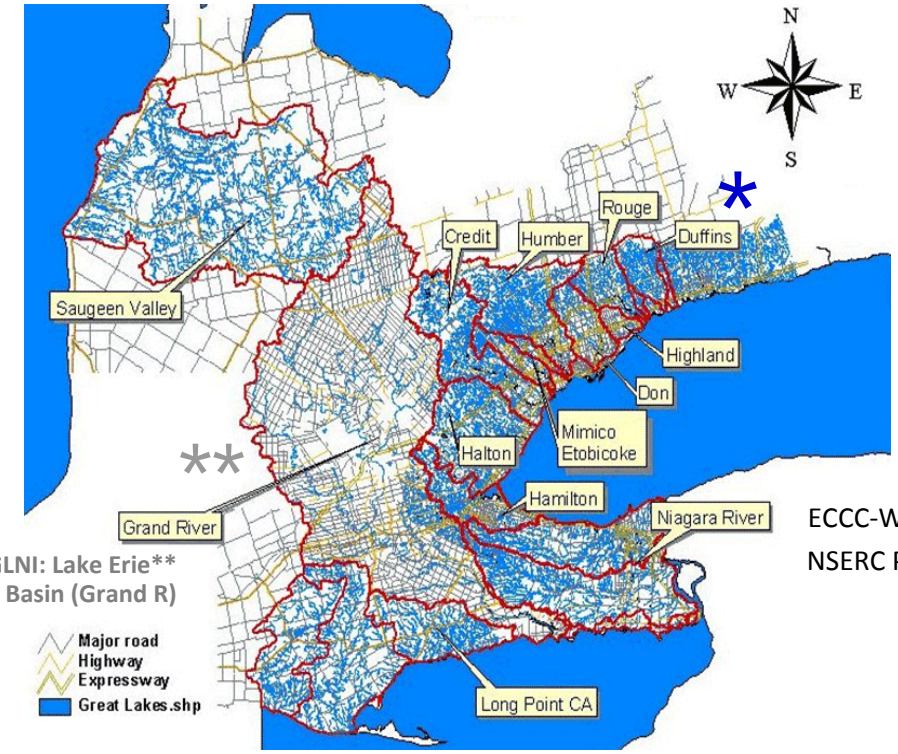
Environment Canada Environnement Canada

Canada



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

Modelling Nutrient Loads and Impact of BMPs on Water Quality

GLAP: Lake Ontario*
***Nearshore (Rouge/Duffins)**

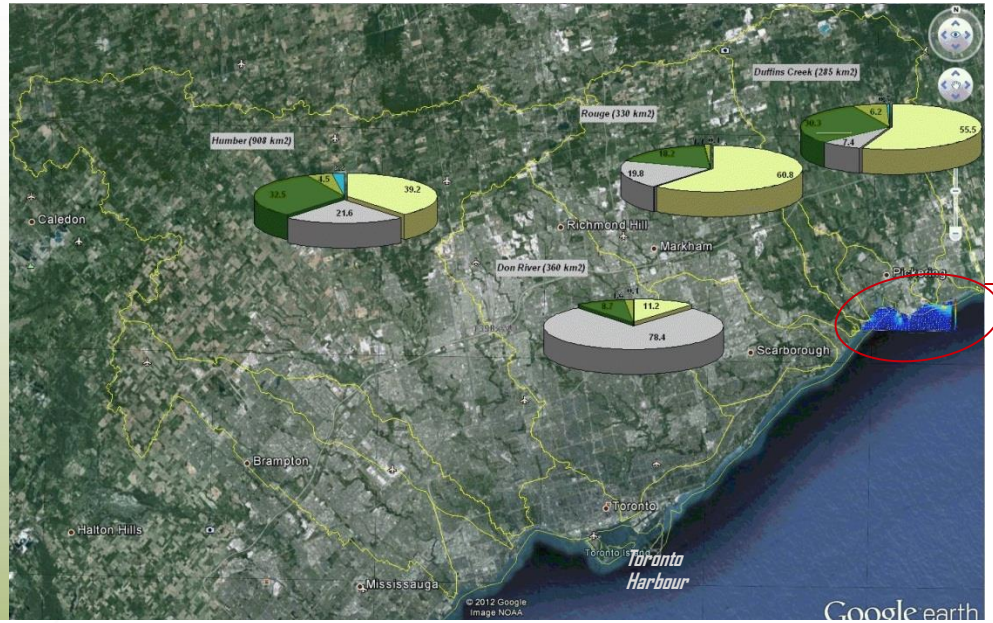
ECCC-WHERD: L. Leon, R. Yerubandi, I. Wong, C. McCrimmon, P. Fong
NSERC Post-Doc: M. Asadzadeh : University of Guelph: Y. Liu, W. Yang

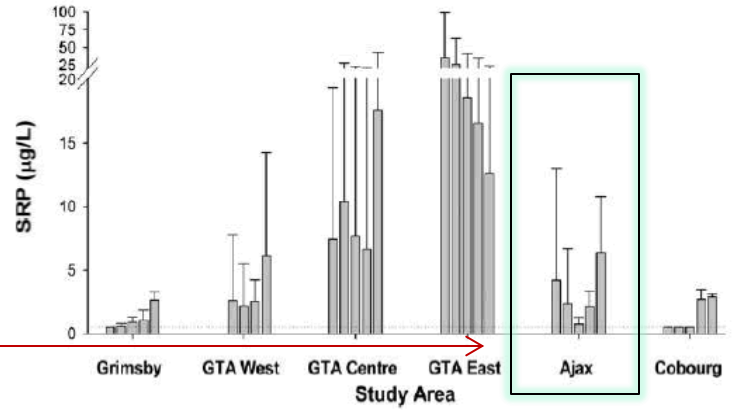
Nov 14, 2016

Objective: integrated modelling to assess water quality and evaluate P loads of Canadian tributaries into selected nearshore zones of the Great Lakes…

Water Quality of Nearshore Lake Ontario

Environment Canada | Environnement Canada



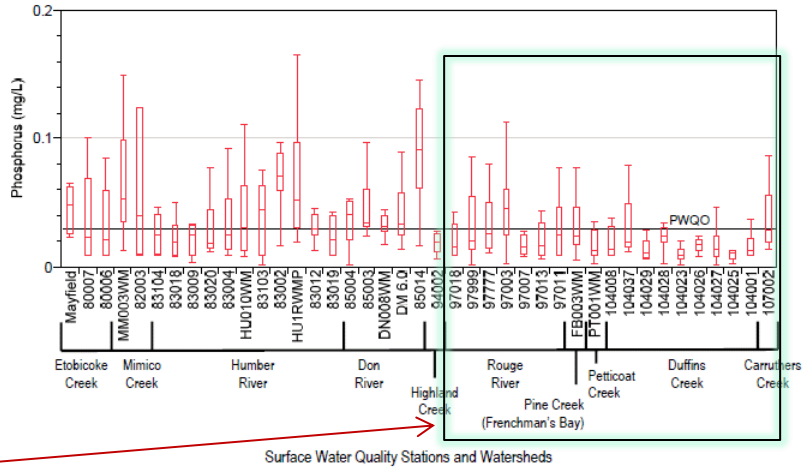


(plots: T. Howell, MOE & TRCA)

Toronto and Region Conservation for The Living City

2012 Surface Water Quality Summary

May 2013



Surface Water Quality Stations and Watersheds

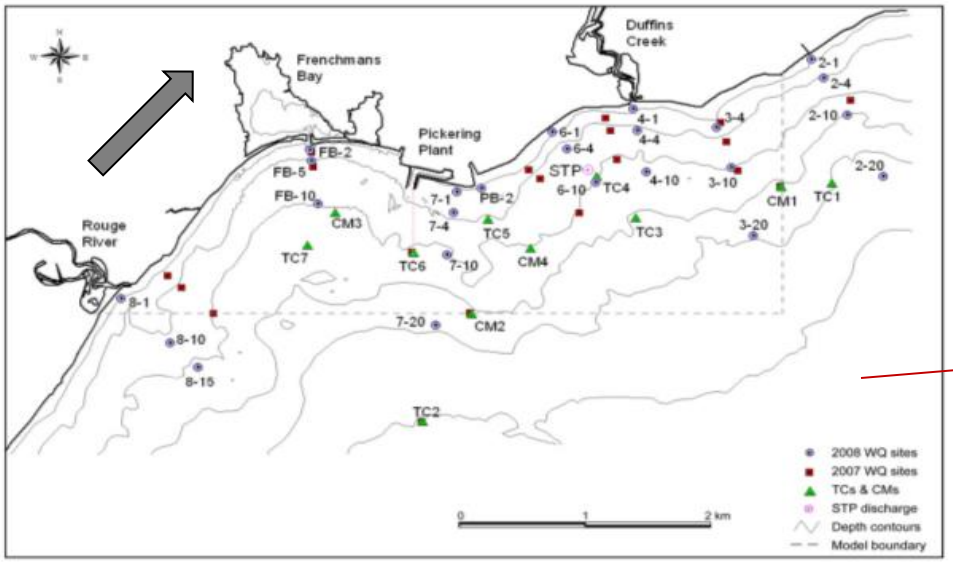


Fig. 1. Lake Ontario study area showing nearshore domain for high resolution model and location of moorings, together with water quality sampling sites in the study area for 2007 (no labels but for UW_2–3) and 2008 (labels).

Watershed Simulation Results

- Calibrated SWAT model of the Rouge River watershed (daily flows)
- In-stream water quality parameters - model performance nutrient components (MinP, OrgN, NO3, and NO2)
- Similar set of calibrated parameter values used in the model for Duffins
- Simulated water quality constituents comparable to observed values (model metrics limited by data availaility)
- **Scenarios (BMPs based on TRCA watershed plans)**
- Current work extending to Carruthers (UM) & Humber (GLAP)

Watershed derived nutrients for Lake Ontario inflows: Model calibration considering typical land operations in Southern Ontario

Masoud Asadzadeh [a,b], Luis Leon [a,*], Craig McCrimmon [a], Wanhong Yang [c], Yongbo Liu [c], Isaac Wong [a], Phil Fong [a], Gary Bowen [d]

[a] Environment Canada, National Water Research Institute, Burlington, ON, Canada
[b] Civil Engineering Department, University of Manitoba, Winnipeg, MB, Canada
[c] Department of Geography, University of Guelph, Guelph, ON, Canada
[d] Toronto and Region Conservation Authority, Toronto, ON, Canada

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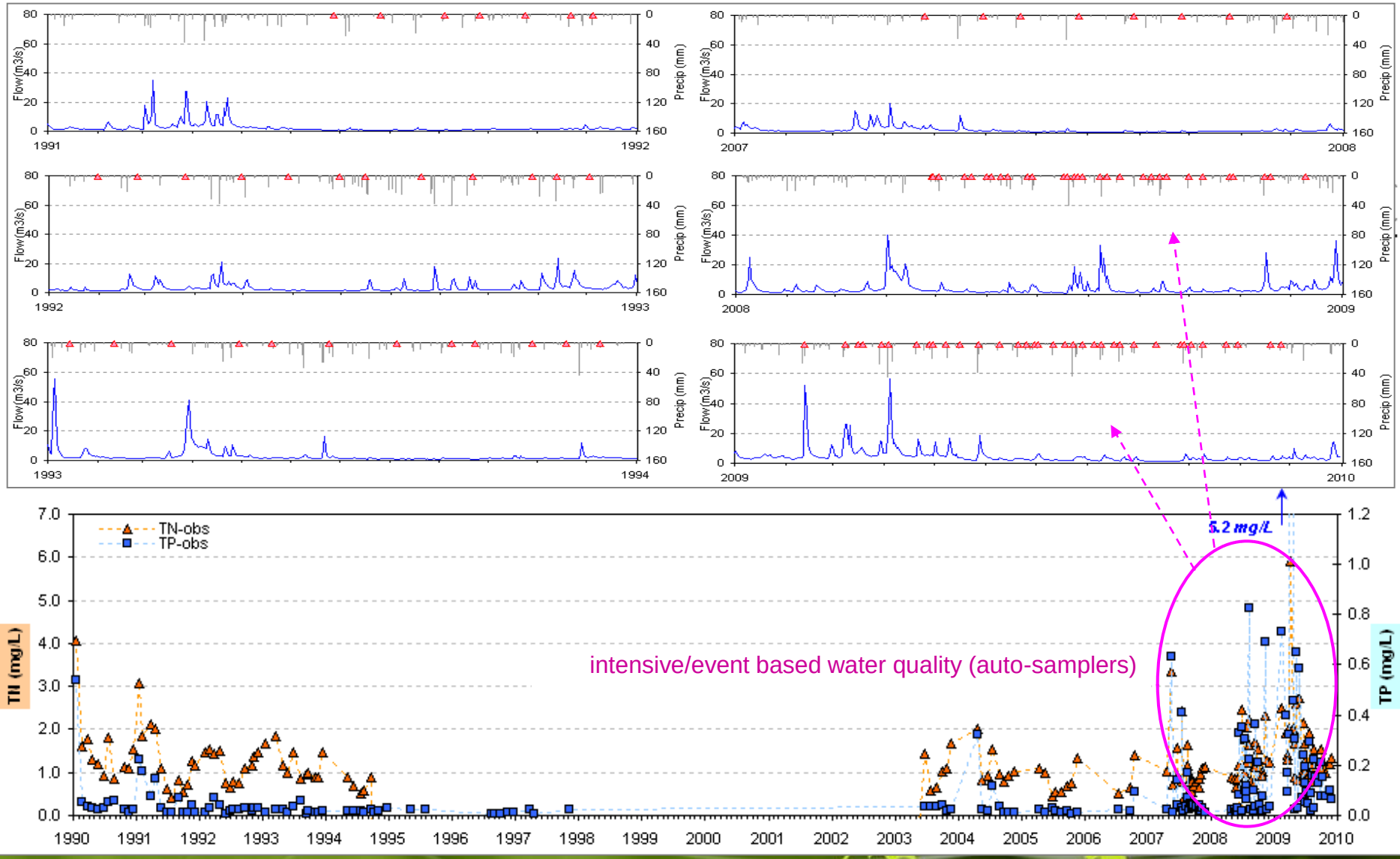
Main sources of model uncertainty

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

Canada

Water quality monitoring



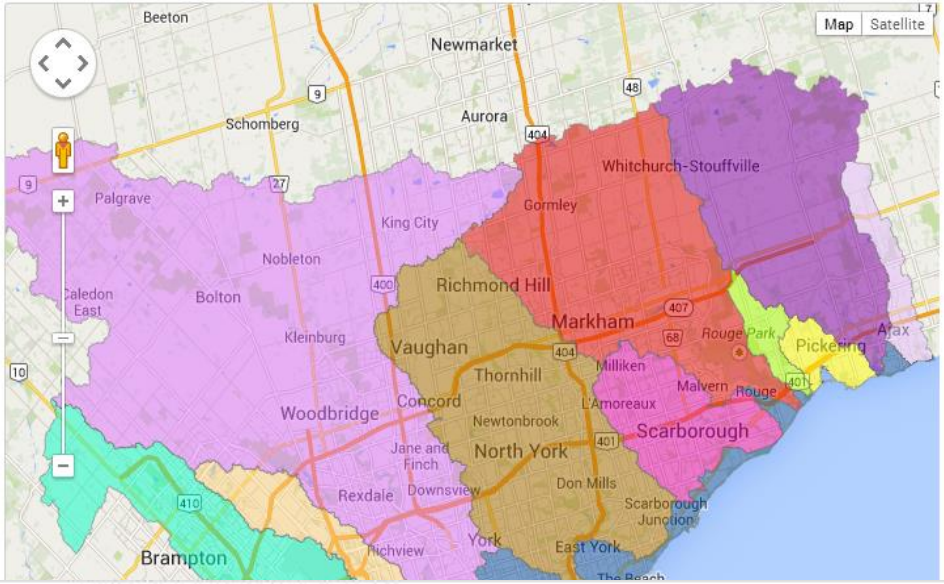
Agricultural Practices

SWAT *(Implementation of Crop Rotation and Management Operations*)*

LU Sub-classes	Area	Rotation Year			
		1	2	3	4
CCBW	10%	Corn	Corn	Soybean	W-Wheat
WCCB	10%	W-Wheat	Corn	Corn	Soybean
BWCC	10%	Soybean	W-Wheat	Corn	Corn
CBWC	10%	Corn	Soybean	W-Wheat	Corn
CBCB	10%	Corn	Soybean	Corn	Soybean
BCBC	10%	Soybean	Corn	Soybean	Corn
HAY	40%	Hay			

*Included in Duffins Cr. Project
improved additions & recalibration/validation

Year. Crop	Month	Day	Operation(s)	Hydrologic Soil Group A	B	C	D
1. Corn	4	30	Disc Plough GE23ft	77	86	91	94
	5	1	Plant/Grow Corn	67	78	85	89
	5	2	Fertilizer: N 110 kg/ha	-	-	-	-
	5	3	Fertilizer: P 22 kg/ha	-	-	-	-
	11	1	Harvest and Kill Corn	74	83	88	90
	11	15	Mouldboard Plough (reg 4-6b)	76	85	90	93
2. Corn	4	30	Disc Plough GE23ft	77	86	91	94
	5	1	Plant/Grow Corn	67	78	85	89
	5	2	Fertilizer: N 110 kg/ha	-	-	-	-
	5	3	Fertilizer: P 22 kg/ha	-	-	-	-
	11	1	Harvest and Kill Corn	74	83	88	90
	11	15	Mouldboard Plough (reg 4-6b)	76	85	90	93
3.Soybean	5	13	Plant/Grow Soybean	67	78	85	89
	5	14	Fertilizer: P 33 kg/ha	-	-	-	-
	10	1	Harvest and Kill Soybean	74	83	88	90
W-Wheat	10	6	Plant/Grow Winter Wheat	67	78	85	89
	10	7	Fertilizer: N 10 kg/ha	-	-	-	-
	10	8	Fertilizer: P 20 kg/ha	-	-	-	-
4.W-Wheat	4	10	Fertilizer: N 70 kg/ha	-	-	-	-
	7	15	Harvest and Kill Winter Wheat	74	83	88	90
	11	15	Mouldboard Plough (reg 4-6b)	76	85	90	93

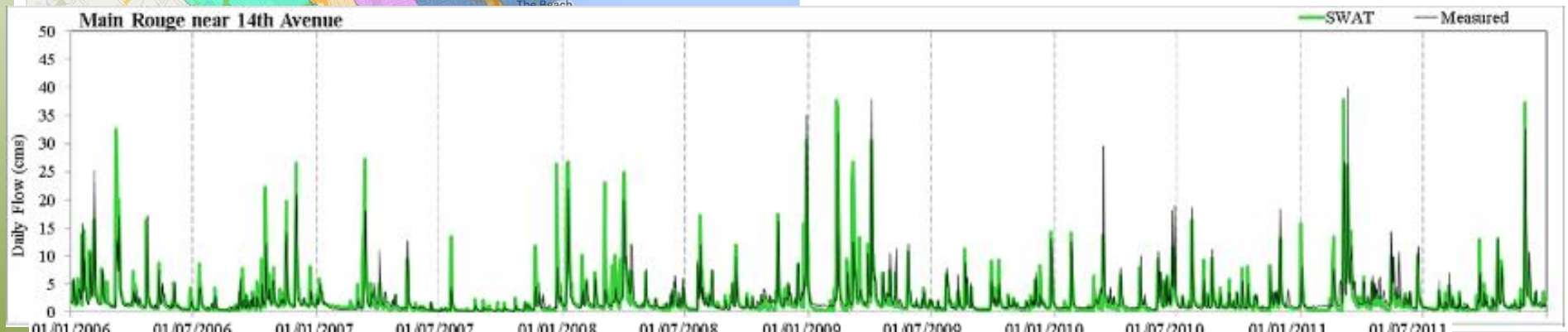


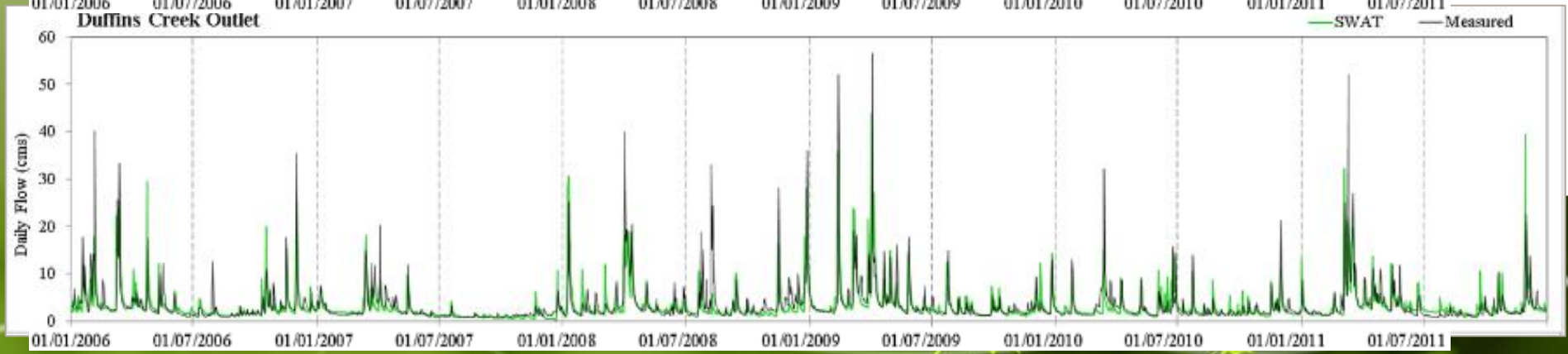
Canada

SWAT Results

(Flows: daily)

Annual Average Water Balance	SWAT for Rouge	SWAT for Duffins
Precipitation (mm)	837	881
Snowfall (mm)	117	138
Evapotranspiration (mm)	452	499
Runoff (mm)	372	355
Surface Flow (mm)	225	152





WQ Results

(TP: daily)

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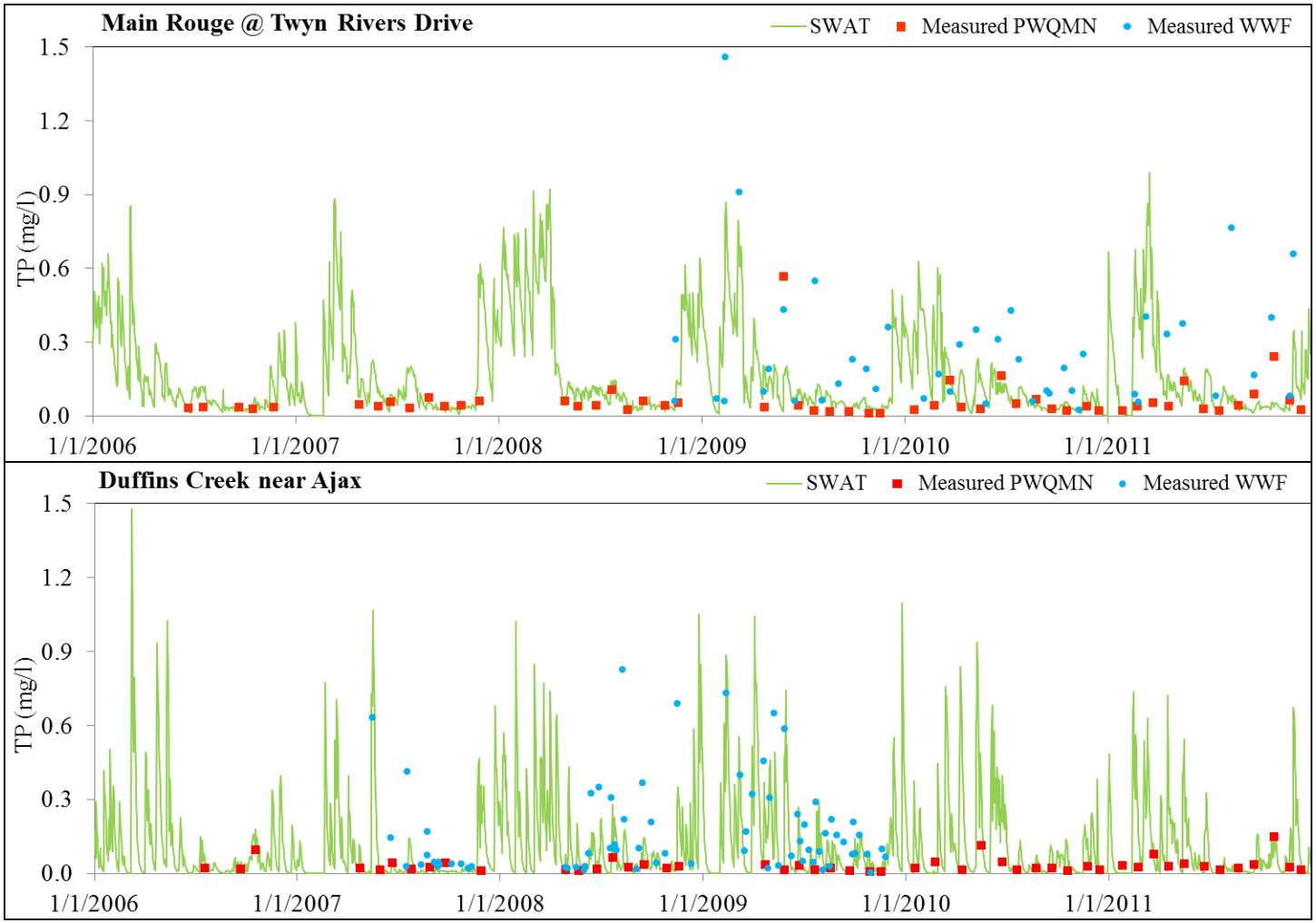
Canada

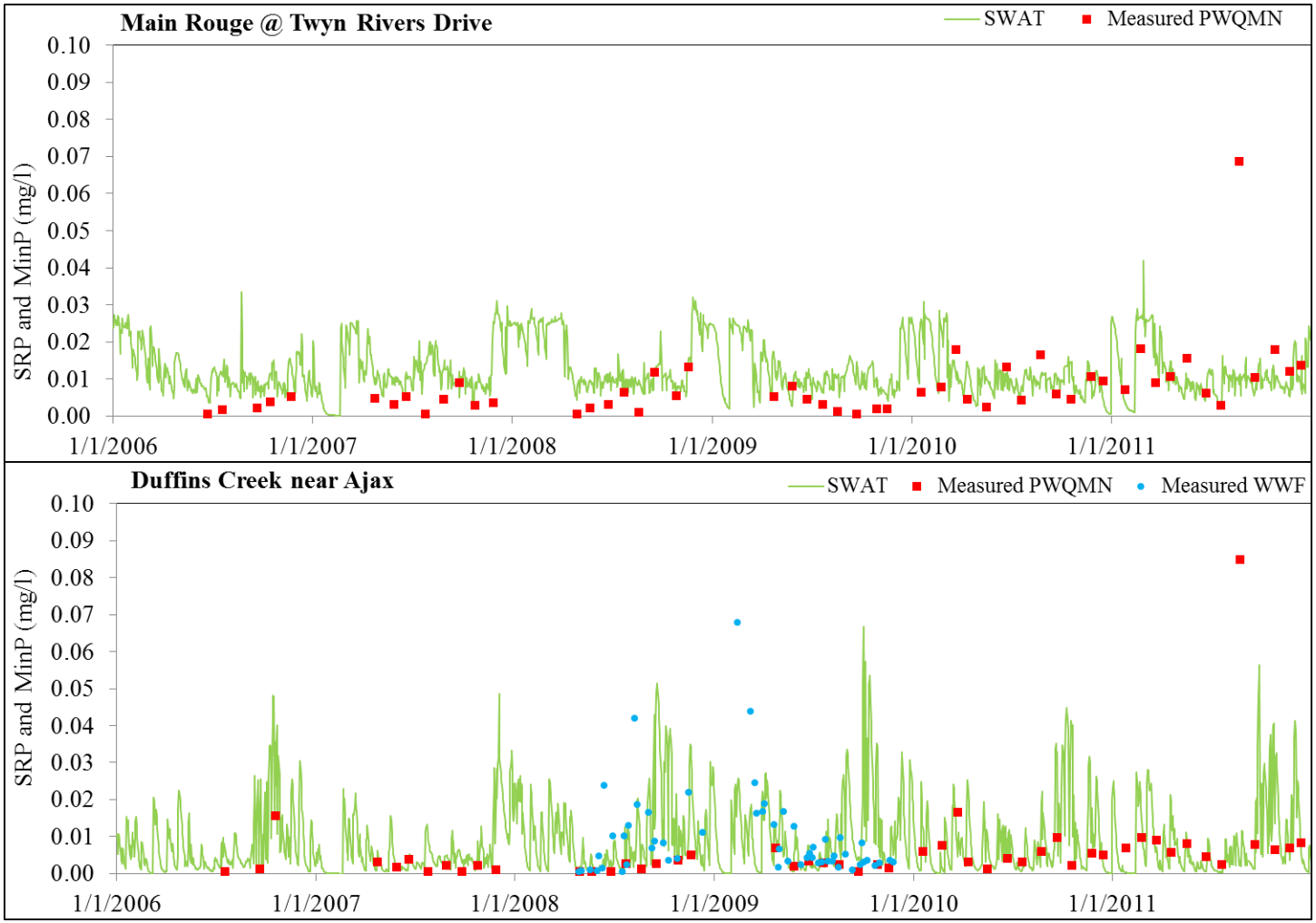


WQ Results

(SRP: daily)

Environment Canada Environnement Canada

Canada

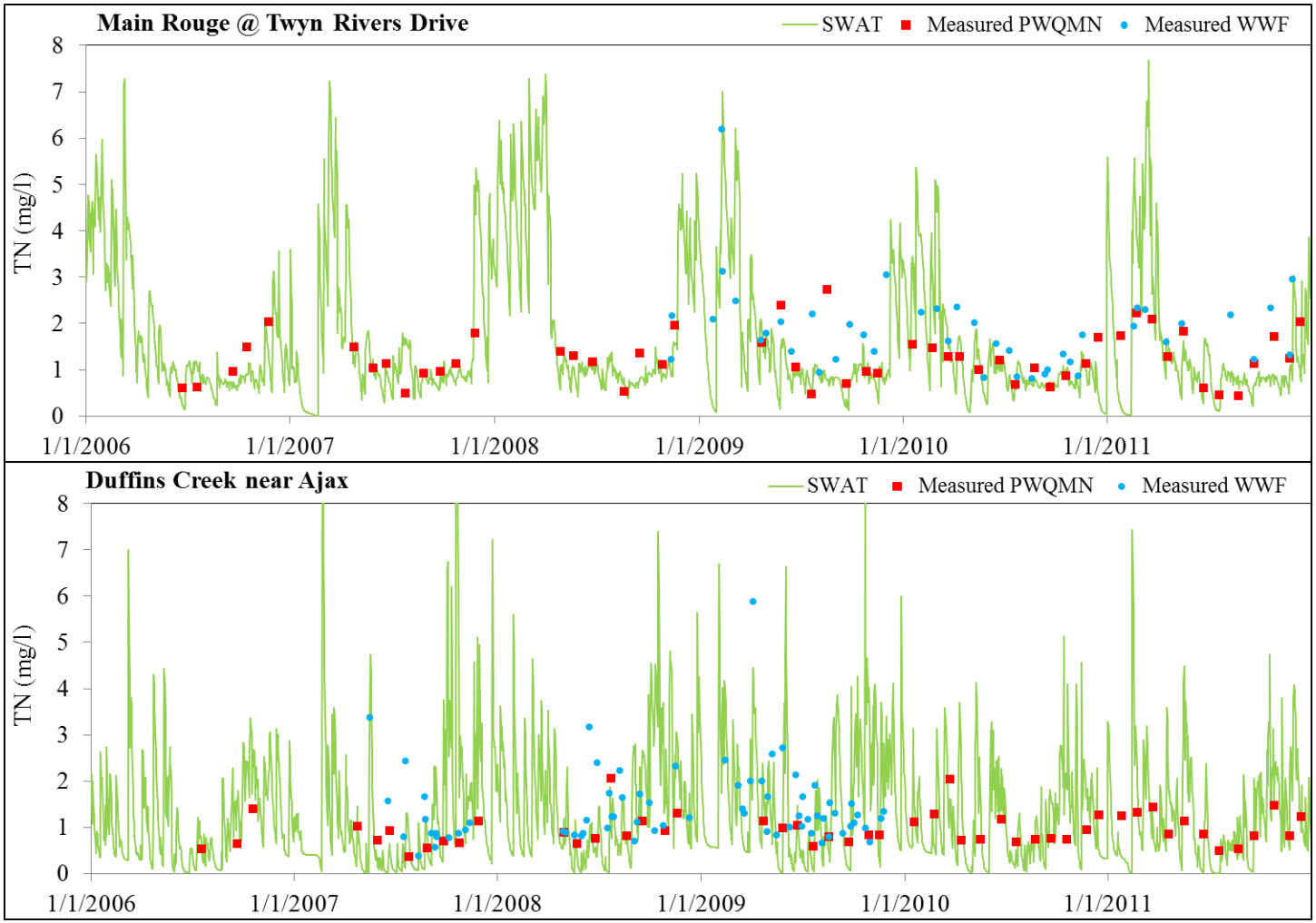


WQ Results

(TN: daily)

Environment Canada Environnement Canada

Canada



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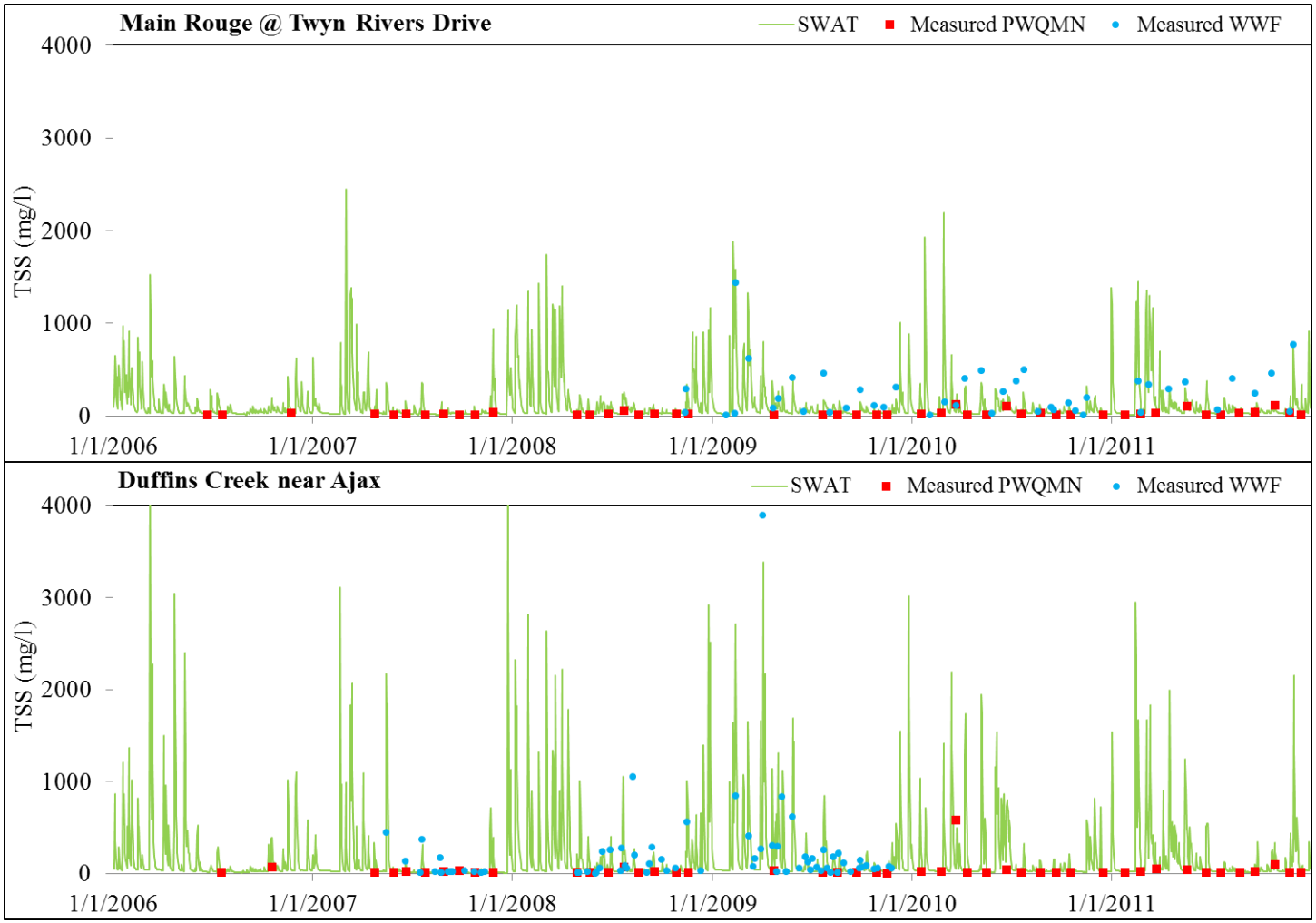
WQ Results

(TSS: daily)

Canada

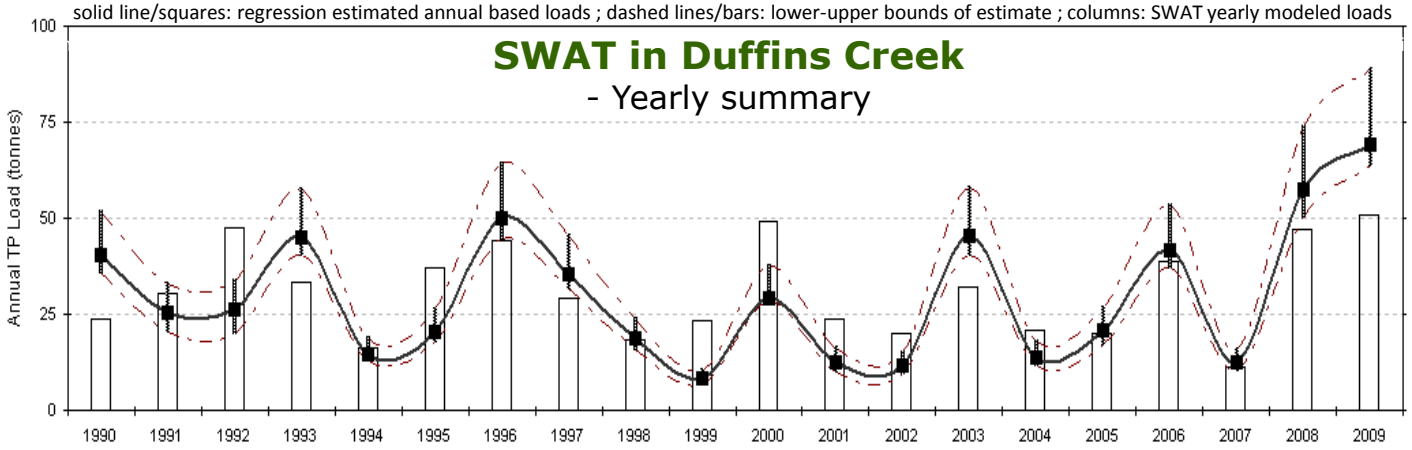


WQ Results
(Loadings)

Table 10: 2005 to 2011 annual TP, TN and TSS loading estimates for Duffins Creek at Ajax.

	TP Load (metric tonnes)	TN Load (metric tonnes)	TSS Load (metric tonnes)
Calendar Year	NWRI Regression [95% CI] r^2 = 0.37	NWRI Regression [95% CI] r^2=0.55	NWRI Regression [95% CI] r^2=0.42
2005*	16.9 [12.2, 23.6]	113.6 [105.7, 122.1]	18138 [11539, 28508]
2006*	33.5 [22.2, 50.5]	182.8 [167.4, 199.6]	41242 [23402, 72680]
2007	10.2 [8.0, 13.0]	83.9 [79.5, 88.5]	9491 [6709, 13426]
2008	44.1 [29.8, 65.3]	225.5 [206.7, 246.0]	54878 [32156, 93656]
2009	51.9 [39.8, 67.8]	215.5 [200.9, 231.2]	57889 [37528, 89298]
2010*	17.5 [13.1, 23.4]	115.5 [108.3, 123.2]	17374 [11091, 27214]
2011*	31.3 [20.6, 47.7]	170.8 [156.6, 186.2]	39461 [21906, 71086]

solid line/squares: regression estimated annual based loads ; dashed lines/bars: lower-upper bounds of estimate ; columns: SWAT yearly modeled loads



*loading estimates based on PWQMN data only

	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
997	20 [14, 27]	18
998	11 [8, 14]	11
999	5 [4, 6]	6
000	16 [12, 21]	14
001	7 [6, 9]	9
002	7 [6, 8]	8
003	25 [17, 36]	21
004	8 [7, 10]	9
005	12 [10, 16]	12
006	23 [17, 31]	26
007	8 [6, 9]	8
008	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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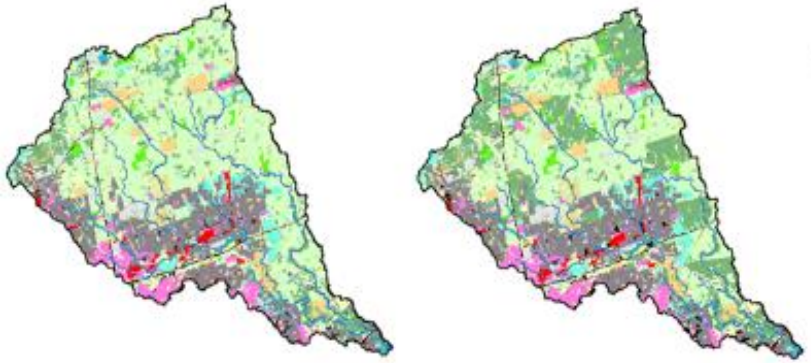
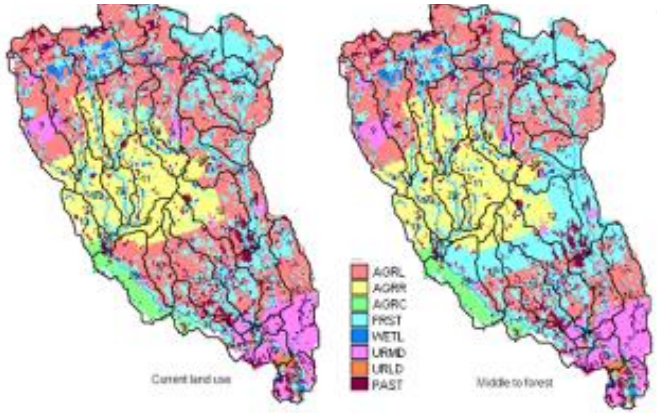
Scenario Generation
(verifying performance)

Canada



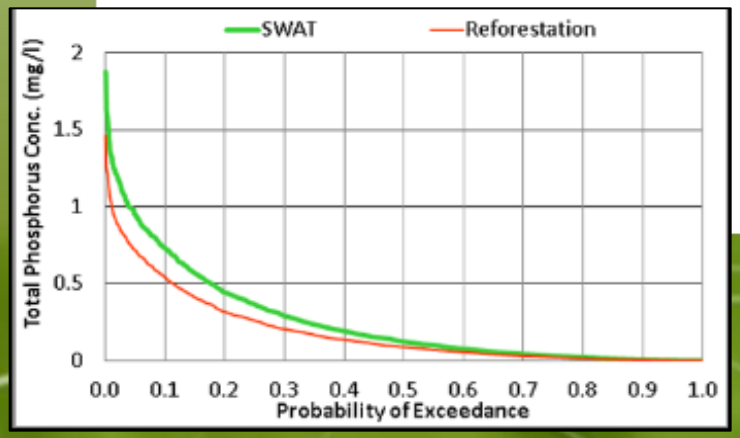


	Base Case	Reforestation	% diff.
AGRL (% area)	46	31	15 ↓
FRST (% area)	11	30	19 ↑
TSS (mg/l)	166	145	13 ↓
TP (mg/l)	0.32	0.25	22 ↓
TN (mg/l)	2.02	1.67	17 ↓

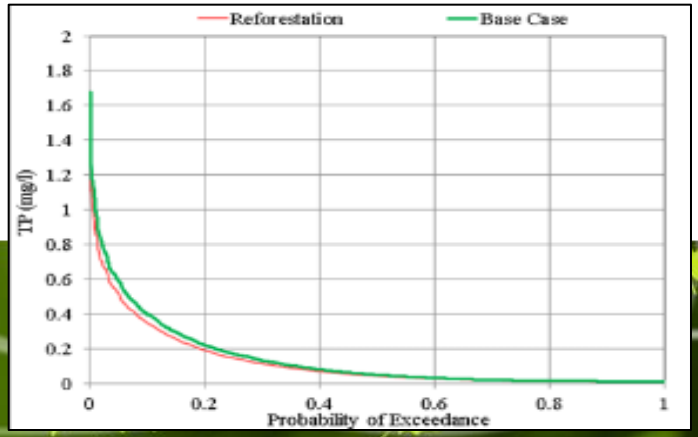
	Base Case	Reforestation	% diff.
AGRL (% area)	63	57	7 ↓
FRST (% area)	25	32	7 ↑
TSS (mg/l)	95	77	19 ↓
TP (mg/l)	0.139	0.121	13 ↓
TN (mg/l)	1.04	0.95	9 ↓

Reforestation BMP: "Middle" Scenario (TRCA)
- 1924 ha of cropland (in middle of watershed) converted to forest
- 12% reduction in average annual TP (2006-2012)

Rouge



Duffins

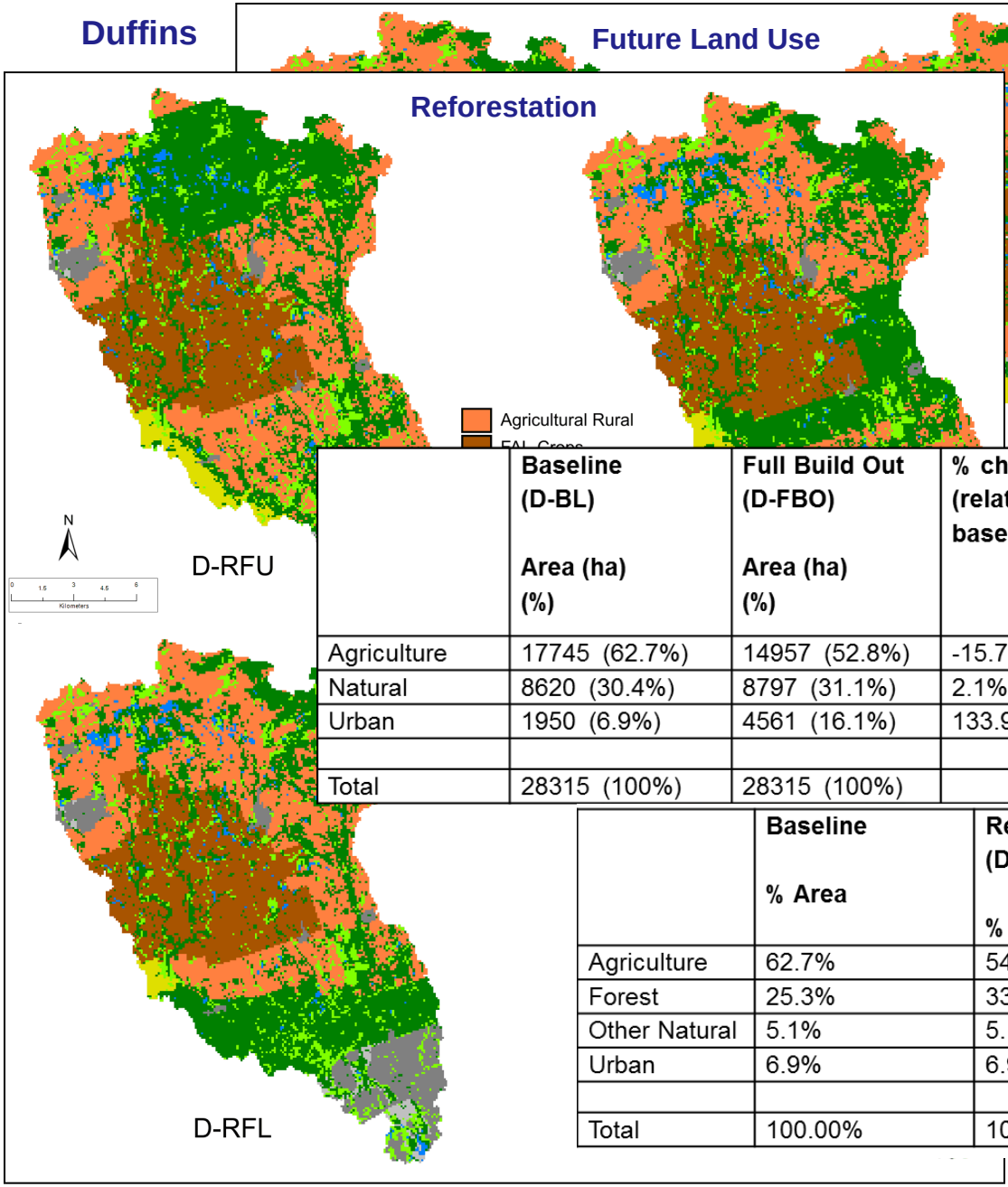


Scenarios: *(Watershed Plans)*

Duffins

Future Land Use

Reforestation



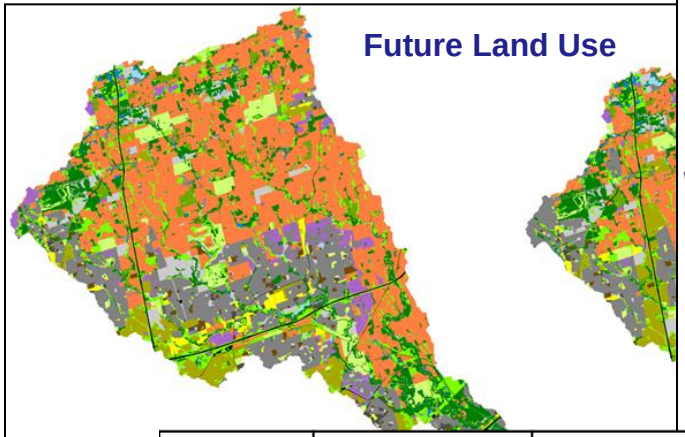
	Baseline (D-BL) Area (ha) (%)	Full Build Out (D-FBO) Area (ha) (%)	% change (relative to baseline)	Enhanced Natural Heritage (D-ENH) Area (ha) (%)	% change (relative to baseline)
Agriculture	17745 (62.7%)	14957 (52.8%)	-15.7%	10744 (37.9%)	-39.5%
Natural	8620 (30.4%)	8797 (31.1%)	2.1%	12092 (42.7%)	40.3%
Urban	1950 (6.9%)	4561 (16.1%)	133.9%	5479 (19.4%)	181.0%
Total	28315 (100%)	28315 (100%)		28315 (100%)	

	Baseline % Area	Reforestation Scenarios (D-RFU, D-RFM, D-RFL, D-RFST) % Area
Agriculture	62.7%	54.7%
Forest	25.3%	33.3%
Other Natural	5.1%	5.1%
Urban	6.9%	6.9%
Total	100.00%	100.00%

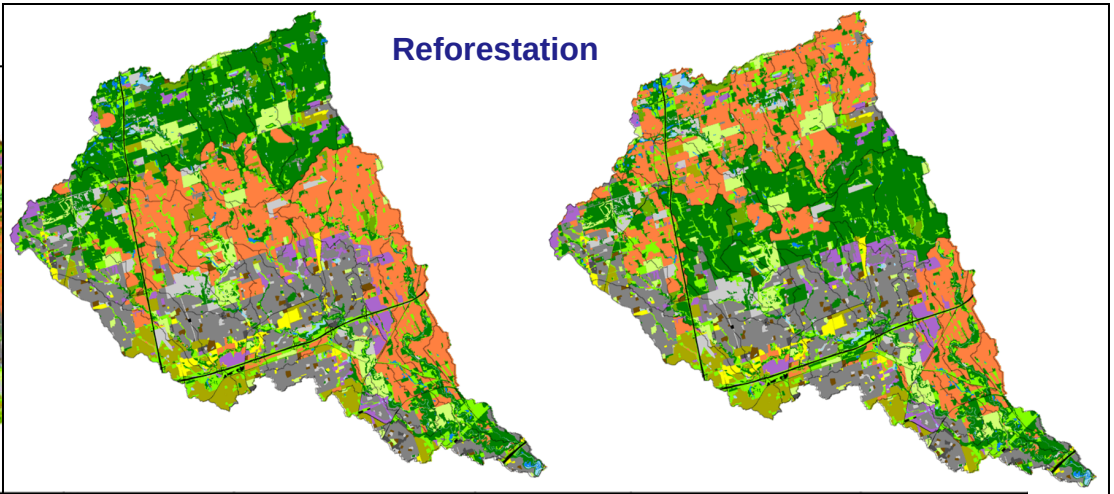
Scenarios: *(Watershed Plans)*

Rouge

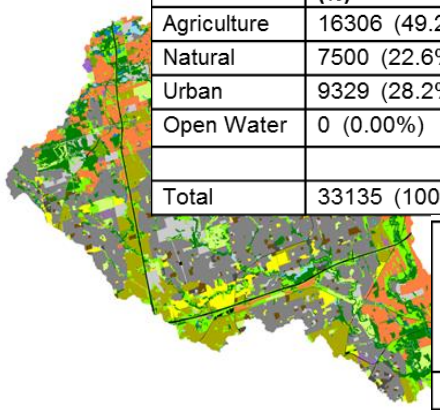
Future Land Use



Reforestation

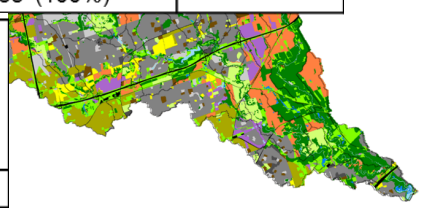


	Baseline (R-BL) Area(ha) (%)	Official Plan Build-Out (R-OBO) Area (ha) (%)	% change (relative to baseline)	Enhanced Natural Heritage (R-ENH) Area (ha) (%)	% change (relative to baseline)	Full Build Out (R-FBO) Area (ha) (%)	% change (relative to baseline)
Agriculture	16306 (49.2%)	10249 (30.9%)	-37.2%	6710 (20.3%)	-58.9%	7773 (23.5%)	-52.3%
Natural	7500 (22.6%)	7283 (22.0%)	-2.9%	11302 (34.1%)	50.7%	7005 (21.1%)	-6.6%
Urban	9329 (28.2%)	15388 (46.4%)	65.0%	15090 (45.5%)	61.8%	18145 (54.8%)	94.5%
Open Water	0 (0.00%)	215 (0.7%)		33 (0.1%)		212 (0.6%)	
Total	33135 (100%)	33135 (100%)		33135 (100%)		33135 (100%)	



R-FBO

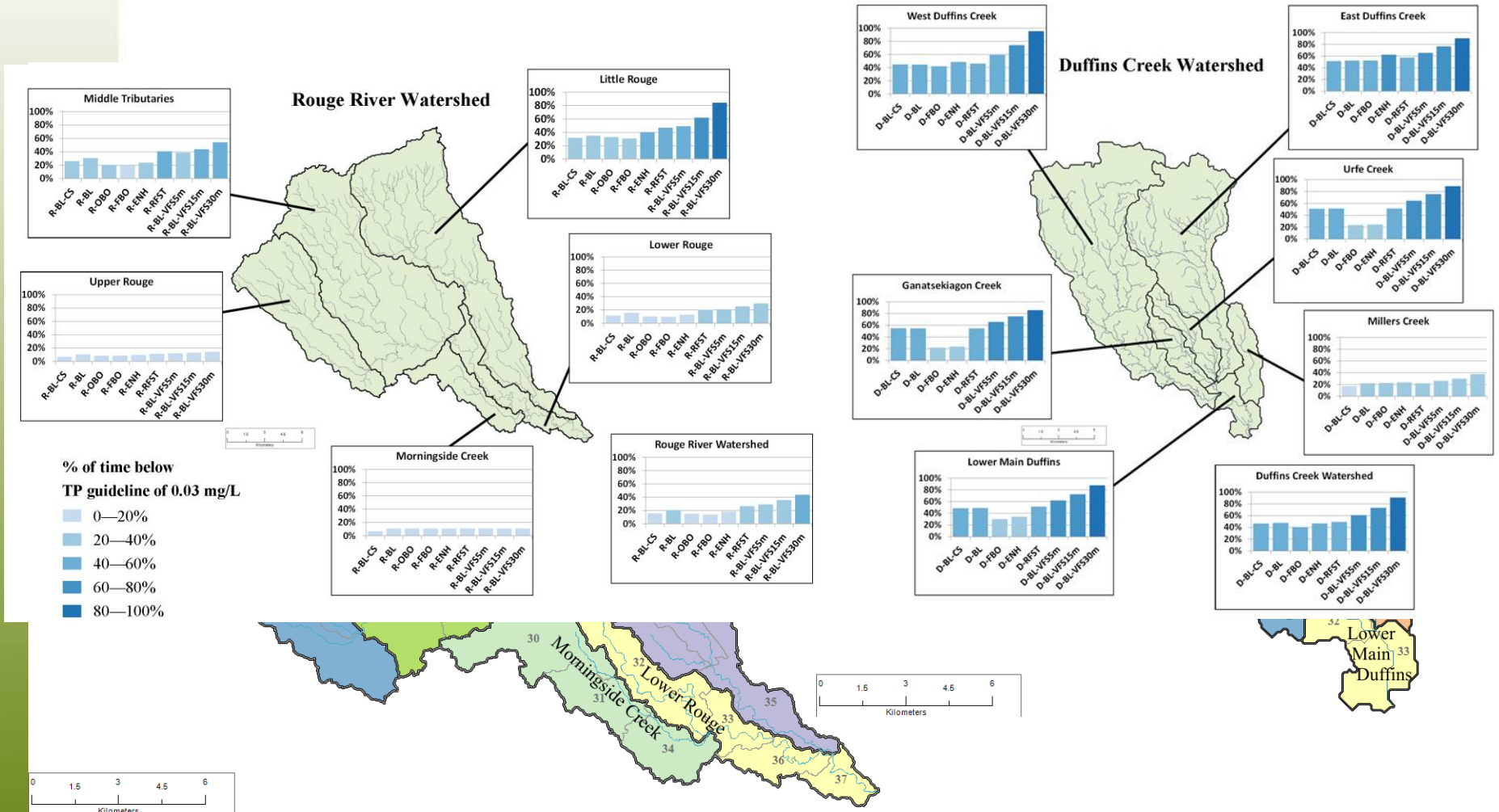
	Baseline % Area	Reforestation Scenarios (R-RFU, R-RFM, R-RFL, R-RFST) % Area
Agriculture	49.2%	27.3%
Forest	11.4%	33.3%
Other Natural	11.2%	11.2%
Urban	28.2%	28.2%
Total	100.00%	100.00%



R-RFST

Duffins and Rouge *(Sub-watershed aggregation analysis → SWAT Sub-basins)*

TP Compliance Percentage



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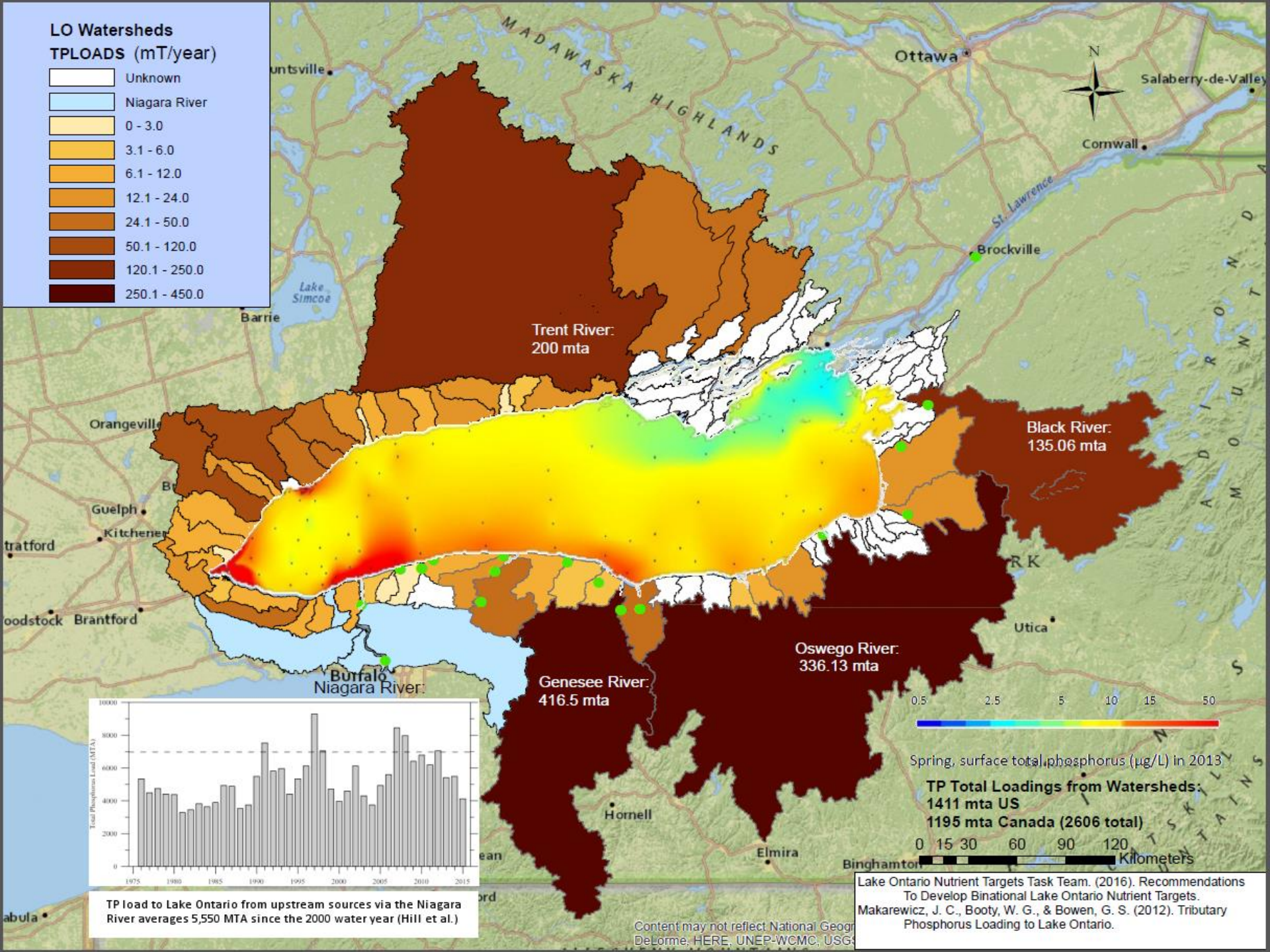

LO Watersheds
TPLOADS (mT/year)
Unknown
Niagara River
0 - 3.0
3.1 - 6.0
6.1 - 12.0
12.1 - 24.0
24.1 - 50.0
50.1 - 120.0
120.1 - 250.0
250.1 - 450.0
Trent River:
200 mta
Black River:
135.06 mta
Oswego River:
336.13 mta
Genesee River:
416.5 mta
Niagara River:
Ottawa
Salaberry-de-Valley
Cornwall
Brockville
Barrie
Lake Simcoe
Orangeville
Guelph
Kitchener
Brantford
Buffalo
Utica
Hornell
Elmira
Binghamton
MADAWASKA HIGHLANDS
St. Lawrence
N
0.5 2.5 5 10 15 50
Spring, surface total phosphorus (µg/L) in 2013
TP Total Loadings from Watersheds:
1411 mta US
1195 mta Canada (2606 total)
0 15 30 60 90 120
Kilometers
Total Phosphorus Load (MTA)
1975 1980 1985 1990 1995 2000 2005 2010 2015
TP load to Lake Ontario from upstream sources via the Niagara River averages 5,550 MTA since the 2000 water year (Hill et al.)
Lake Ontario Nutrient Targets Task Team. (2016). Recommendations To Develop Binational Lake Ontario Nutrient Targets.
Makarewicz, J. C., Booty, W. G., & Bowen, G. S. (2012). Tributary Phosphorus Loading to Lake Ontario.
Content may not reflect National Geogr
DeLorme, HERE, UNEP-WCMC, USGS

References (Scenarios, DSS, Lake Modelling)

Watershed Plans: TRCA

A Watershed Plan for Duffins and Carruthers Creek, 2003

Rouge River Watershed Scenario Modelling and Analysis Report, 2007

Reforestation Scenarios: TRCA (personal communication)

Water Quality Objectives

PWQO OMEE 1994 Water management policies, guidelines, provincial water quality objectives

Source Tracing

Wong, I., Leon, L.F., Vanrobaeys, J., McCrimmon, C., Fong, P., 2014. A decision support system approach for identifying pollutant source for optimization of beneficial management practices scenario modelling in Lake Winnipeg watersheds. In: Ames, D.P., Quinn, N.W.T., Rizzoli, A.E. (Eds.), Proceedings of the 7th International Congress on Environmental Modelling and Software, June 15-19, San Diego, California, USA. ISBN: 978-88-9035-744-2

Lake Modelling

Leon, L.F., Smith, R.E.H., Malkin, S.Y., Depew, D., Hipsey, M.R., Antenucci, J.P., Higgins, S.N., Hecky, R.E., Rao, R.Y., 2012. Nested 3D modelling of the spatial dynamics of nutrients and phytoplankton in a Lake Ontario nearshore zone. J. Great Lakes Res.

Scenarios SWAT : Duffins & Rouge

Summary of Duffins Scenarios (91)

D-BL
D-FBO
D-ENH
D-RFU
D-RFM
D-RFL
D-RFS
D-BL-
D-BL-
D-BL-
D-BL-
D-BL-
D-BL-
D-BL-
D-FBO
D-FBO
D-FBO
D-FBO
D-FBO
D-FBO
D-ENH
D-ENH
D-ENH
D-ENH
D-ENH
D-ENH
D-FBO-CS-VFS

Summary of Rouge Scenarios (107)

R-BL
R-OBO
R-FBO
R-ENH
R-RFU
R-RFM
R-RFL
R-RFST
R-BL-VF
R-BL-VF
R-BL-VF
R-BL-VF
R-BL-VF
R-BL-VF
R-BL-CS
R-OBO-
R-OBO-
R-OBO-
R-OBO-
R-OBO-
R-OBO-
R-FBO-
R-FBO-
R-FBO-
R-FBO-
R-FBO-
R-FBO-
R-FBO-

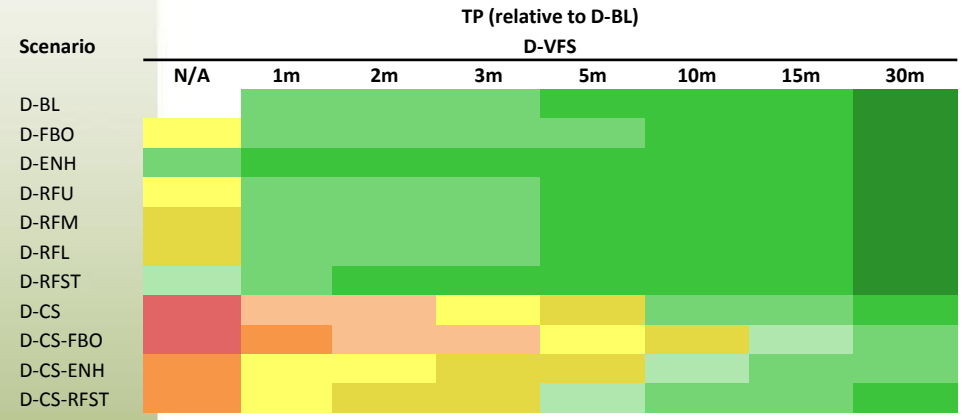
R-ENH-CS	Enhanced Natural Heritage with Future Climate
R-RFU-CS	Upper Reforestation with Future Climate
R-RFM-CS	Middle Reforestation with Future Climate
R-RFL-CS	Lower Reforestation with Future Climate
R-RFST-CS	Hotspot Source Tracing Reforestation with Future Climate
R-BL-CS-VFS1m	Baseline with Future Climate and 1 m VFS
R-BL-CS-VFS2m	Baseline with Future Climate and 2 m VFS
R-BL-CS-VFS3m	Baseline with Future Climate and 3 m VFS
R-BL-CS-VFS5m	Baseline with Future Climate and 5 m VFS
R-BL-CS-VFS10m	Baseline with Future Climate and 10 m VFS
R-BL-CS-VFS15m	Baseline with Future Climate and 15 m VFS
R-BL-CS-VFS30m	Baseline with Future Climate and 30 m VFS

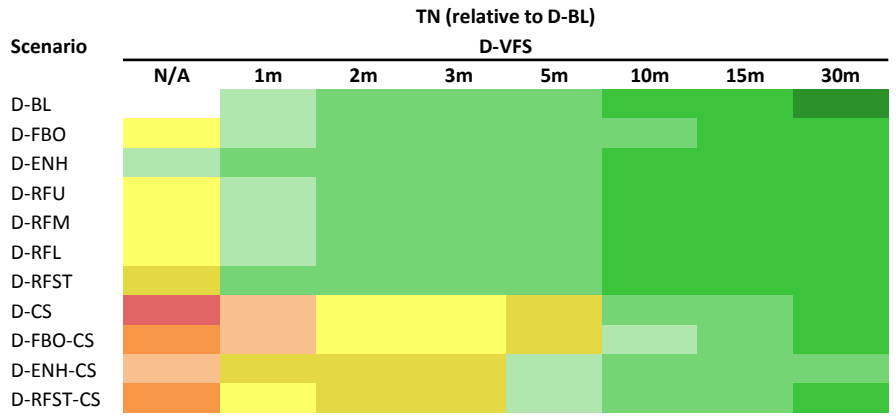
R-ENH-CS-VFS1m	Enhanced Natural Heritage with Future Climate and 1 m VFS
R-ENH-CS-VFS2m	Enhanced Natural Heritage with Future Climate and 2 m VFS
R-ENH-CS-VFS3m	Enhanced Natural Heritage with Future Climate and 3 m VFS
R-ENH-CS-VFS5m	Enhanced Natural Heritage with Future Climate and 5 m VFS
R-ENH-CS-VFS10m	Enhanced Natural Heritage with Future Climate and 10 m VFS
R-ENH-CS-VFS15m	Enhanced Natural Heritage with Future Climate and 15 m VFS
R-ENH-CS-VFS30m	Enhanced Natural Heritage with Future Climate and 30 m VFS

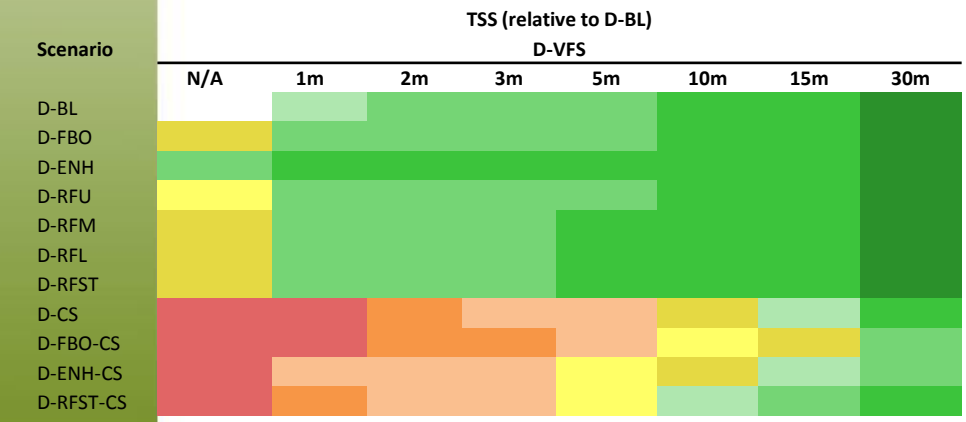
R-RFST-CS-VFS1m	Hotspot Source Tracing Reforestation with Future Climate and 1 m VFS
R-RFST-CS-VFS2m	Hotspot Source Tracing Reforestation with Future Climate and 2 m VFS
R-RFST-CS-VFS3m	Hotspot Source Tracing Reforestation with Future Climate and 3 m VFS
R-RFST-CS-VFS5m	Hotspot Source Tracing Reforestation with Future Climate and 5 m VFS
R-RFST-CS-VFS10m	Hotspot Source Tracing Reforestation with Future Climate and 10 m VFS
R-RFST-CS-VFS15m	Hotspot Source Tracing Reforestation with Future Climate and 15 m VFS
R-RFST-CS-VFS30m	Hotspot Source Tracing Reforestation with Future Climate and 30 m VFS

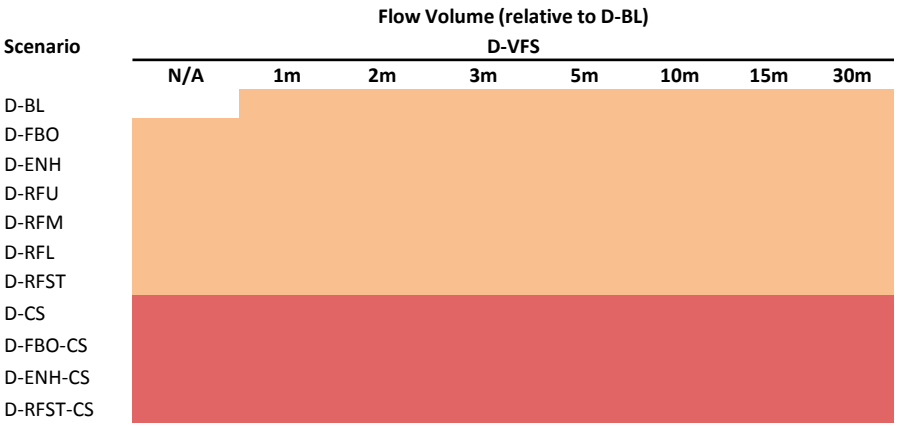
R-FBO-CS-VFS3m	Full Build Out with Future Climate and 3 m VFS
R-FBO-CS-VFS5m	Full Build Out with Future Climate and 5 m VFS
R-FBO-CS-VFS10m	Full Build Out with Future Climate and 10 m VFS
R-FBO-CS-VFS15m	Full Build Out with Future Climate and 15 m VFS
R-FBO-CS-VFS30m	Full Build Out with Future Climate and 30 m VFS

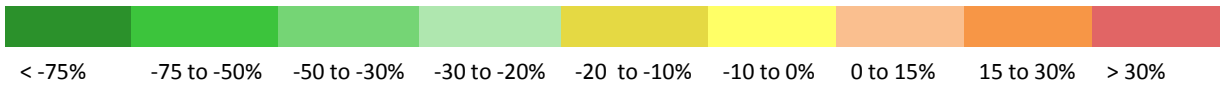
Duffins Scenarios + Vegetative Filter Strip











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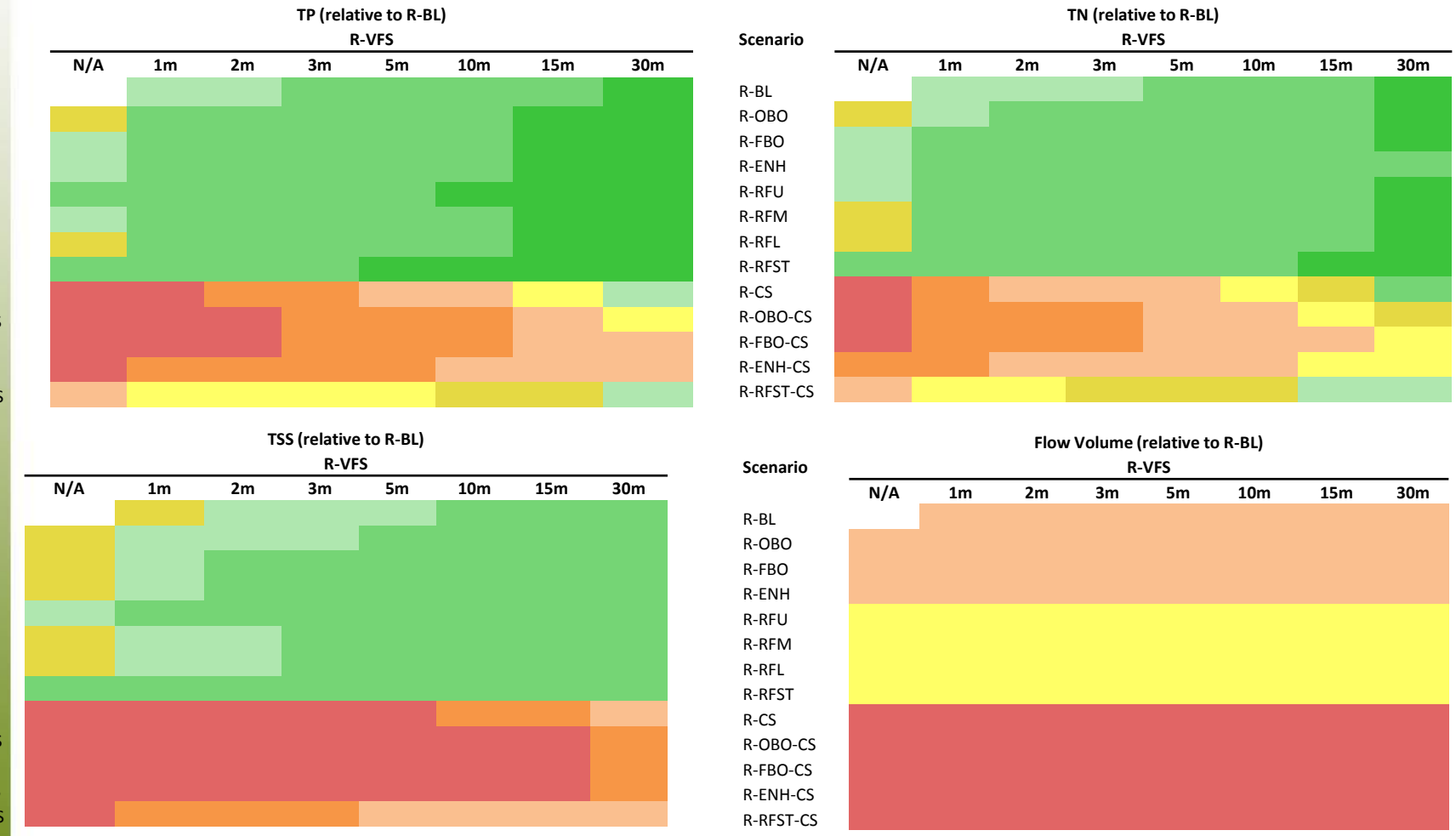
Rouge Scenarios + Vegetative Filter Strip



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