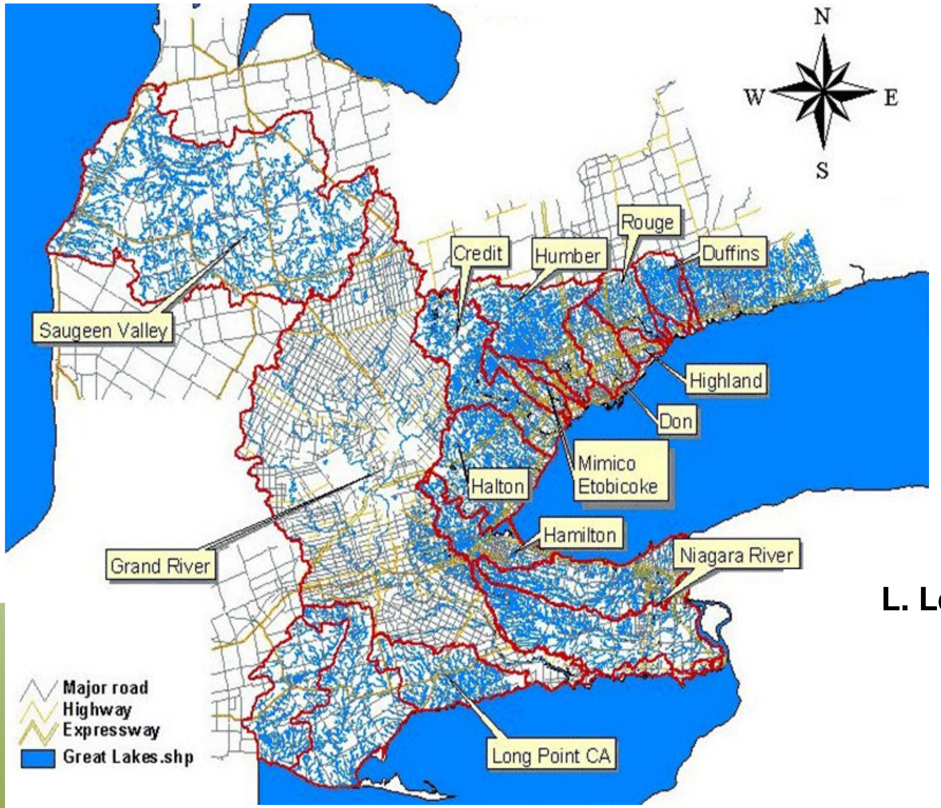


NPS Watershed Modeling- Inflows for Lake Models

Applications:

GLAP: Lake Ontario*

GLNI: Lake Erie**

L. Leon, W. Booty, I. Wong, C. McCrimmon, P. Fong

SWAT Modeling Workshop

University of Michigan, Ann Arbor, US

18-19 Mar, 2014

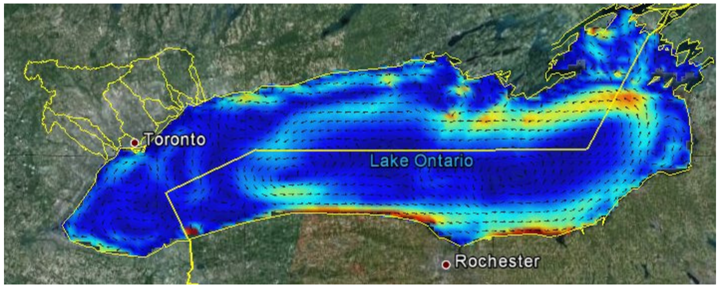
*GLAP: Nearshore (Pickering: Duffins-Rouge)

**GLNI: Lake Erie Eastern Basin (Grand R)

Integrated Watershed-Lake Modelling

Objective: suitable NPS models to assess water quality and evaluate P loads of Canadian tributaries into selected nearshore zones of the Great Lakes.

- Analyze main factor of model uncertainty : sparse water quality monitoring data.
- Develop suitable methods to evaluate P loads for model calibration from field historic and event based sampled concentrations.
- Calibration/validation of watershed model for flows, suspended solids and nutrients (yearly, monthly and daily → lake model).
- Evaluate what if scenarios (i.e., landuse change-BMPs) as well as *climate change* impacts (current vs. future conditions).
- Integrate with 3D nearshore lake modeling ELCOM-CAEDYM → ELCD: parallel efforts in Lake Erie east basin (GLNI) with mussels and macro-algae (Cladophora) components (…work in progress…)



Integrated Watershed-Lake Modelling

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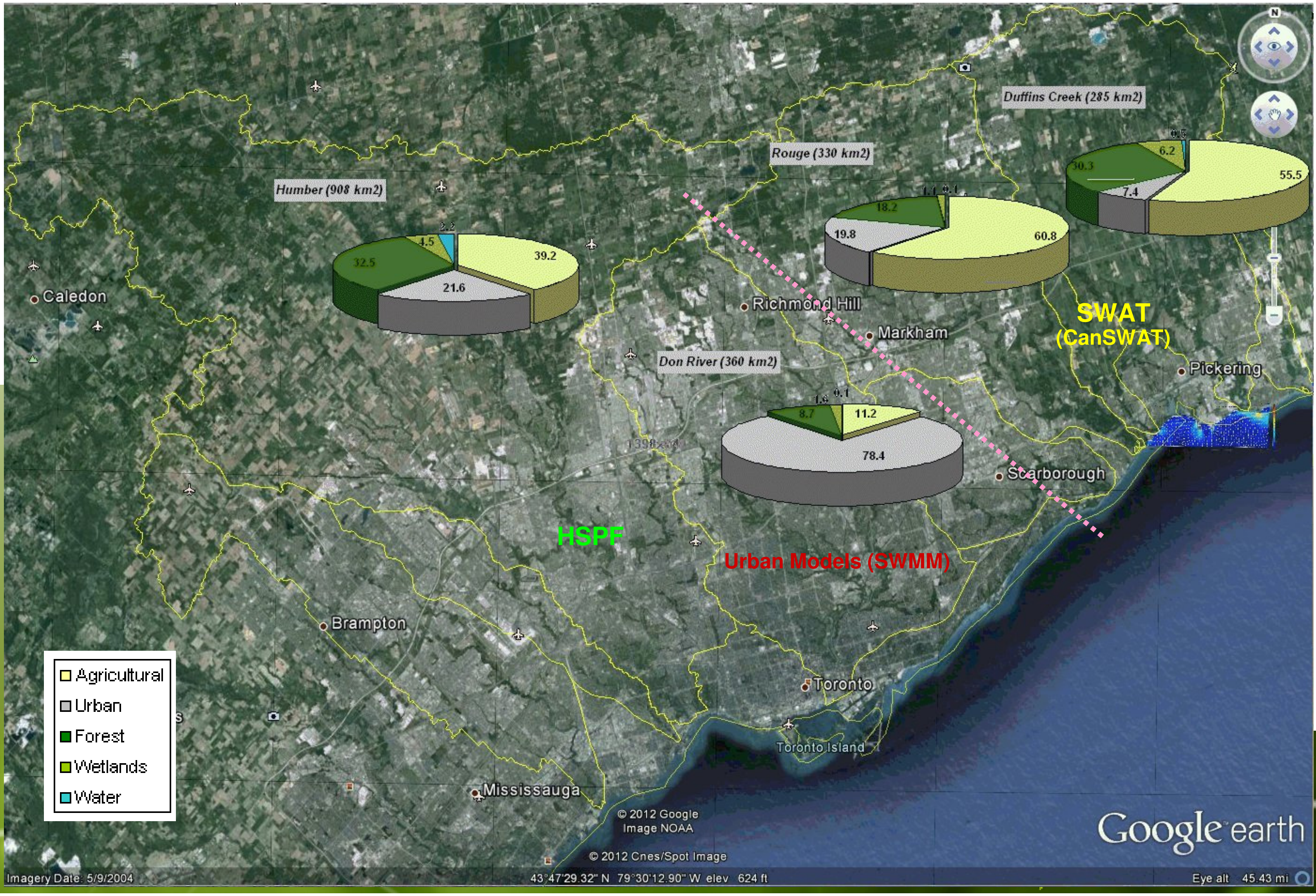
Southern Ontario Watersheds [TRCA]

Urban growth MTA (W) ; Agriculture (E)



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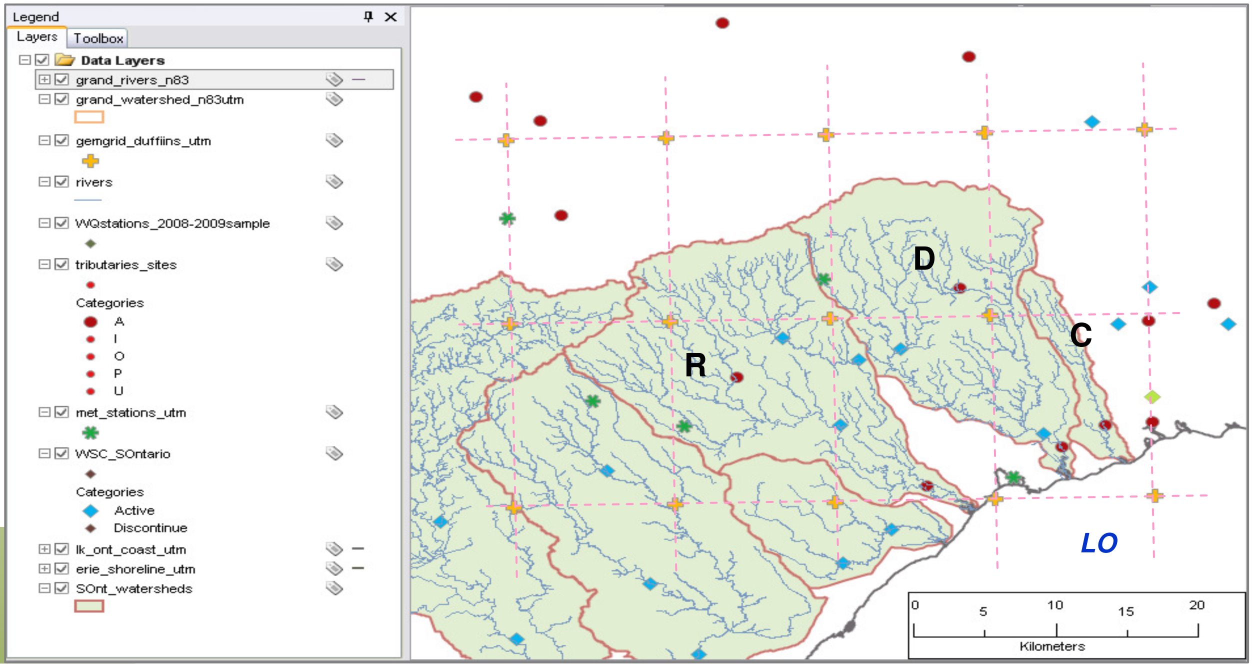
Lake Ontario TRCA Study Area

Rouge-Duffins-Carruthers

Meteorological forcing



(D, C, R) analysis of available met forcing and WQ monitoring data…

(D, C, R) evaluate P loads for model calibration from field data…

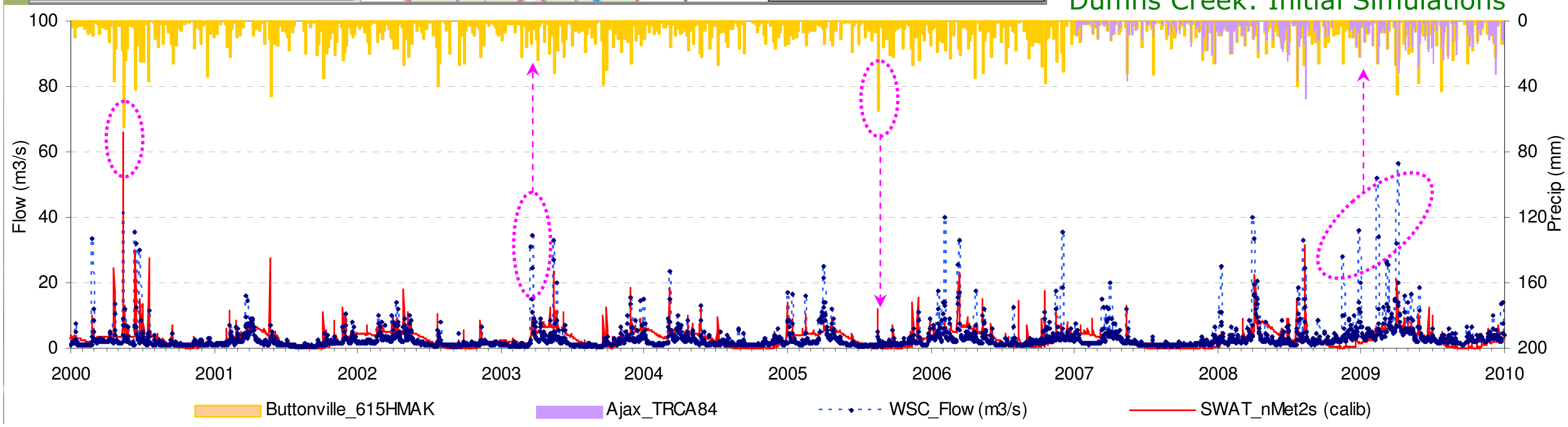
(D, C, R) exhaustive calibration-validation of watershed model…

(D) scenarios (landuse change, BMPs, climate change impacts)…

Integration Lake Model:

(LO) lake modelling 3D ELCD & Lake Erie east basin → GLNI (mussels & Cladophora)…

Duffins Creek: Initial Simulations



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Main sources of model uncertainty

- precipitation main NPS driver (spatial distribution)…
- water quality monitoring (load estimates/sparse field data)…

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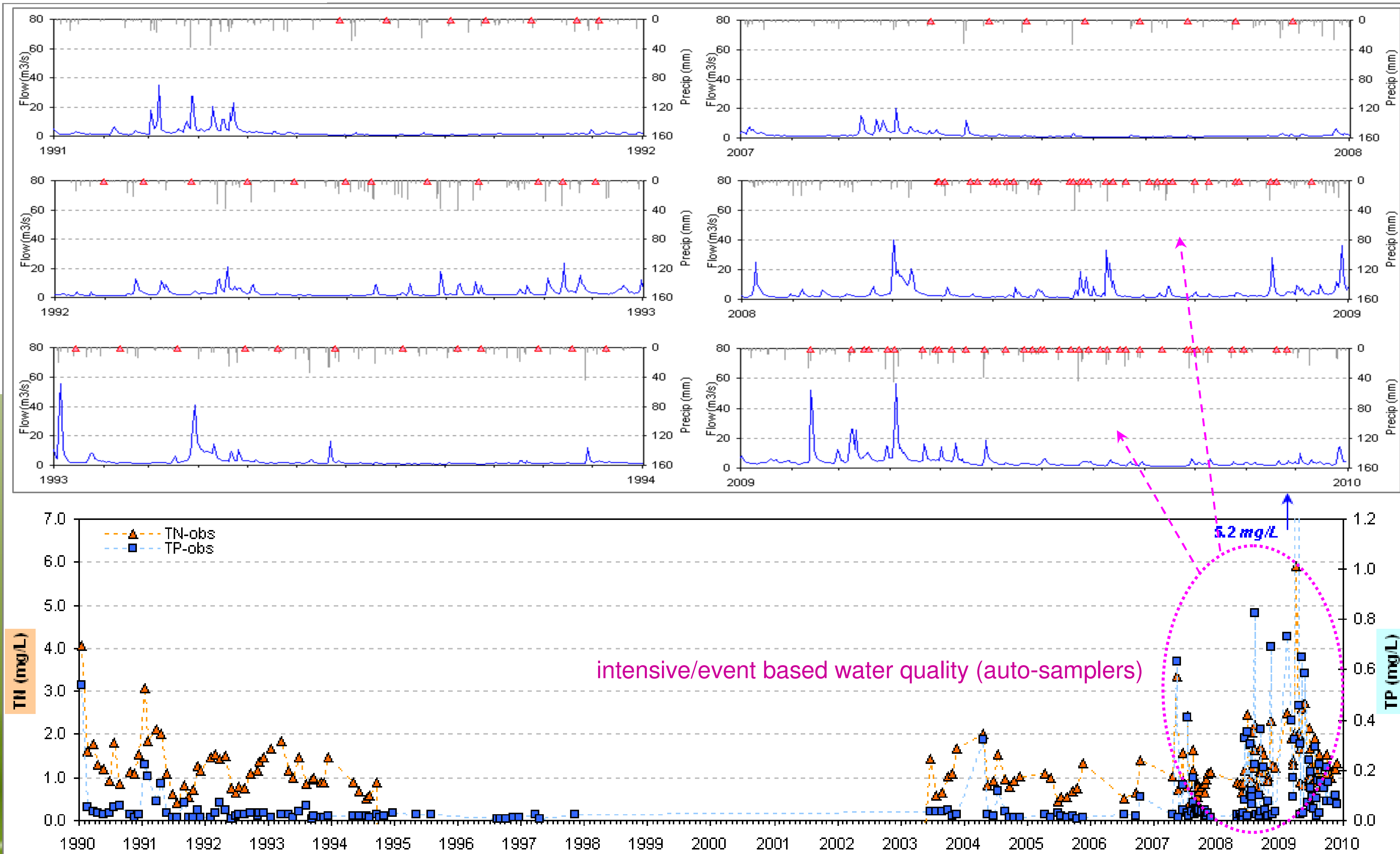
Water quality monitoring



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Loading Methods

- Range of loading estimate predictions from various methods (Wong *et al*)…

-Analysis of loading estimates delivered to TRCA
(possible continuation of daily event based sampling in 2014-15)

Loading Estimate Equations

AvgMethod1 $$Load = K\left(\frac{1}{n}\sum_{i=1}^{n} c_i\right)\left(\frac{1}{n}\sum_{i=1}^{n} Q_i\right)$$

AvgMethod2 $$Load = K\frac{1}{n}\sum_{i=1}^{n}(Q_i c_i)$$

AvgMethod3 $$Load = K\sum_{i=1}^{n}(\overline{Q}_p c_i)$$

AvgMethod4 $$Load = K\overline{Q}_r \frac{1}{n}\sum_{i=1}^{n} c_i$$

AvgMethod5 $$Load = \frac{K\sum_{i=1}^{n}(Q_i c_i)}{\sum_{i=1}^{n} Q_i}\overline{Q}_r$$

* Literature Review

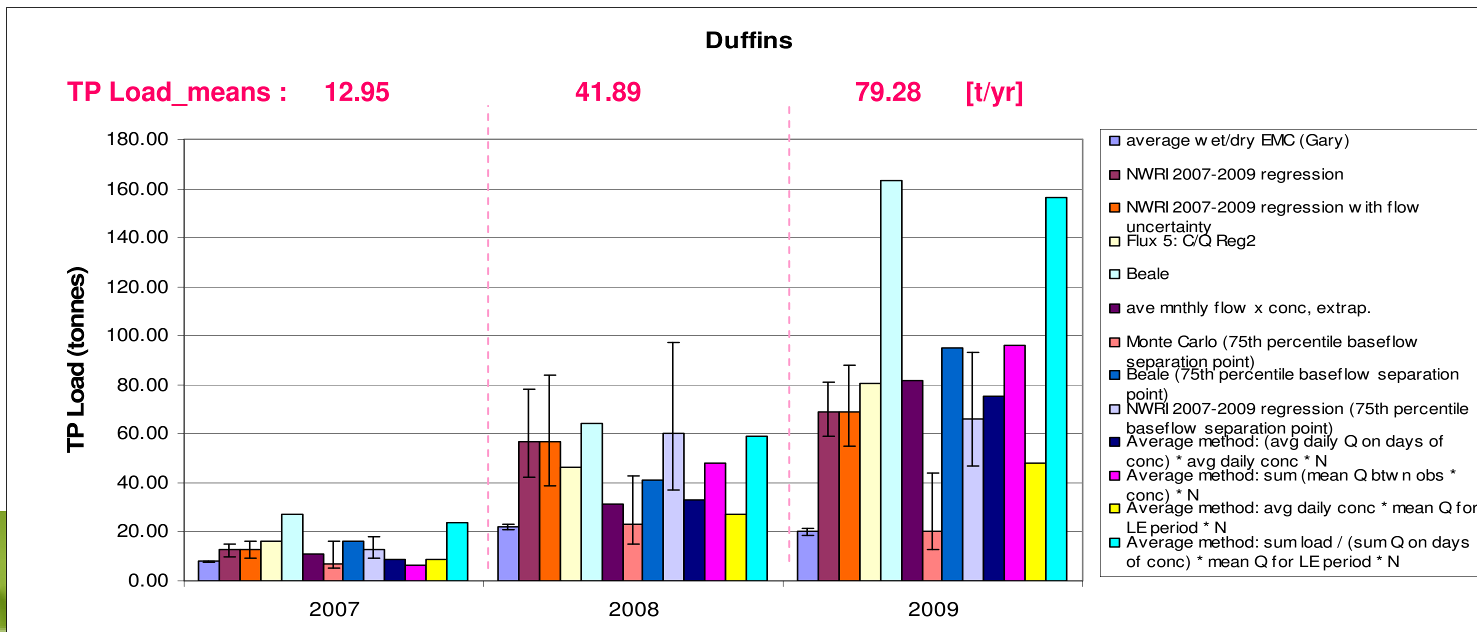
Beale Ratio method $$Load = K\overline{Q}_r \frac{\overline{l}}{\overline{Q}_o}\left(\frac{1+\frac{S_{lQ}}{n\overline{l}\,\overline{Q}_o}}{1+\frac{S_{QQ}}{n\overline{Q}_o^2}}\right)$$

$$S_{lQ} = \frac{1}{n-1}\left(\sum_{i=1}^{n}(Q_i^2 c_i) - n\overline{Q}_o\overline{l}\right) \qquad S_{QQ} = \frac{1}{n-1}\left(\sum_{i=1}^{n}(Q_i^2) - n\overline{Q}_o^2\right)$$

c_i = observed concentration at time i
Q_i = flow at time i
$\overline{Q}_p$ = mean flow over period between observations
$\overline{Q}_r$ = mean flow for period of load estimate
n = number of observations
K = conversion factor to account for period of load estimate and units

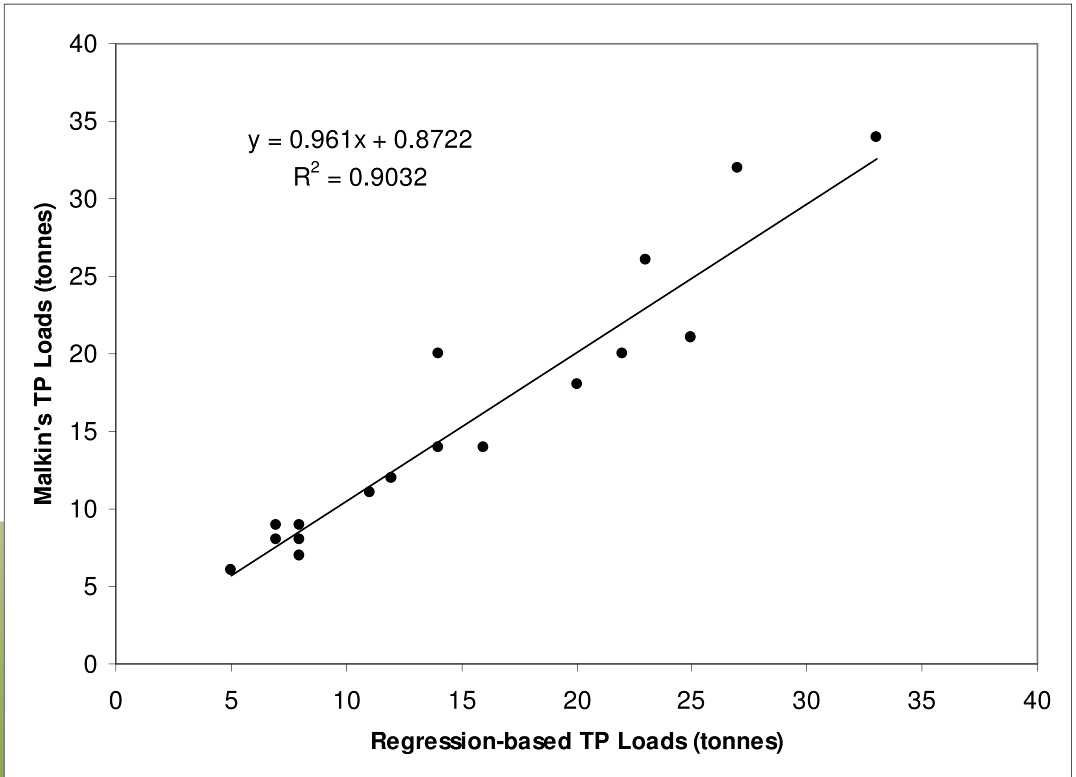
Regression-based method
I.W. Wong, , W.G. Booty, P. Fong, G. Bowen, R.C. McCrimmon & L.F. Leon, (2012 - *sub*) Adjusted Regression-based Chemical Annual Loading Estimates Modelling Procedure in Canadian Streams for Imprecise Data, *Journal of Environmental Modelling and Software*

* Ullrich & Volk (2010) Influence of different nitrateN monitoring strategies on load estimation as a base for model calibration and evaluation. Environ Monit Assess 171:513-527



Cross-Compare (Yearly)

Comparison of TP loads at Duffins (tonnes)



	1990-2009 regression TP (tonnes) [95% C.I.]	Malkin paper Figure 9b TP (tonnes)
1990	22 [16, 31]	20
1991	14 [11, 19]	14
1992	14 [12, 18]	20
1993	25 [17, 36]	21
1994	8 [6, 11]	7
1995	12 [9, 15]	12
1996	27 [20, 36]	32
1997	20 [14, 27]	18
1998	11 [8, 14]	11
1999	5 [4, 6]	6
2000	16 [12, 21]	14
2001	7 [6, 9]	9
2002	7 [6, 8]	8
2003	25 [17, 36]	21
2004	8 [7, 10]	9
2005	12 [10, 16]	12
2006	23 [17, 31]	26
2007	8 [6, 9]	8
2008	33 [25, 44]	34
2009	46 [40, 52]	

Malkin, S., Dove, A., Depew, D., Smith, R., Guildford, S., Hecky, R., 2010. Spatiotemporal patterns of water quality in Lake Ontario & their implications for nuisance growth of Cladophora, J. Great Lakes Research 36: 477-489

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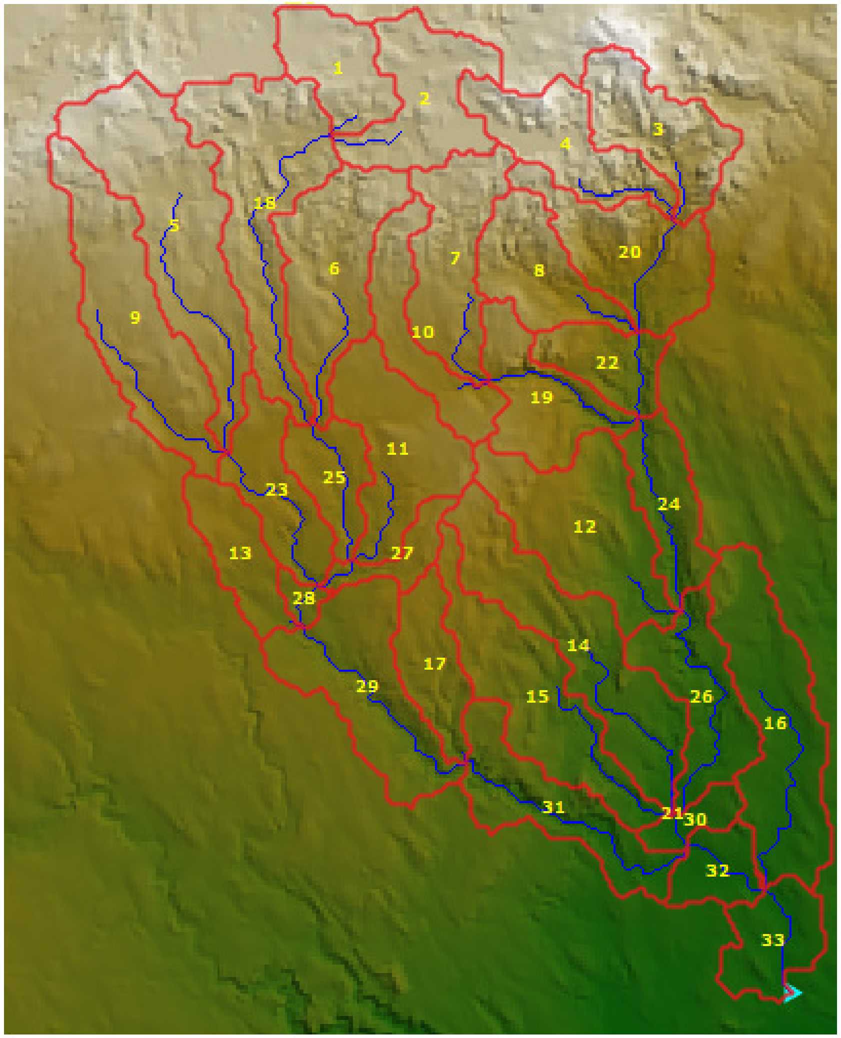
SWAT in Duffins Creek

Canada



- Calibration/Verification for Flow, TSS, TN, TP 1990-2009
- EC met. data and hybrid met. data combining multiple sources (GEMS grid and EC)
- Water quality MOE+EMC TRCA and PWQMN
- Sensitivity analysis on SWAT parameters completed for Flow, TSS, TP and TN.
- Winter conditions and modifications for daily simulations and recalibration (…next steps…).

List of Flow & TSS Parameters & Ranges		
Parameters	**min**	**max**
v__ALPHA_BF.gw	0	1
r__SOL_AWC(1).sol	-5	1
v__SFTMP.bsn	-5	5
v__SMTMP.bsn	-5	5
v__SMFMX.bsn	0	10
v__SMFMN.bsn	0	10
v__TIMP.bsn	0.01	1
v__ESCO.hru	0.01	1
v__EPCO.hru	0.01	1
v__SURLAG.bsn	0	10
v__GWQMN.gw	0	20
v__GW_DELAY.gw	0	100
v__GW_REVAP.gw	0.02	0.2
v__SNOCOVMX.bsn	0	50
v__PRF.bsn	0	2
v__SPCON.bsn	0.0001	0.01
v__SPEXP.bsn	1	1.5
v__CH_EROD.rte	0	10
v__CH_COV.rte	0	1

List of Nutrients Parameters & Ranges		
Parameters	**min**	**max**
v__ERORGP.hru	1	1
v__ERORGN.hru	0	1
v__NPERCO.bsn	0.01	1
v__PPERCO.bsn	10	17.5
v__PHOSKD.bsn	100	175
v__SOL_ORGN().chm	1	10000
v__SOL_ORGP().chm	1	400
v__GWSOLP.gw	0	10
v__P_UPDIS.bsn	0	40
v__N_UPDIS.bsn	0	40
v__PSP.bsn	0.01	0.7
v__CMN.bsn	0.0001	0.003
v__RCN.bsn	0	2
v__SDNCO.bsn	0.5	1.1

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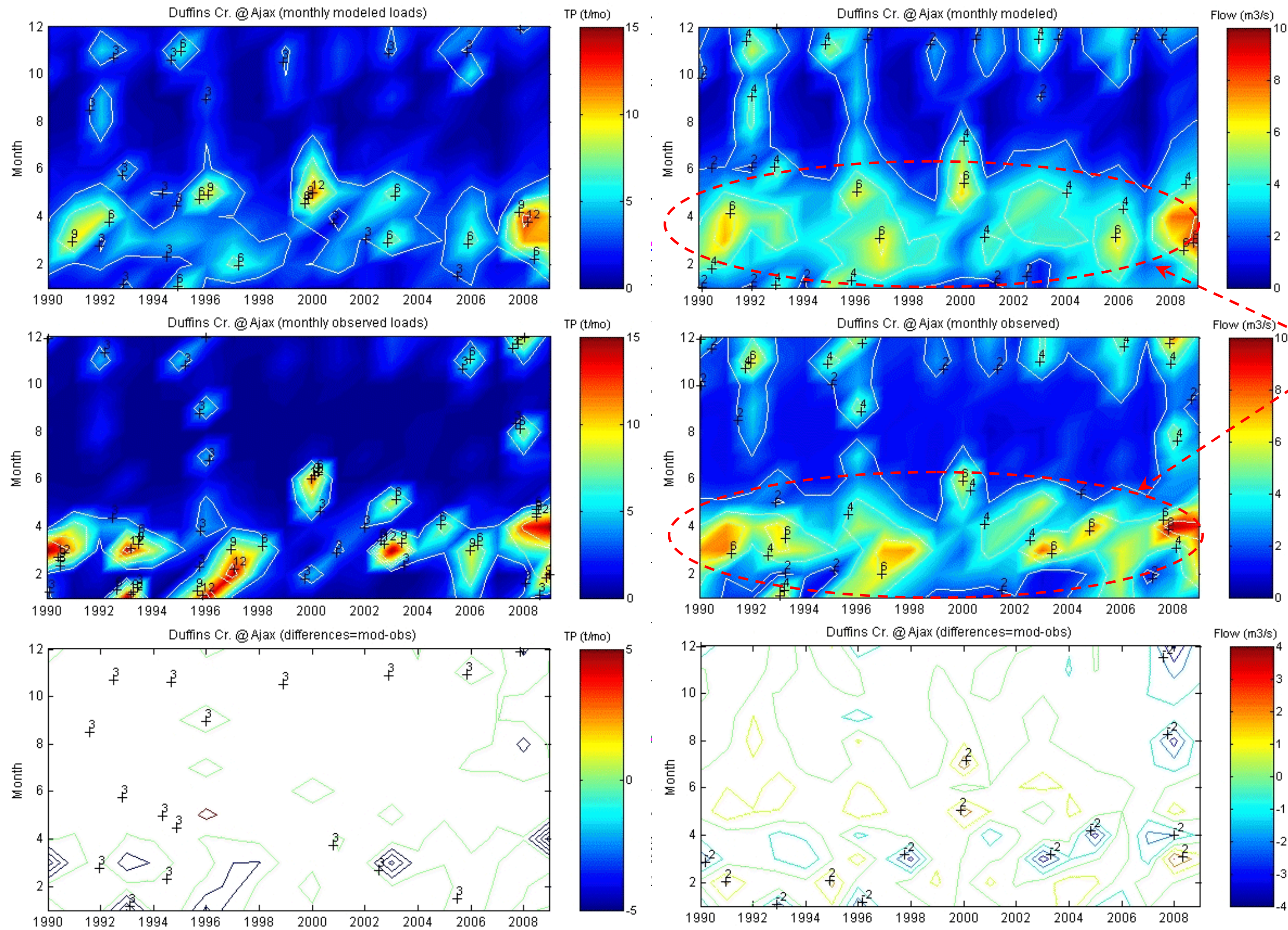
SWAT: Monthly Results

Canada



*spring snow-melt period (zone of high uncertainty)

-model under-predicts
-daily grid met (short+ detailed-events calib)

Co-op UG-CanSwat (spring snowmelt and frozen soils mods)…

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Daily simulations

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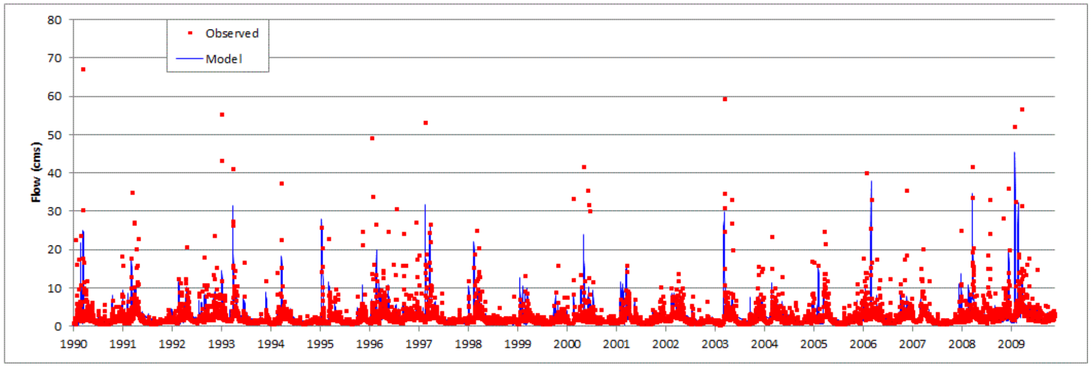
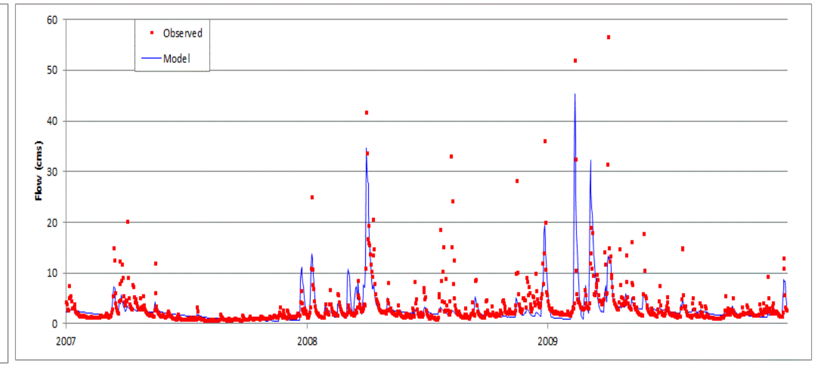
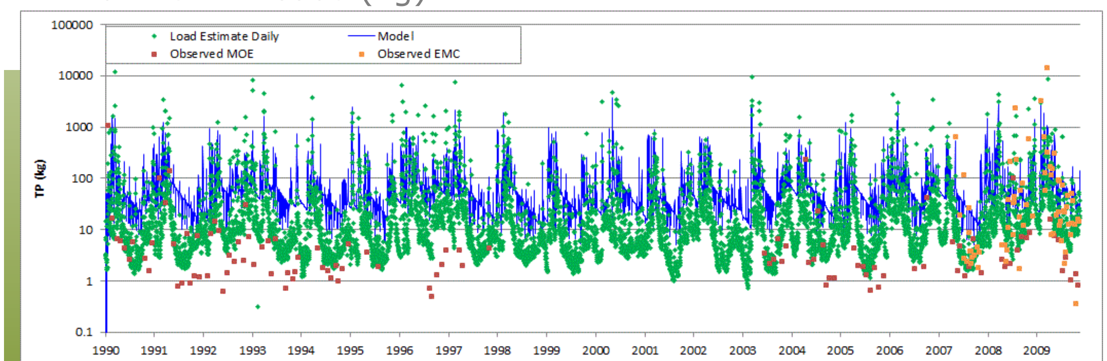
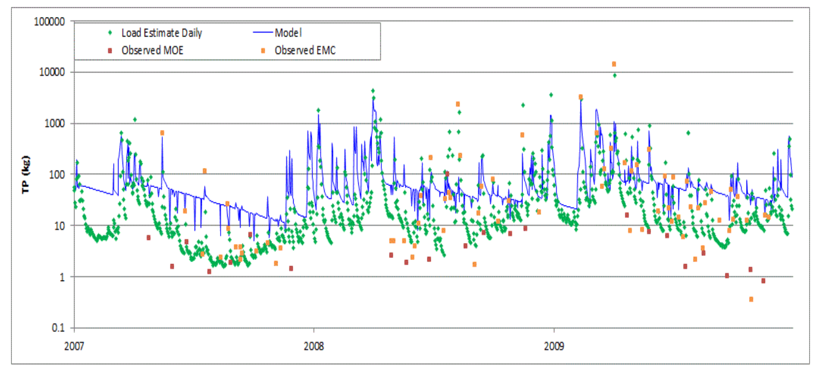
- Duffins: Flows (m^3/s)





- Duffins: TP loads (kg)





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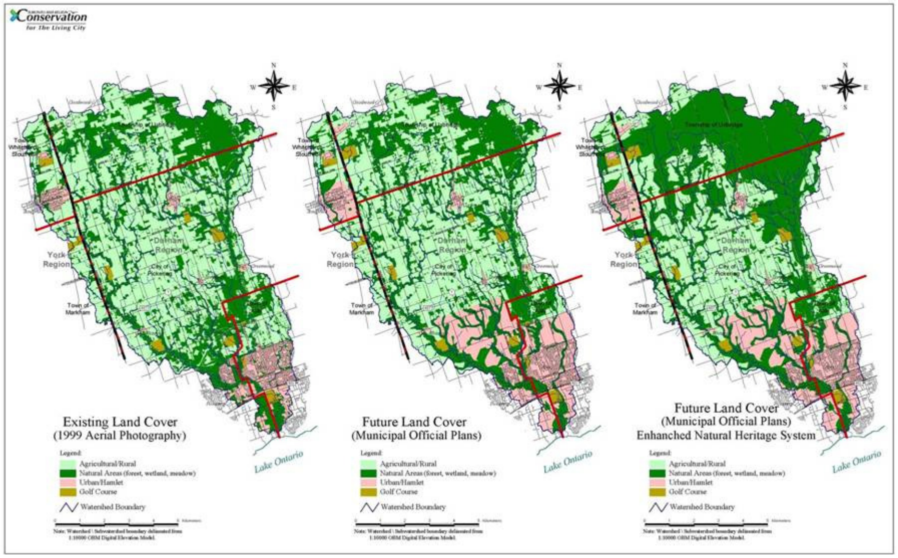
Landuse Scenarios

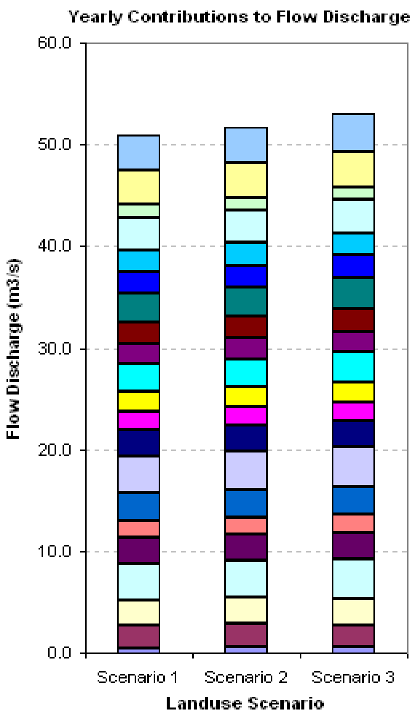
Mod GIS land changes – preliminary results

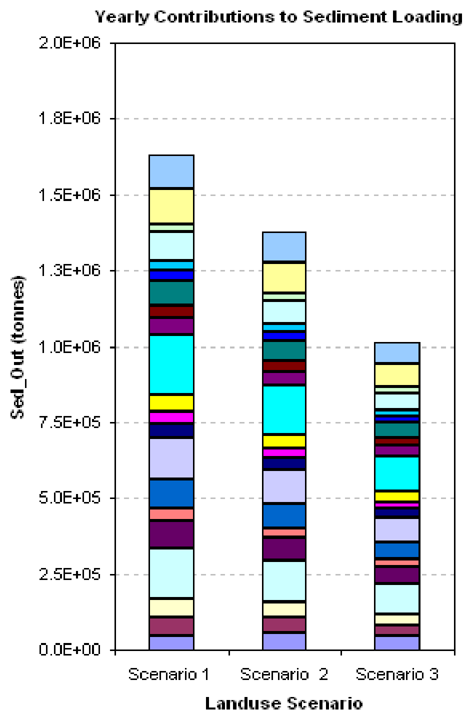
Canada

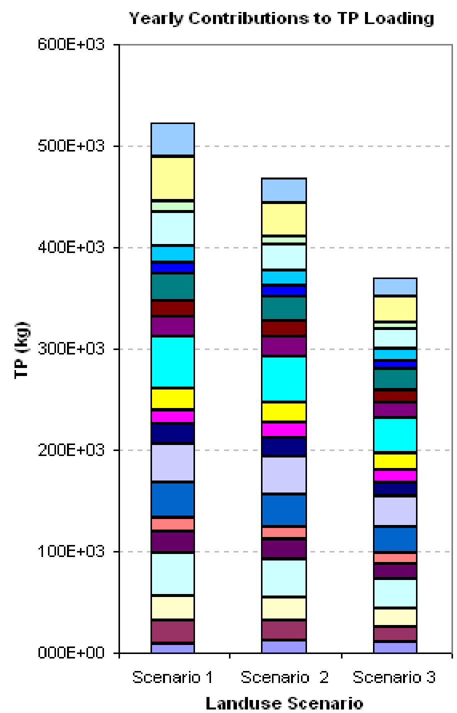


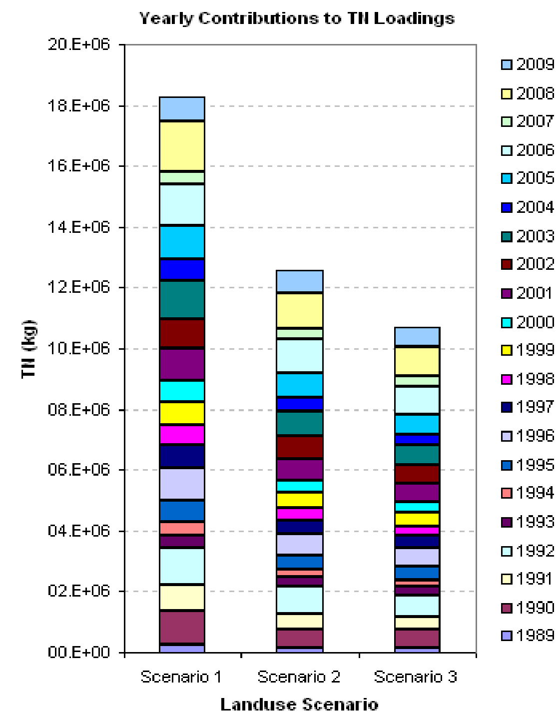
# of Years:	21	total chng	rate of change
Flow		%	% per year
	Rate of Change (m3/s/year)		
Scn 1- Scn 2	0.036	1.495	0.07
Scn 1- Scn 3	0.095	3.910	0.19
Scn 2- Scn 3	0.059	2.379	0.11
TSS			
	Rate of Change (tonnes/year)		
Scn 1- Scn 2	12259.048	-15.771	-0.75
Scn 1- Scn 3	29552.857	-38.018	-1.81
Scn 2- Scn 3	17293.810	-26.413	-1.26
TP			
	Rate of Change (kg/year)		
Scn 1- Scn 2	2642.333	-10.606	-0.51
Scn 1- Scn 3	7273.190	-29.193	-1.39
Scn 2- Scn 3	4630.857	-20.793	-0.99
TN			
	Rate of Change (kg/year)		
Scn 1- Scn 2	271933.810	-31.264	-1.49
Scn 1- Scn 3	360803.333	-41.481	-1.98
Scn 2- Scn 3	88869.524	-14.864	-0.71

Landuse	Landuse Scenario		
	Scenario 1	Scenario 2	Sceanrio 3
PAST	8.38	6.02	1.33
URLD	1.08	2.35	4.87
URMD	6.50	11.30	11.49
WETL	1.79	1.87	2.22
FRST	23.17	24.06	39.20
AGRC	1.85	1.73	1.56
AGRR	18.04	16.18	15.71
AGRI	36.58	29.06	18.22
UCOM	N/A	2.79	2.88









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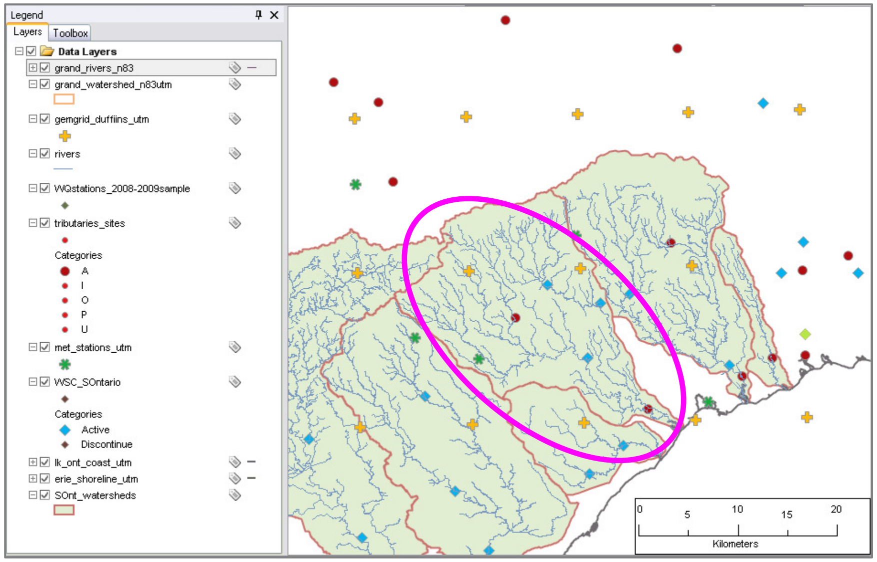
Rouge River

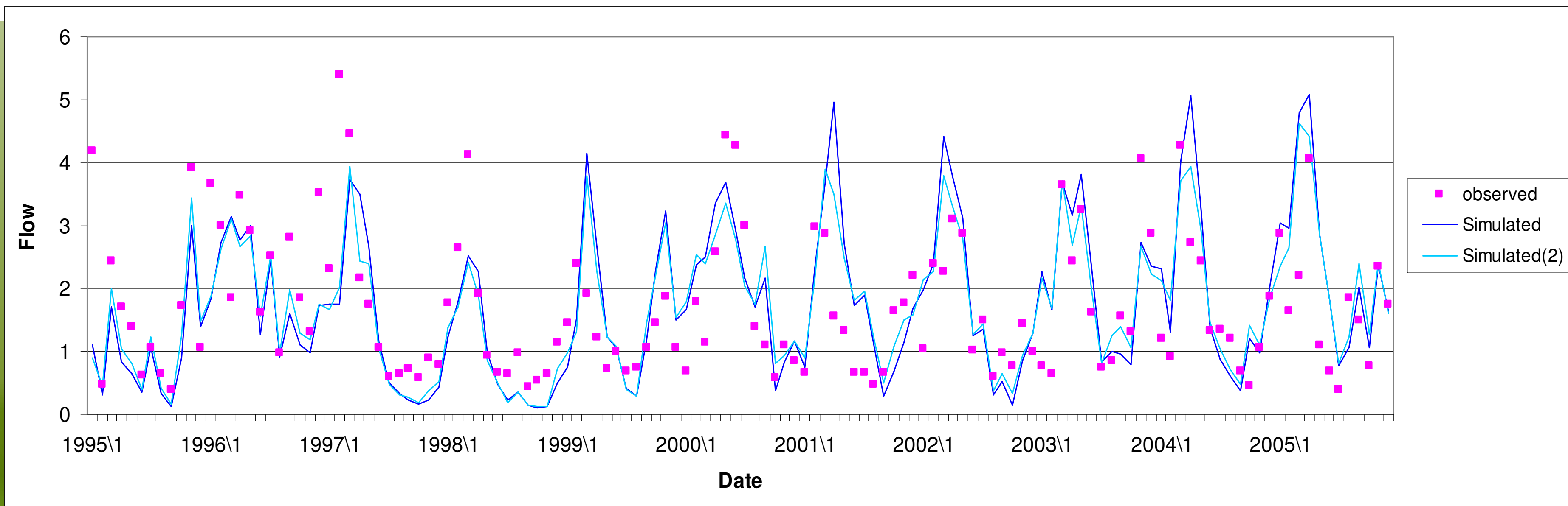
Canada



→Test run for flow using Duffins calibration parameters:
"Simulated" = manual, nse=0.23
"Simulated(2)"=calibration tool, nse=0.38
→Also, test Flow calibration tool with GEMS grid met data 2006-2010, nse=0.45)

→ Post-Doc (CanSWAT)
→ Sensitivity analysis and expand calibration parameter list

WSC flow station 02HC022 Rouge River Near Markham



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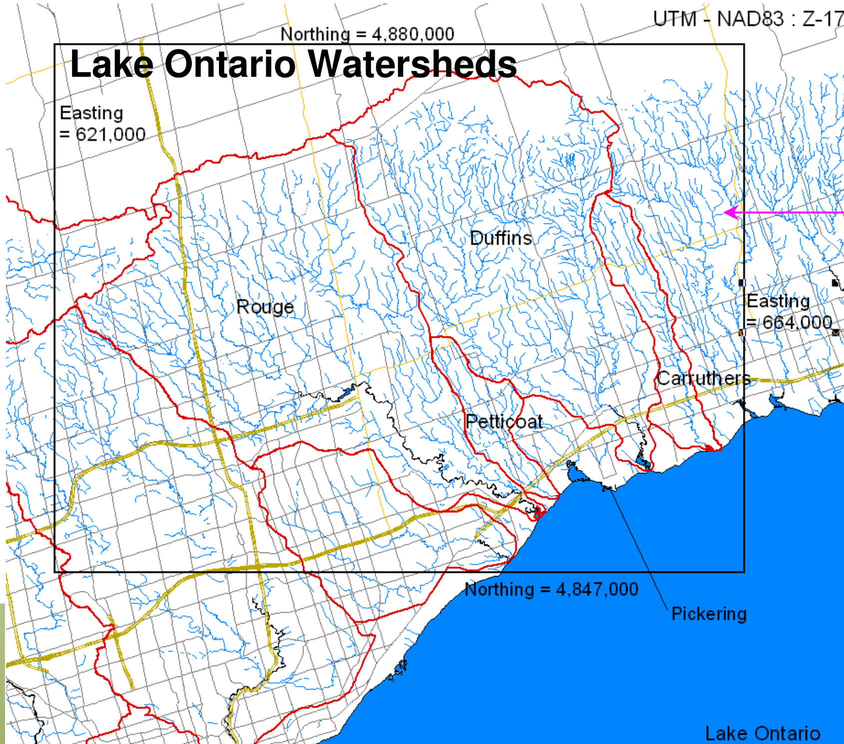
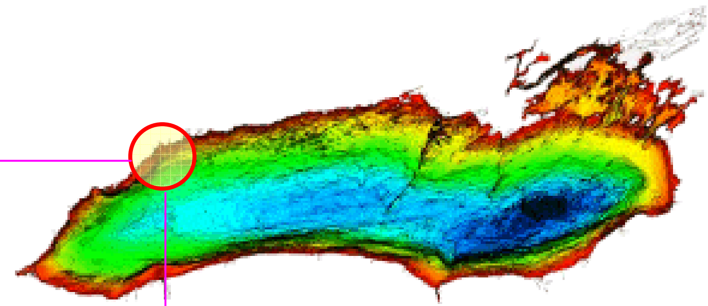
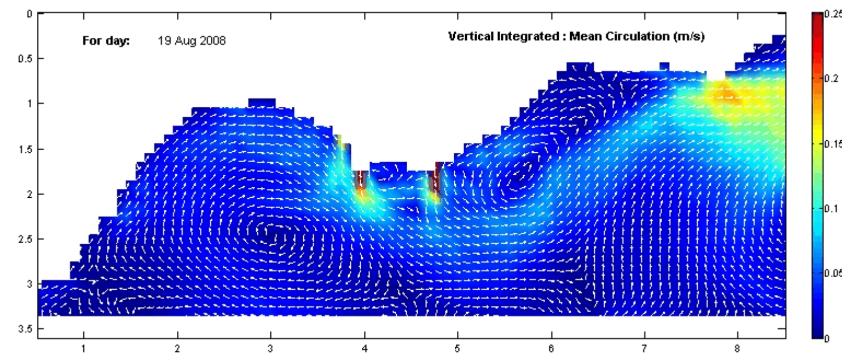
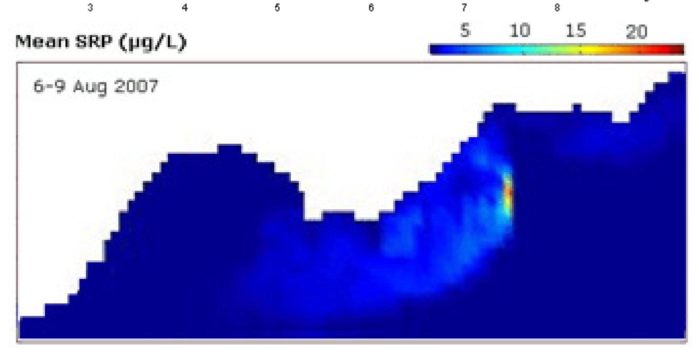
Watershed-Lake Model Integration

Canada





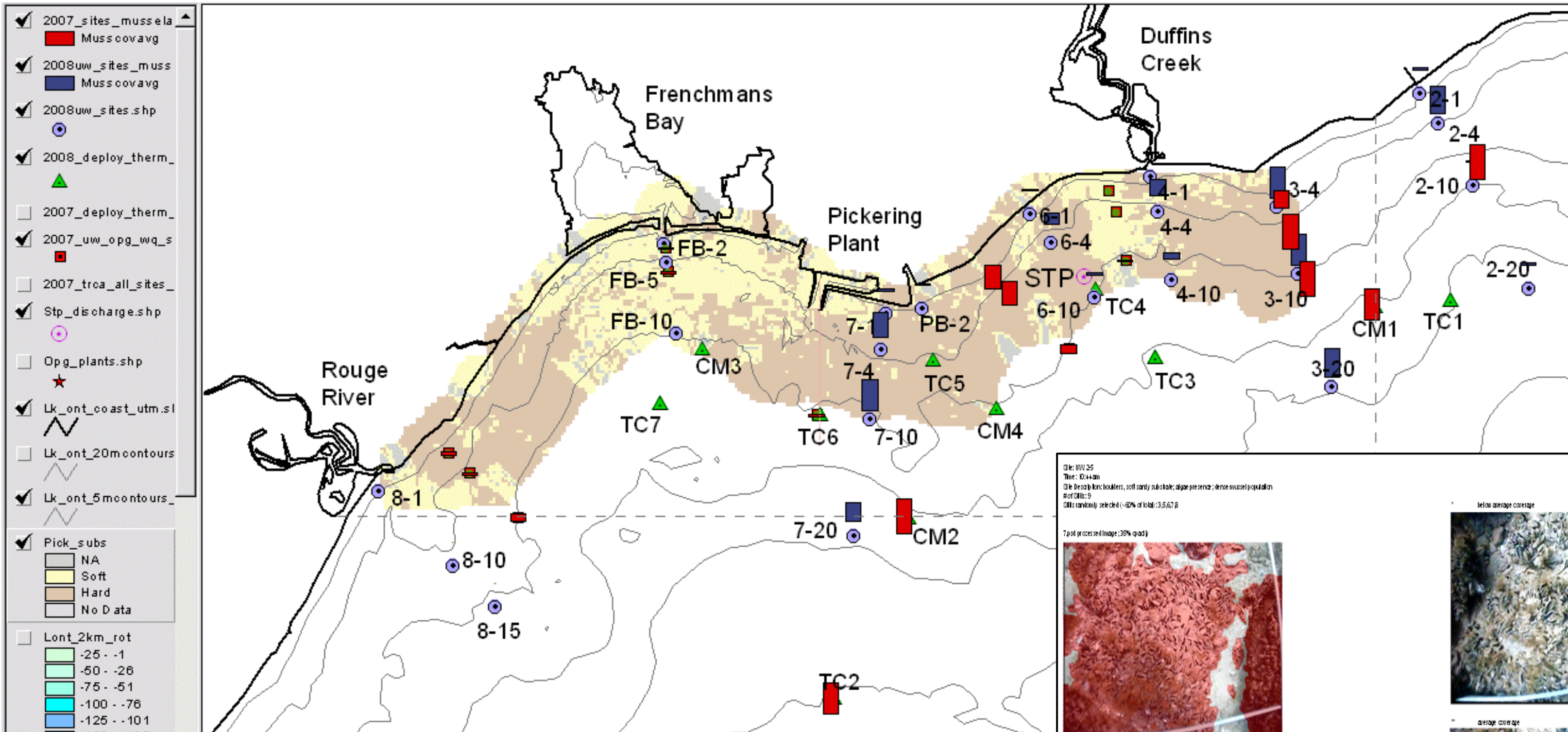


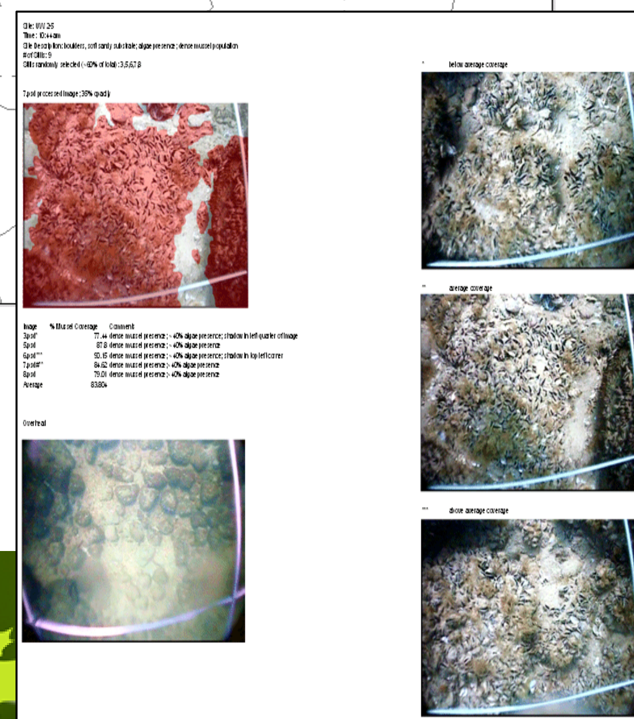


Watershed & Lake modeling (link w/Ram Yerubandi *et al.*):
Evaluate nutrient and sediment loading to the lake: estimated loads (from provincial WQ dataset 2002-2009 + Duffins and TRCA historic)

→ calibration/validation and uncertainty propagation
→ input loads for lake modeling
→ lakewide & nearshore coupled model domains

Lake Ontario: Pickering-Mussel Coverage (2007-2008)





- similar density #s in both years (combine sampled sites 07-08)
- consistent with higher values of mussels in hard/rocky substrate
- density/biomass grids for nearshore (high-res model @ 100m)
- **ELCD + (CGM + Mussels)**

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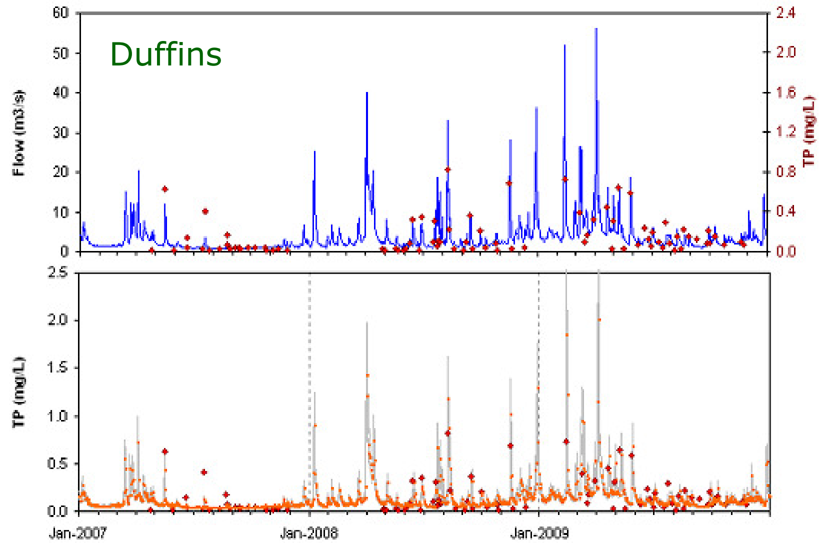
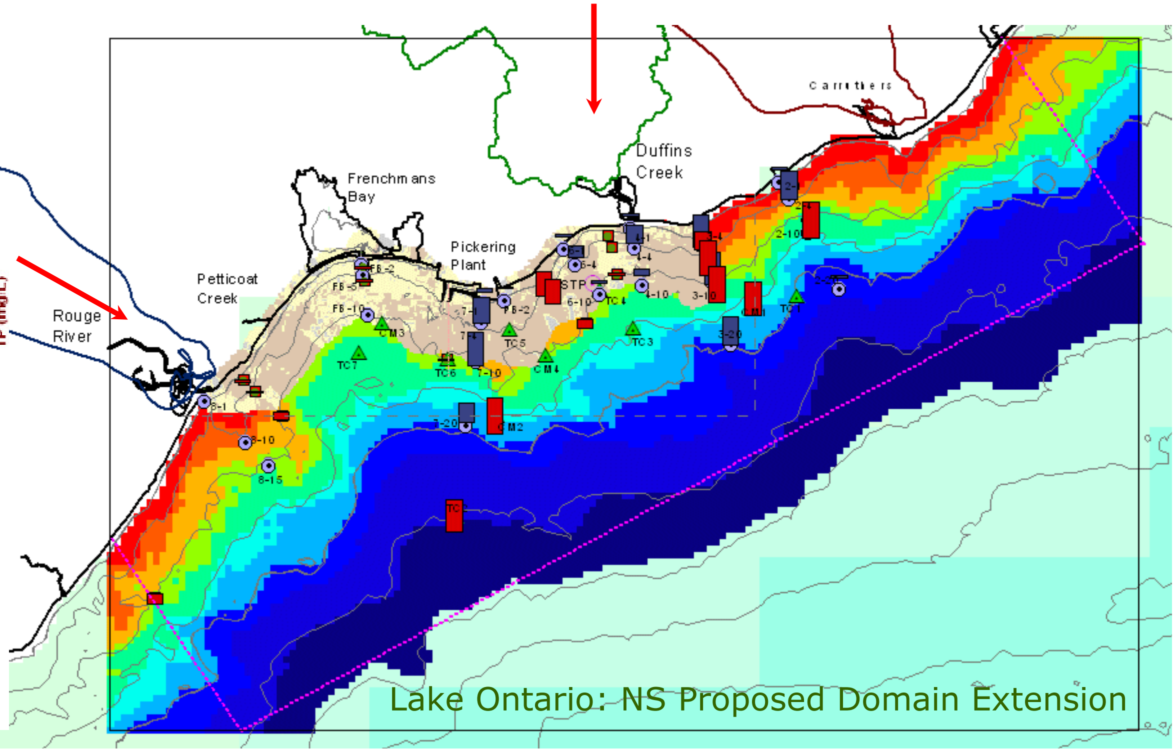
Watershed-Lake Model Integration

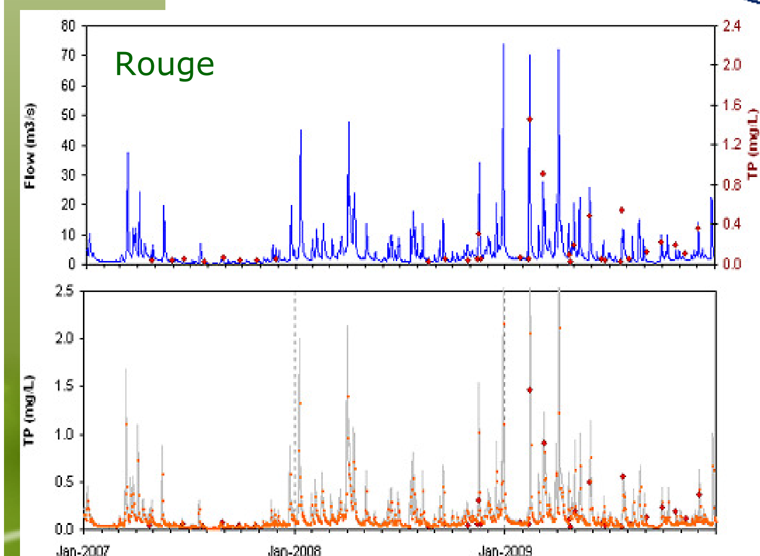
GLAP (…work in progress…):

-Lake model ELCD: Lake Ontario (near shore w/mussels)

-Watershed inflows (NPS): Duffins + Carruthers + Rouge + Petticoat & FB (estuary/lake interactions)







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Grand River
(NPS-Watershed Model)

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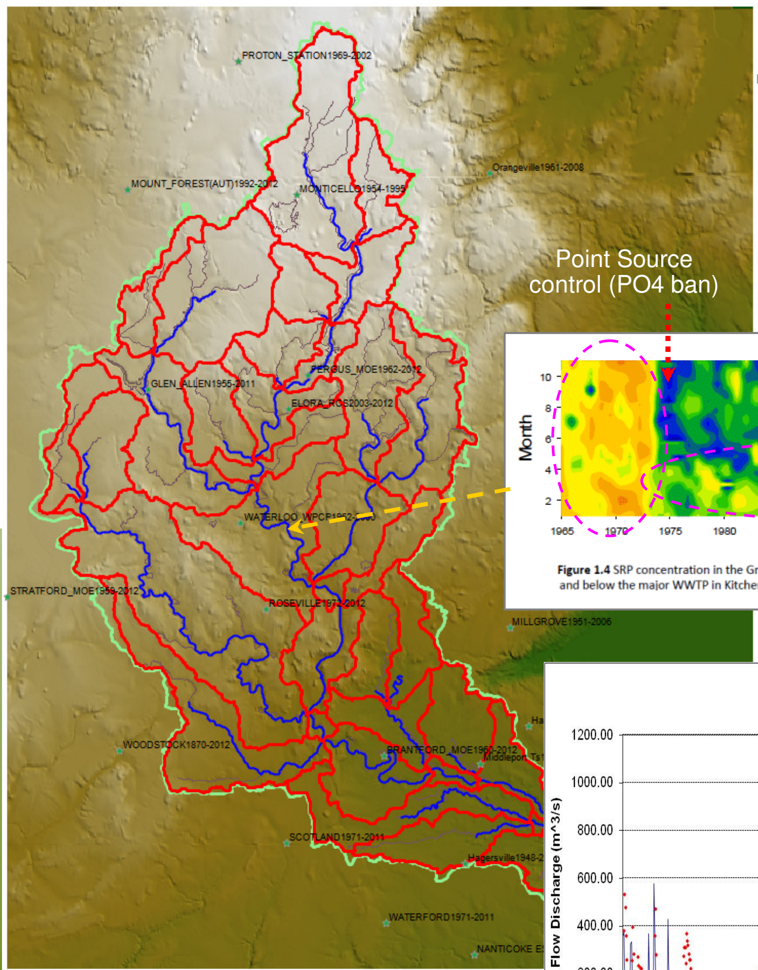
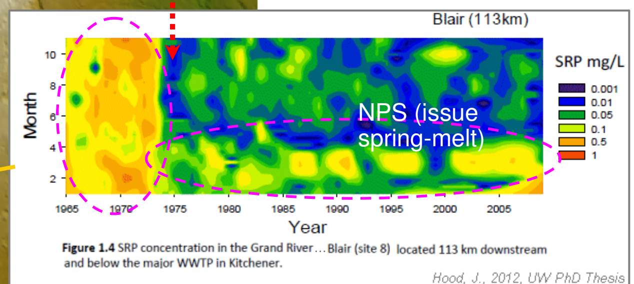




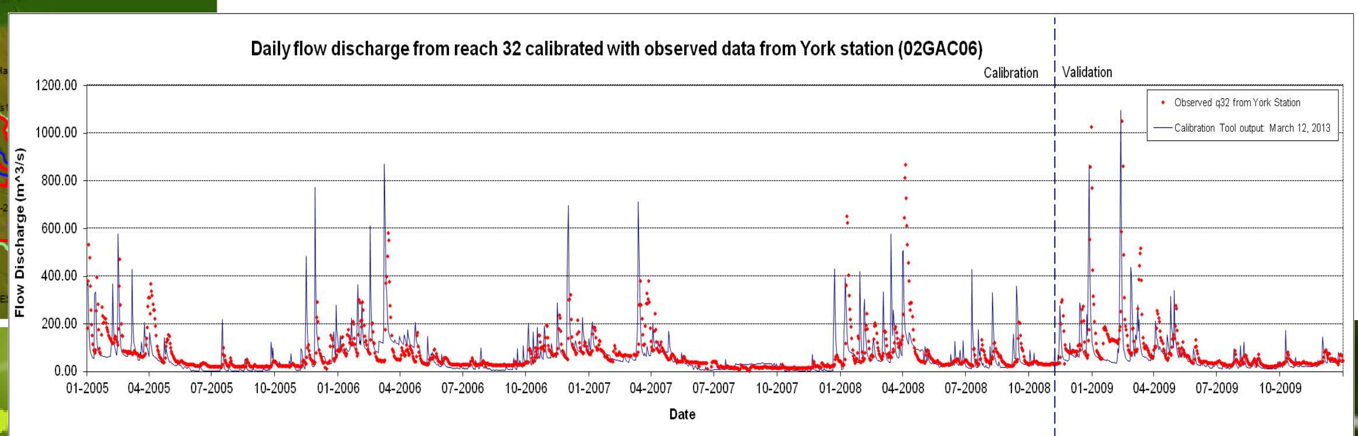
Digital data assembled for NPS models

-SRTM-DEM; 200m resolution…
(evaluating 30m MNR-DSM Ontario Radar Digital Surface Model)

-GRCA-WSC: land use, soil, point sources, reservoirs, flows & weather data…

Watershed Model Setup (MW-SWAT)

-monthly calibration...
-daily (NSE drops all accross the board)
-expect some improvement with snowmelt and frozen soil modules...(CanSwat-UG)
-expect more improvement additional event based load sampling...(link Alice Dove)



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Grand River
(SWAT monthly/yearly)

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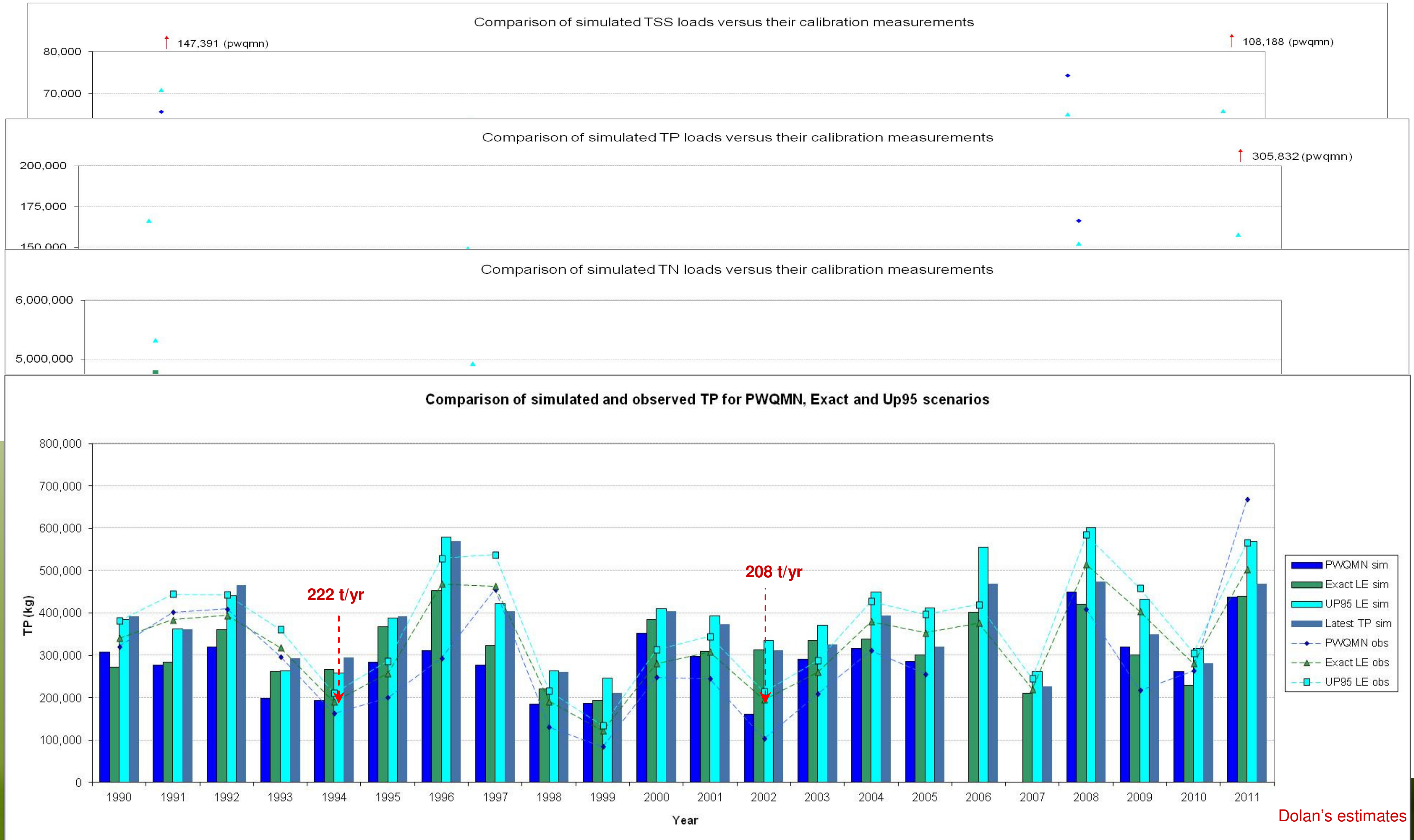

Dolan's estimates

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Lake Model Integration

Nearshore Modelling – (link w/Ram Yerubandi *et al.*)

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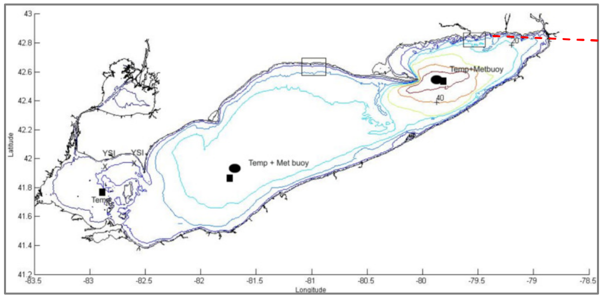
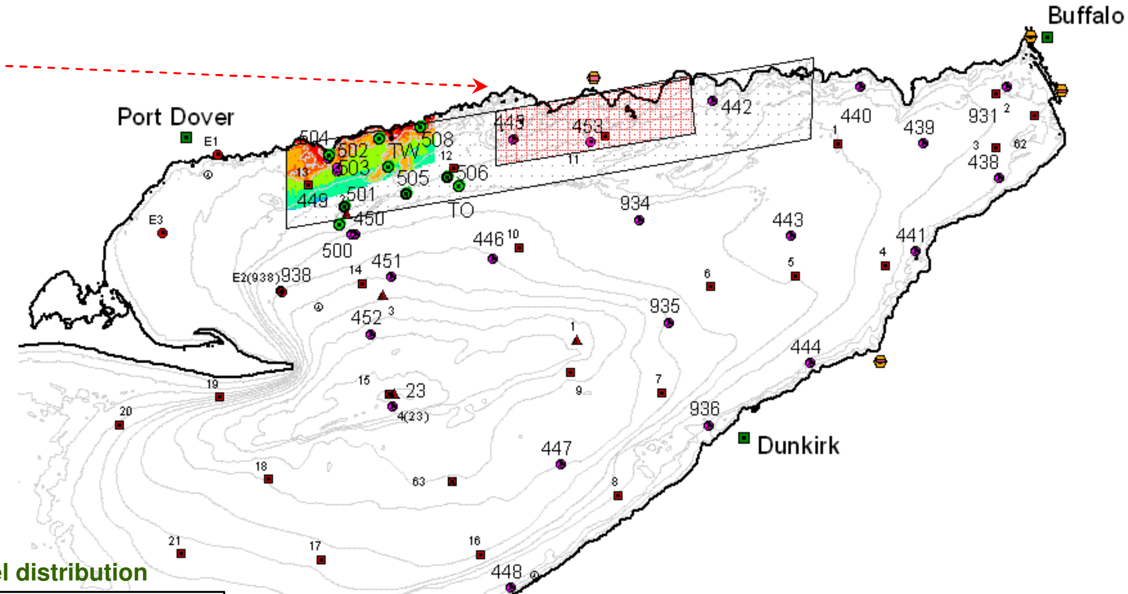




Lake Erie simulations (ELCD)

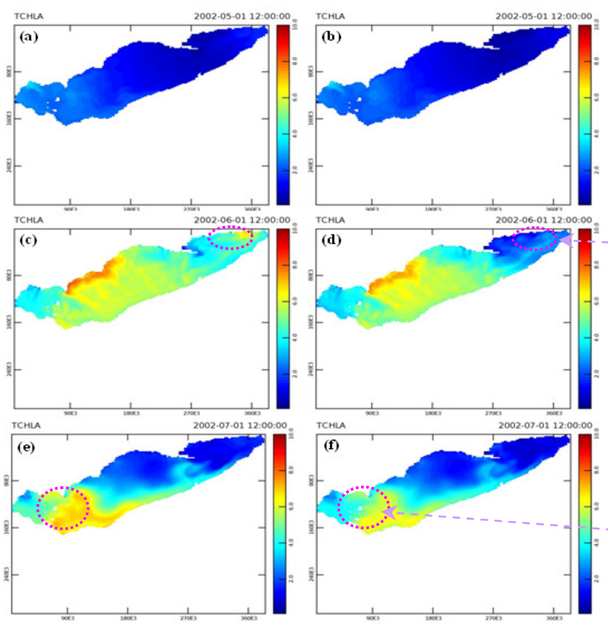
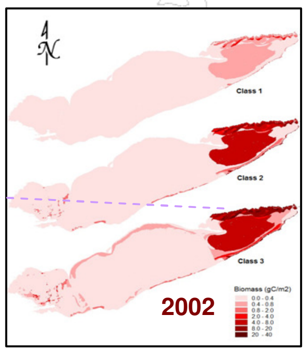
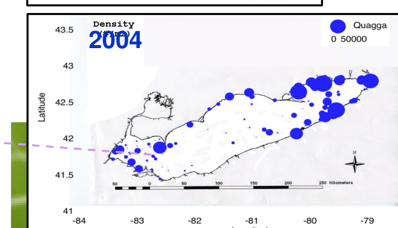


Figure 7. Model predictions of the spatial distribution of Chl-a in the surface layer at 2 m depth of Lake Erie: May 1: mussels OFF (a) and mussels ON (b); June 11: mussels OFF (c) and mussels ON (d); July 1: mussels OFF (e) and mussels ON (f)

- Mussel distribution





Three-dimensional computer modelling of the impact of *dreissenid* mussels on phytoplankton in Lake Erie.

S.A. Bocaniov, R.E.H. Smith, C. Spillman, M.R. Hipsey, L.F. Leon

Future tasks (already initiated):

Lake Model Integration

→ Setup Nearshore Higher Resolution Model Grid
(to test simulations including mussels
linked to load analysis – Grand River inflows)