Adapting SWAT for Riparian Wetlands in Ontario Watershed

Amanjot Singh, Ramesh Rudra and Wanhong Yang

University of Guelph

School of Engineering

UNIVERSITY of GUELPH

Outline

- **Background – Where we are coming from?**
- **Watershed Scale Model -- SWAT**
- **Riparian-Wetland Model -- REMM**
- **Interfacing Hypothesis**
- **Case Study**
- **Economic Implications**

Where We Are Coming From

- Great Lakes Pollution
- Walkerton Tragedy in 2000

  E-Coli pollution of drinking water

  7 died and more than 2000 ill

  Nutrient Management Legislation

- Royal Commission

  Source Water Protection

- Wild life habitat

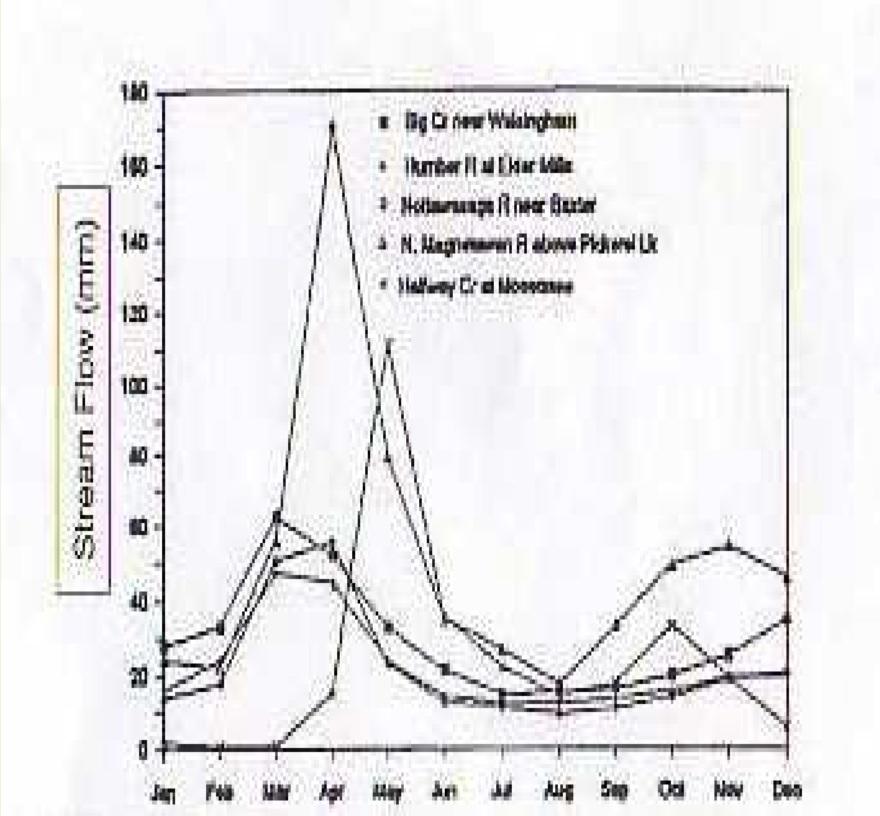
Agencies Involved

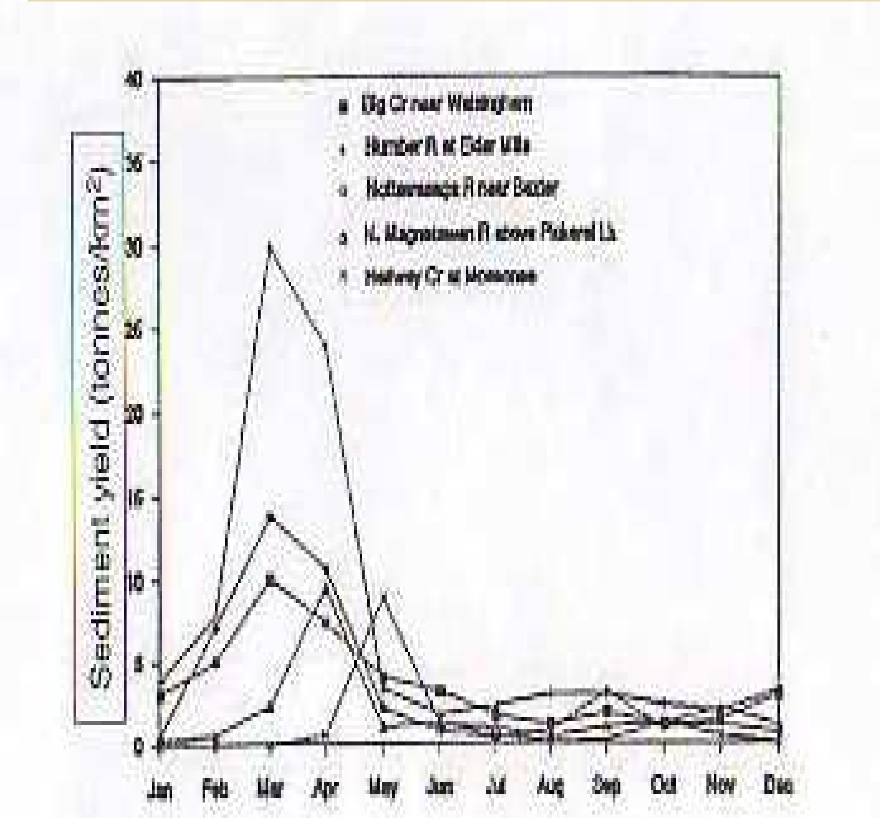
- Provincial Acencies
  - Conservation Authorities
  - Ontario Ministry of Environment
  - Ontario Ministry of Natural Resources
  - Ontario Ministry of Agricultural and Food
- Environment Canada
  - Great Lakes Sustainability Program

Interest in Models

- Conservation Authorities
  - AnnAGNPS, AGNPS, GAWSER, AVGWLF (CANWET), HSPF, ANSWERS200, MikeShe
- Environment Canada
  - AGNPS, AnnAGNPS
- Ministry of Agriculture and Food
  - GoeWEPP, SWAT
- Ministry of Natural Resources
  - GAWSER
- Ministry of Environment
  - SWAT, Other Models

Models Selected for Evaluation





- Daily

Objectives

Economic Evaluation of Wetlands

Available Options

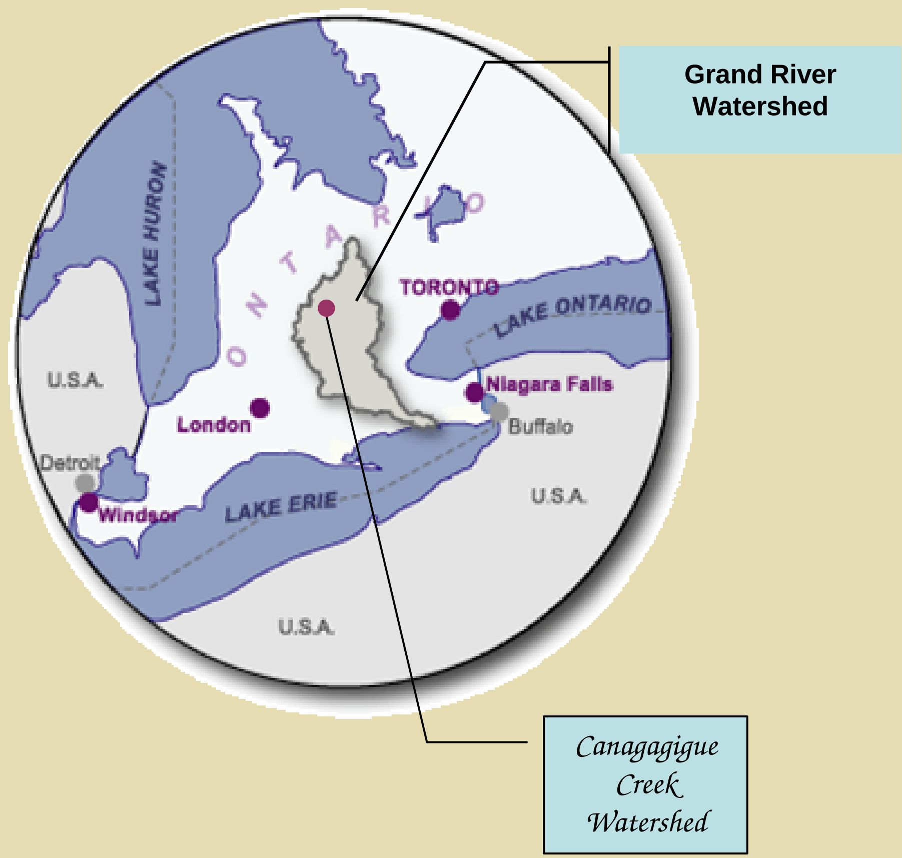
1) To develop interface for a Watershed Scale model and Riparian Wetland model to understand the role of wetlands on watershed hydrology and hydraulics.
2) To add wetland component to the watershed scale model

Watershed Models Short Listed

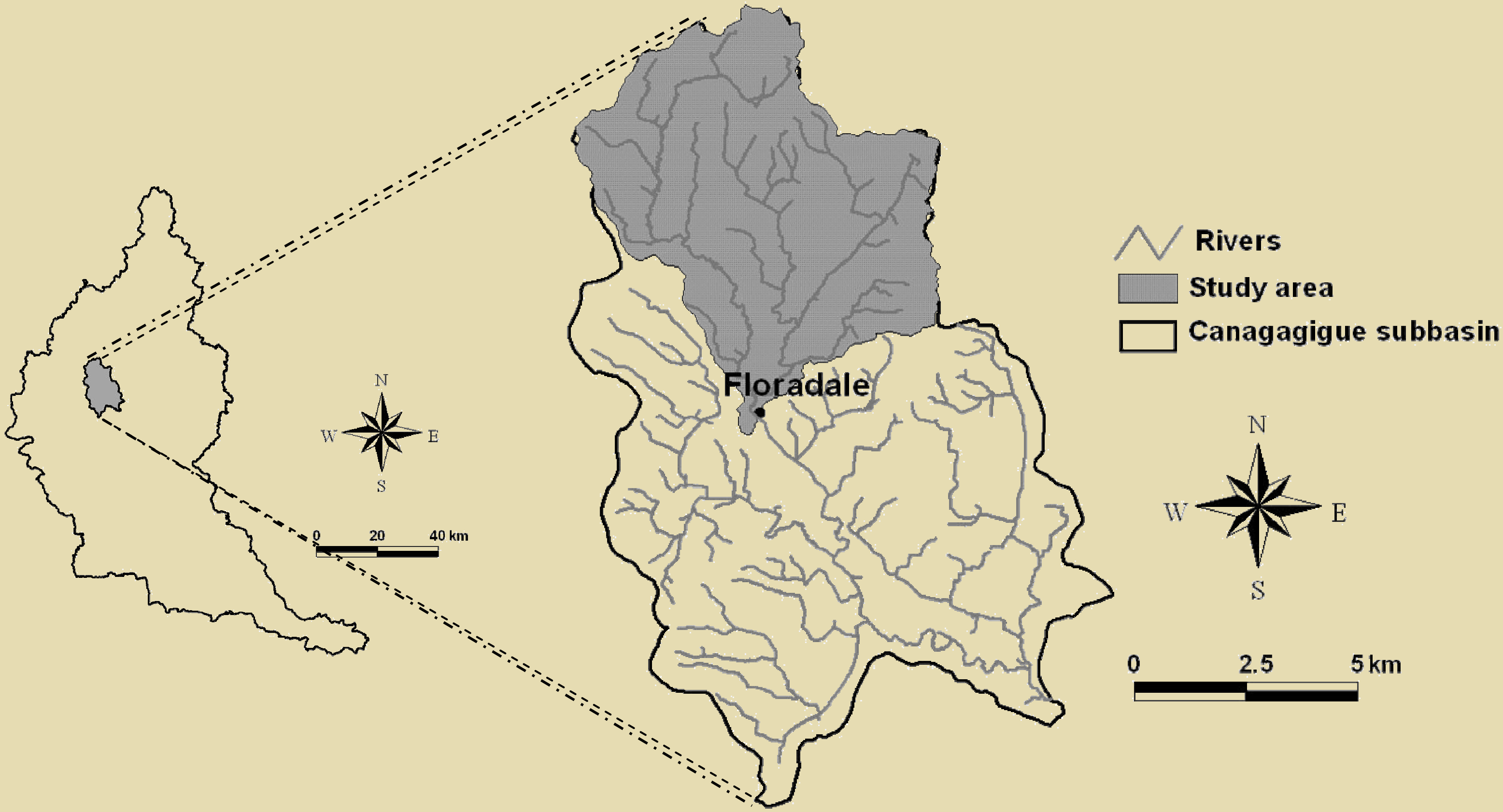
SWAT

AnnAGNPS

Study Watershed



Canagagigue Creek Watershed



UNIVERSITY of GUELPH

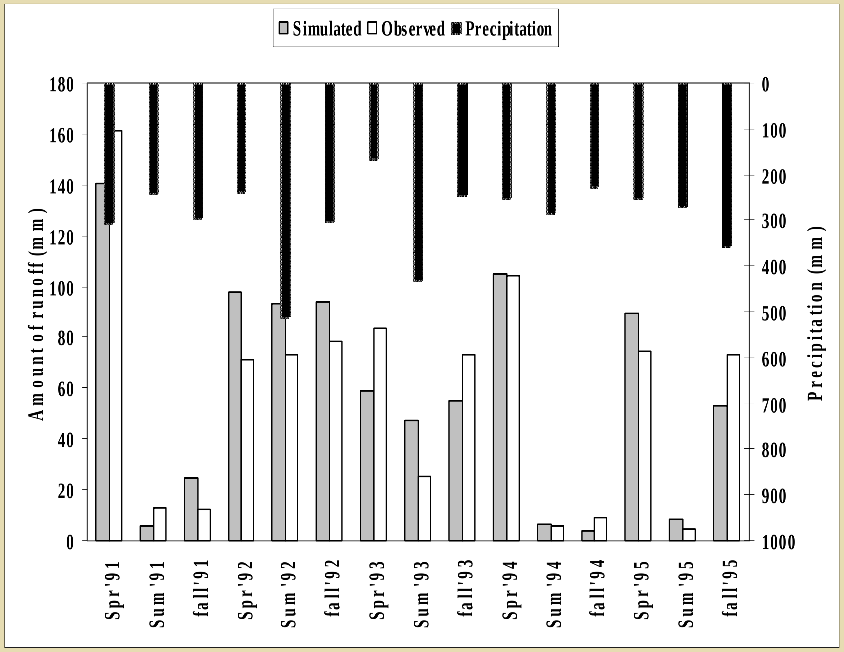
SWAT
Calibrated: Seasonal Water Balance

			Observed		Simulation	
Season	**% P**	**% E**	**% Q_s**	**% Q_g**	**% Q_s**	**% Q_g**
JFM	**21.6**	**5.6**	**10.1**	**7.3**	**11.8**	**2.2**
AMJ	**26.7**	**22.3**	**5.5**	**6.5**	**2.9**	**7.5**
JAS	**31.5**	**25.2**	**2.0**	**2.4**	**4.7**	**1.0**
OND	**23.7**	**8.2**	**2.5**	**4.2**	**3.7**	**3.8**

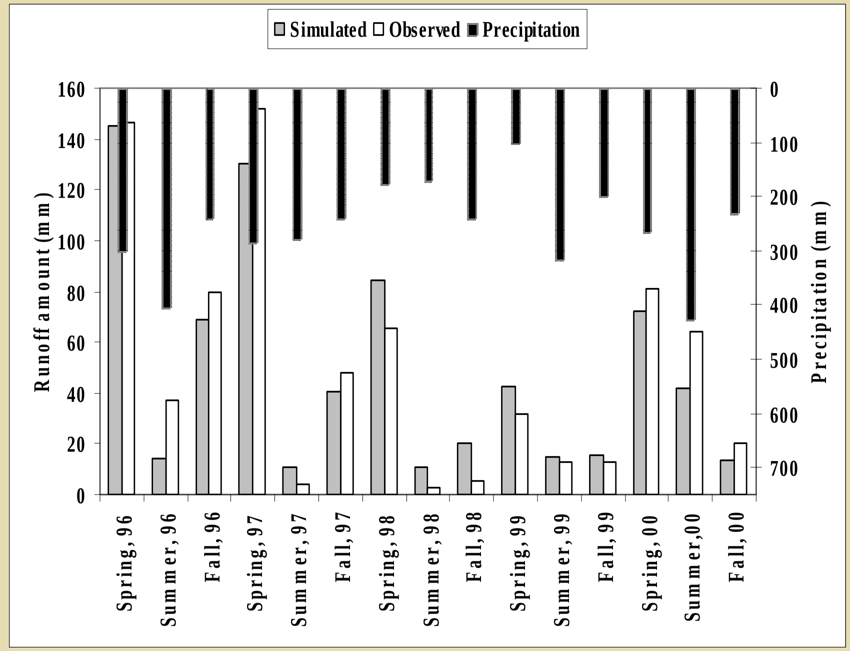
SWAT
Validation: Seasonal Water Balance

Season	% P	% E	Observed		Simulation	
			$\% Q_s$	$\% Q_g$	$\% Q_s$	$\% Q_g$
JFM	24.9	7.5	11.4	8.0	11.6	2.2
AMJ	26.6	23.5	6.2	7.5	5.3	5.7
JAS	30.3	23.9	2.4	2.8	4.1	1.1
OND	22.7	9.2	2.9	4.9	2.3	3.0

AnnAGNPS
Simulated and Observed Runoff



Calibration Phase



Validation Phase

UNIVERSITY of GUELPH

Models Short Listed

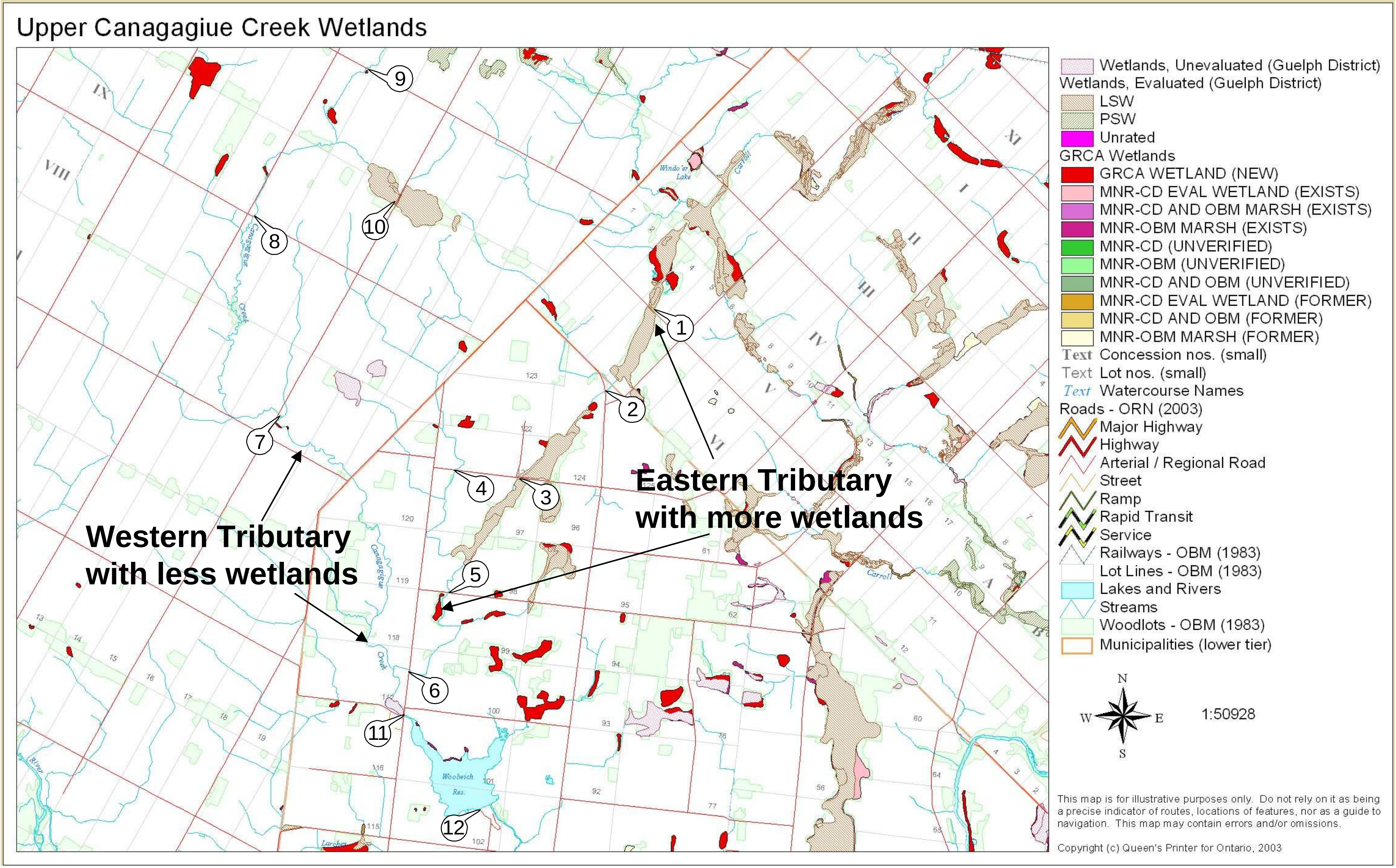
SWAT

The SWAT model can simulate the annual, seasonal, monthly and daily water balances well.

AnnAGNPS

AnnAGNPS can simulate the hydrology and sediment transport fairly well, howver, Effective daily base flow separation technique is required to incorporate with the model

Canagagigue Creek Watershed



Riparian Wetland

Canagagigue Creek Watershed

Point of Merger of two Tributaries

Tributary draining wetland side

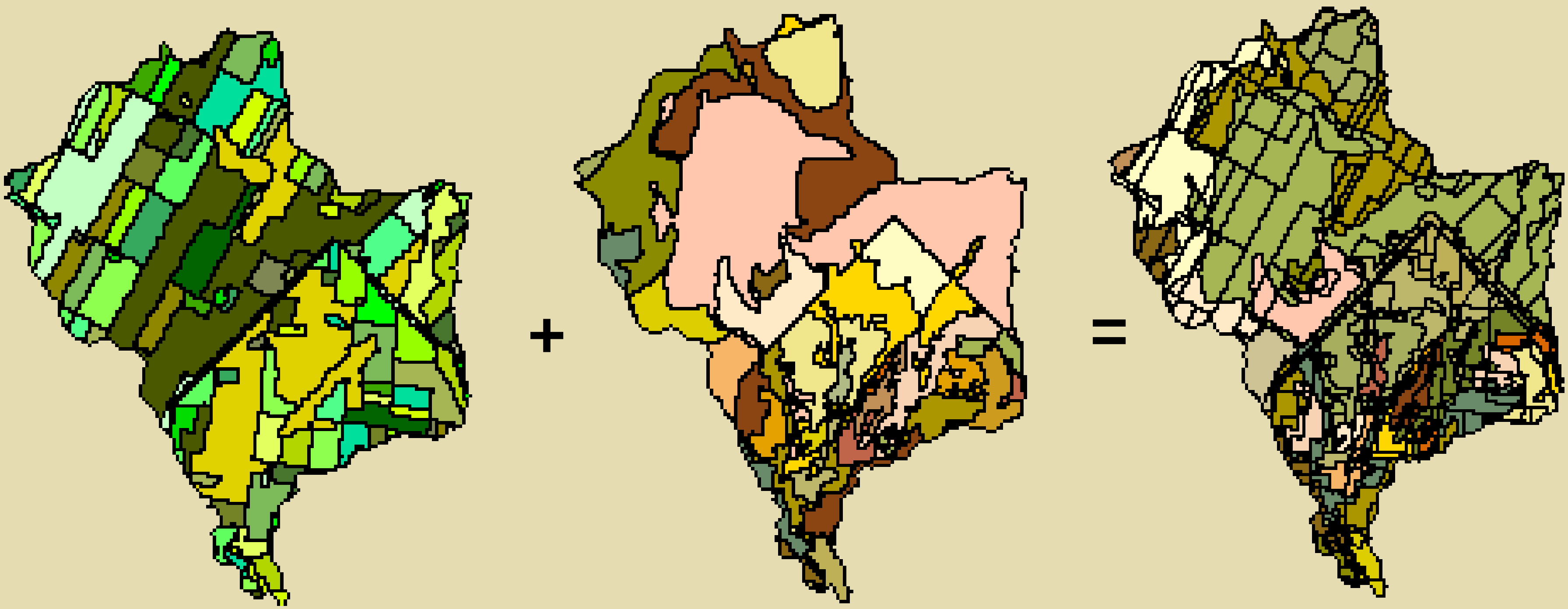
Tributary draining non-wetland side

Source: Wayne Jenkinson (UOW)

SWAT Approach

- **Delineates watershed into sub-basins and sub-basins further into Hydrologic Response Units (HRU) based upon unique soil/land-use characteristics.**
- **Flow, sediment and nutrient loadings from each HRU are summed at sub-basin level and resulting loads then routed through channels, ponds and reservoirs to the watershed outlet.**

Hydraulic Response Unit, SWAT



Land Use Layer

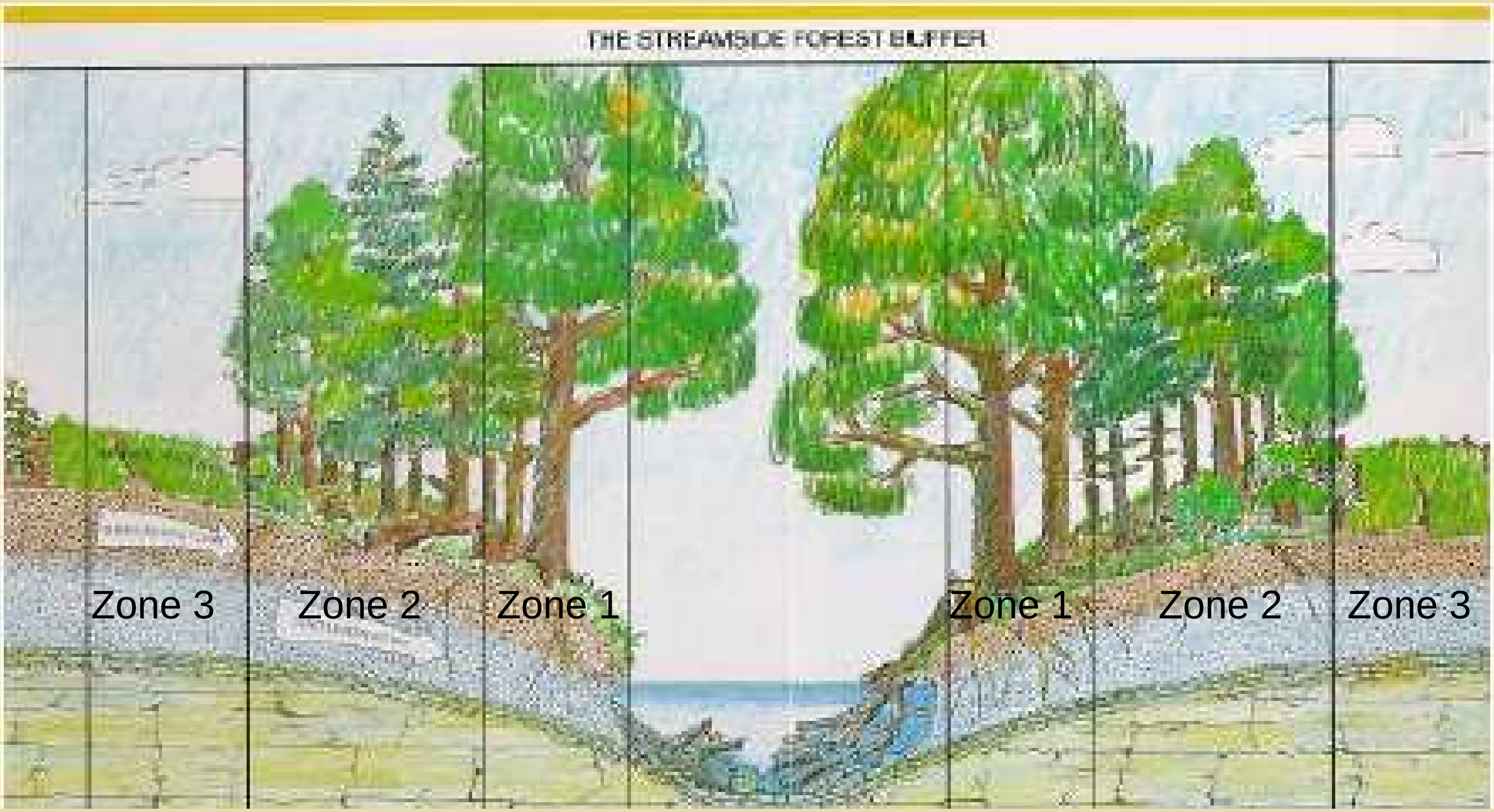
Soil Layer

HRUs with unique soil and land use Layer

REMM Approach

- **Divides riparian buffer zone into three zones. Zone 1 adjacent to stream, Zone 2 managed forest and Zone 3 grassed strip receiving runoff from upland fields.**
- **Vertically, soil is divided into three layers with litter layer at the top which interacts with surface runoff**
- **Mass balance and rate-controlled approaches are used for water storage in three zones.**

REMM


THE STREAMSIDE FOREST BUFFER
Zone 3
Zone 2
Zone 1
Zone 1
Zone 2
Zone 3

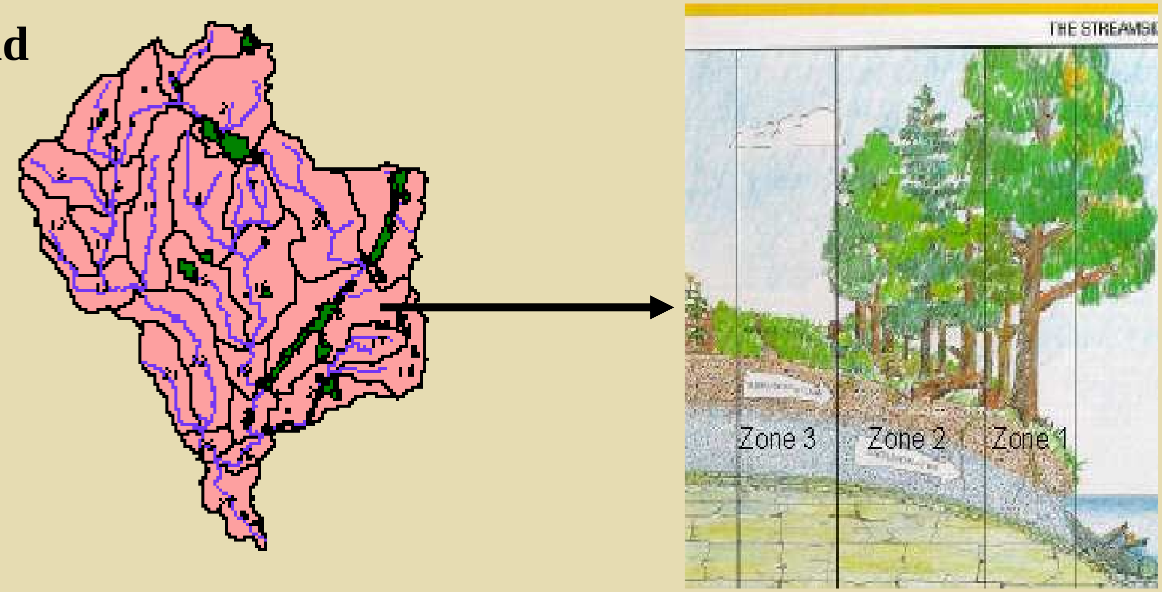
REMM Limitations

- **Needs measured or simulated upland field input (runoff, sediments and nutrients).**
- **Doesn’t have any user interface.**

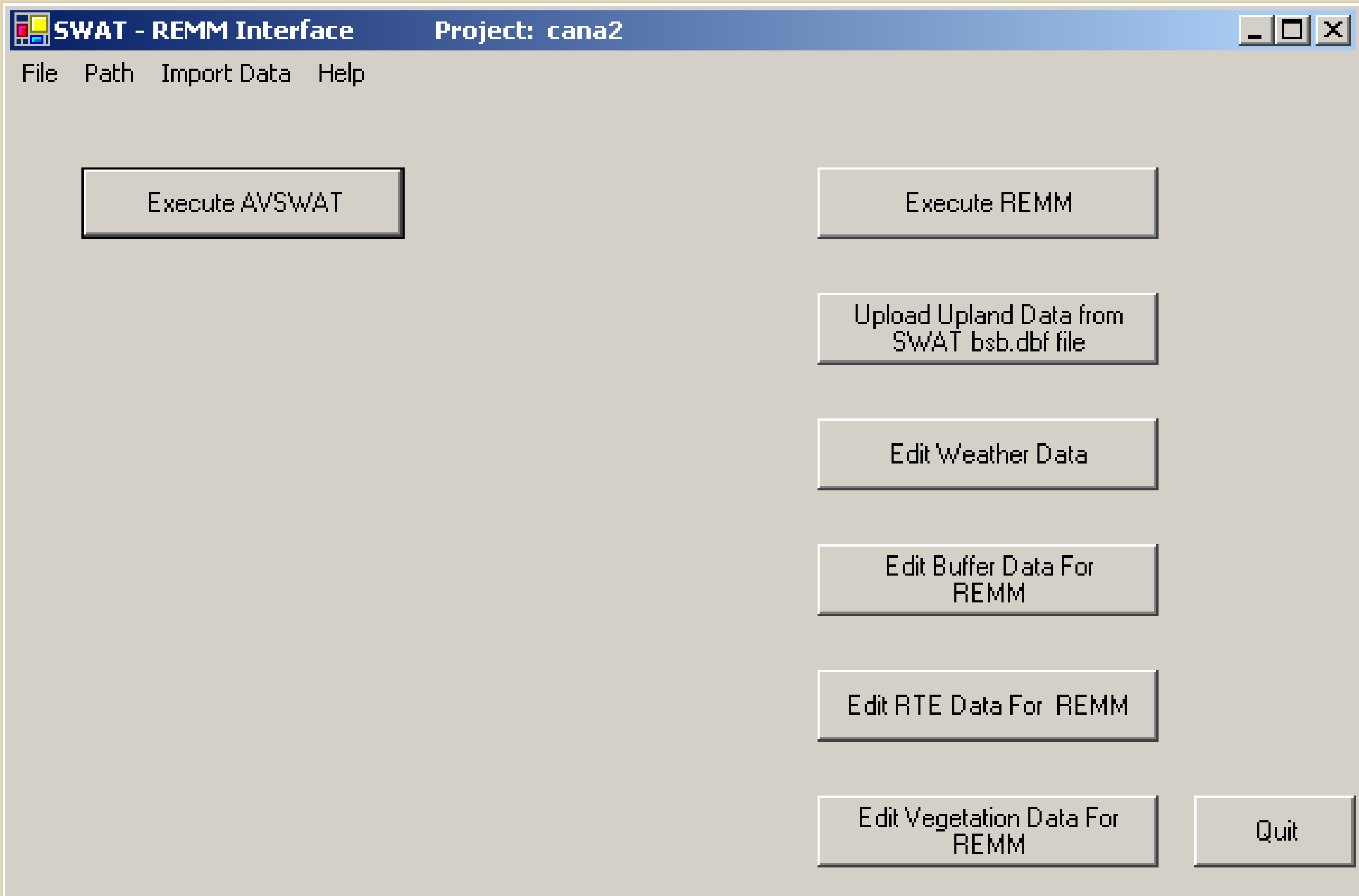
SWAT-REMM Interface

- **Sub-basin is first considered draining into riparian wetland and then into channel.**
- **SWAT is run for entire watershed and output is generated for all sub-basins.**
- **Interface extracts data for marked sub-basin from SWAT output and generates upland field file for REMM.**
- **REMM is then run to simulate riparian hydrology associate with marked sub-basin.**

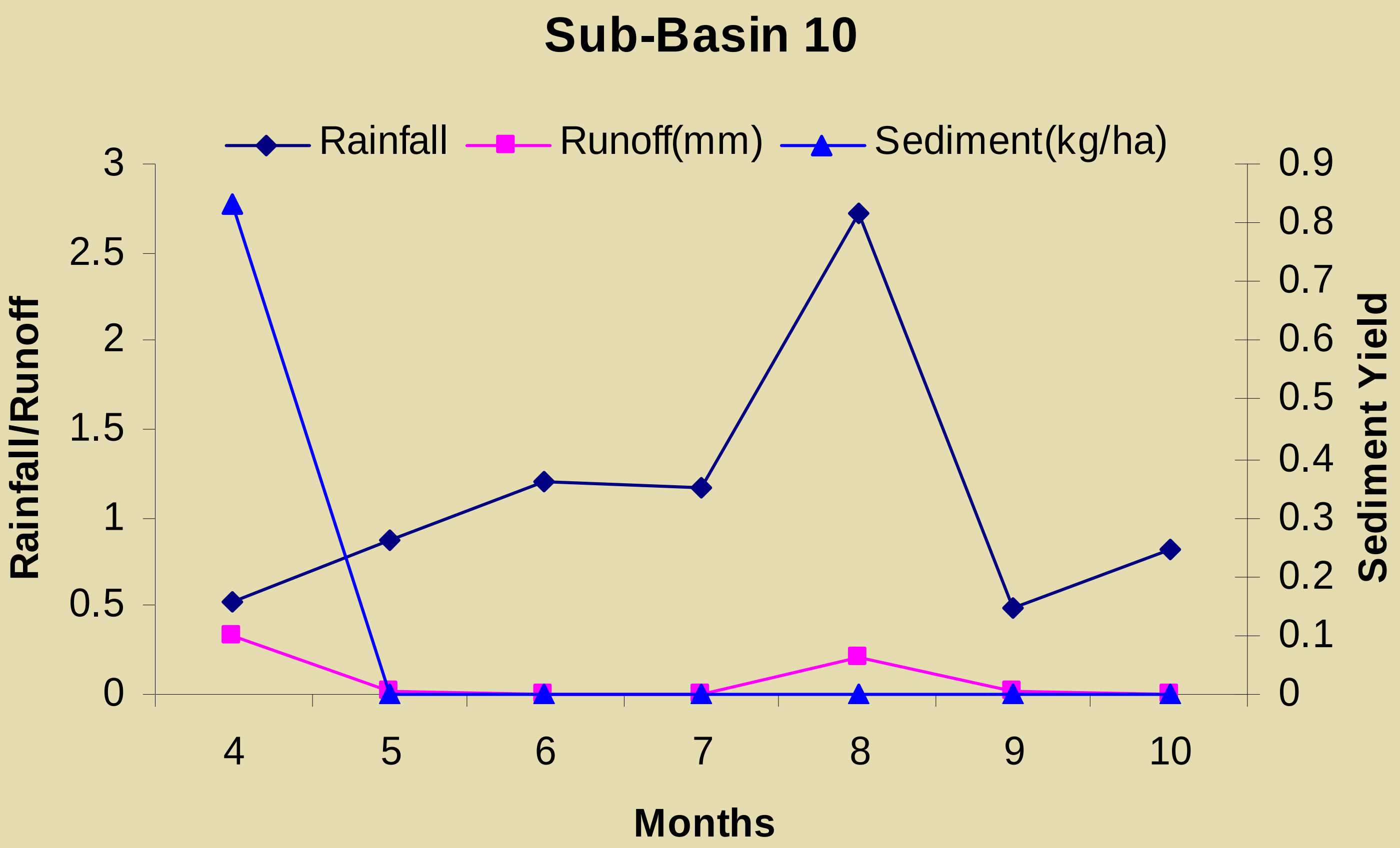
SWAT REMM



SWAT – REMM Interface



SWAT Output



Sub-Basin 10
Rainfall
Runoff(mm)
Sediment(kg/ha)
Rainfall/Runoff
Sediment Yield
Months
0
0.5
1
1.5
2
2.5
3
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
4
5
6
7
8
9
10

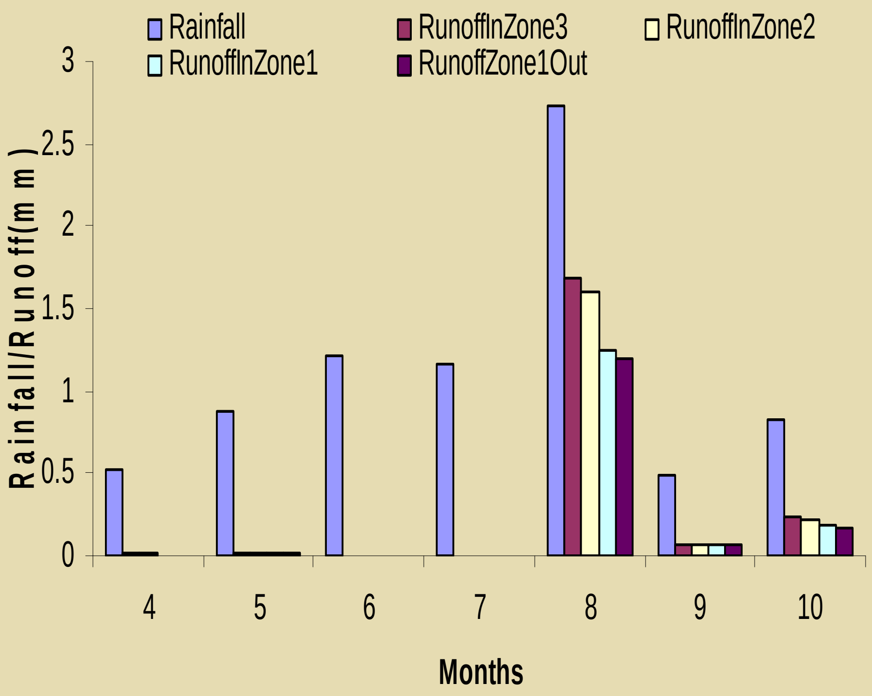
REMM Input

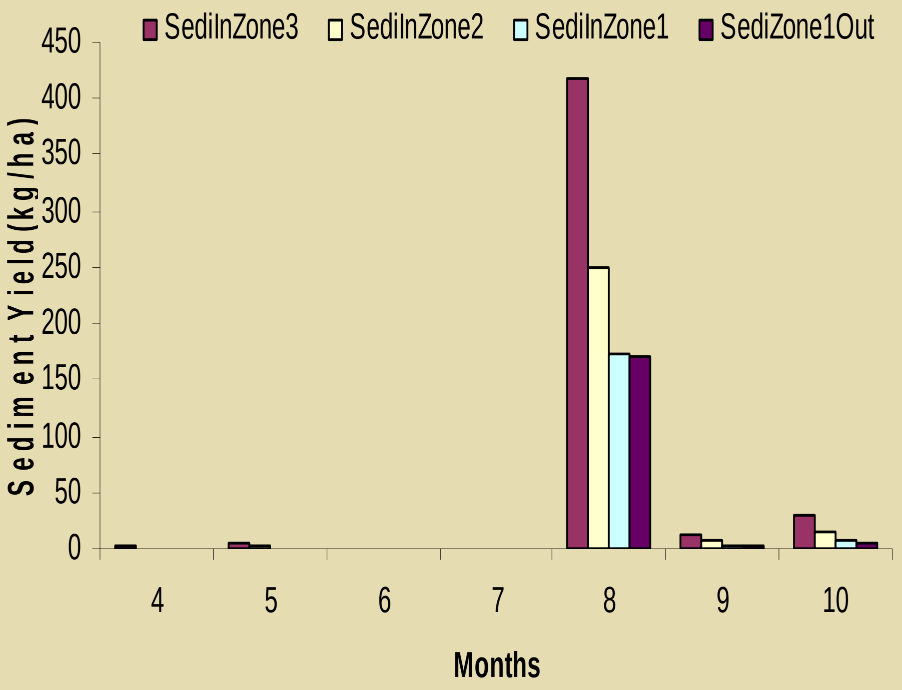
Zone 1 = 30 m

Zone 2 = 150 m

Zone 3 = 20 m

REMM Output


Rainfall
RunoffInZone3
RunoffInZone2
RunoffInZone1
RunoffZone1Out
Rainfall/Runoff(mm)
3
2.5
2
1.5
1
0.5
0
4
5
6
7
8
9
10
Months


SediInZone3
SediInZone2
SediInZone1
SediZone1Out
Sediment Yield(kg/ha)
450
400
350
300
250
200
150
100
50
0
4
5
6
7
8
9
10
Months

REMM Output

Runoff (cm)

Mnth	Rainfall	SrfIn3	SrfIn2	%Reduction Through Zone 3	SrfIn1	%Reduction Through Zone 2	SrfOut	%Reduction Through Zone 1	%Reduction Total
4	0.53	0.01	0.01	6.71	0.01	29.21	0.01	7.95	39.21
5	0.88	0.02	0.02	6.37	0.01	27.83	0.01	7.34	37.39
6	1.21	0.00	0.00	7.88	0.00	33.99	0.00	10.28	45.44
7	1.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	2.73	1.68	1.60	4.84	1.25	21.89	1.20	4.28	28.85
9	0.49	0.07	0.07	3.43	0.07	0.41	0.07	2.80	6.52
10	0.83	0.23	0.22	3.64	0.18	16.98	0.17	6.98	25.59

Sediment (kg/ha)

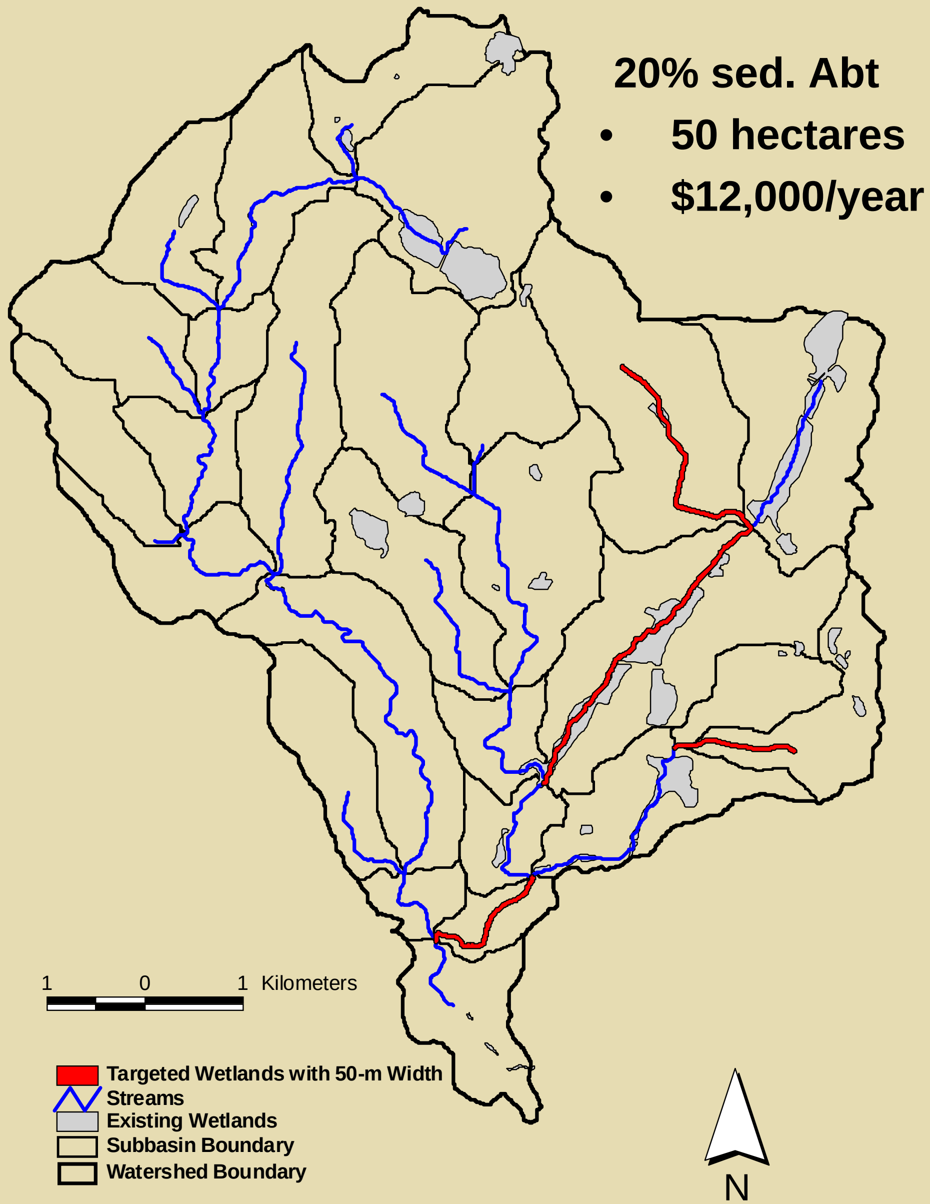
Mnth	Rainfall	SedYIn3	SedIn2	%Reduction Through Zone 3	SedIn1	%Reduction Through Zone 2	SedOut	%Reduction Through Zone 1	% Reduction Total
4	2.63	1.02	61.45	0.43	83.67	57.63	0.41	4.04	84.33
5	5.10	2.27	55.46	0.71	86.14	68.87	0.69	2.39	86.47
6	0.07	0.01	81.76	0.01	90.25	46.58	0.01	1.57	90.10
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	417.29	250.88	39.88	173.25	58.48	30.94	169.65	2.08	59.35
9	12.17	6.28	48.40	2.44	79.97	61.17	2.39	1.89	80.34
10	29.03	15.28	47.38	6.27	78.39	58.93	6.12	2.44	78.92

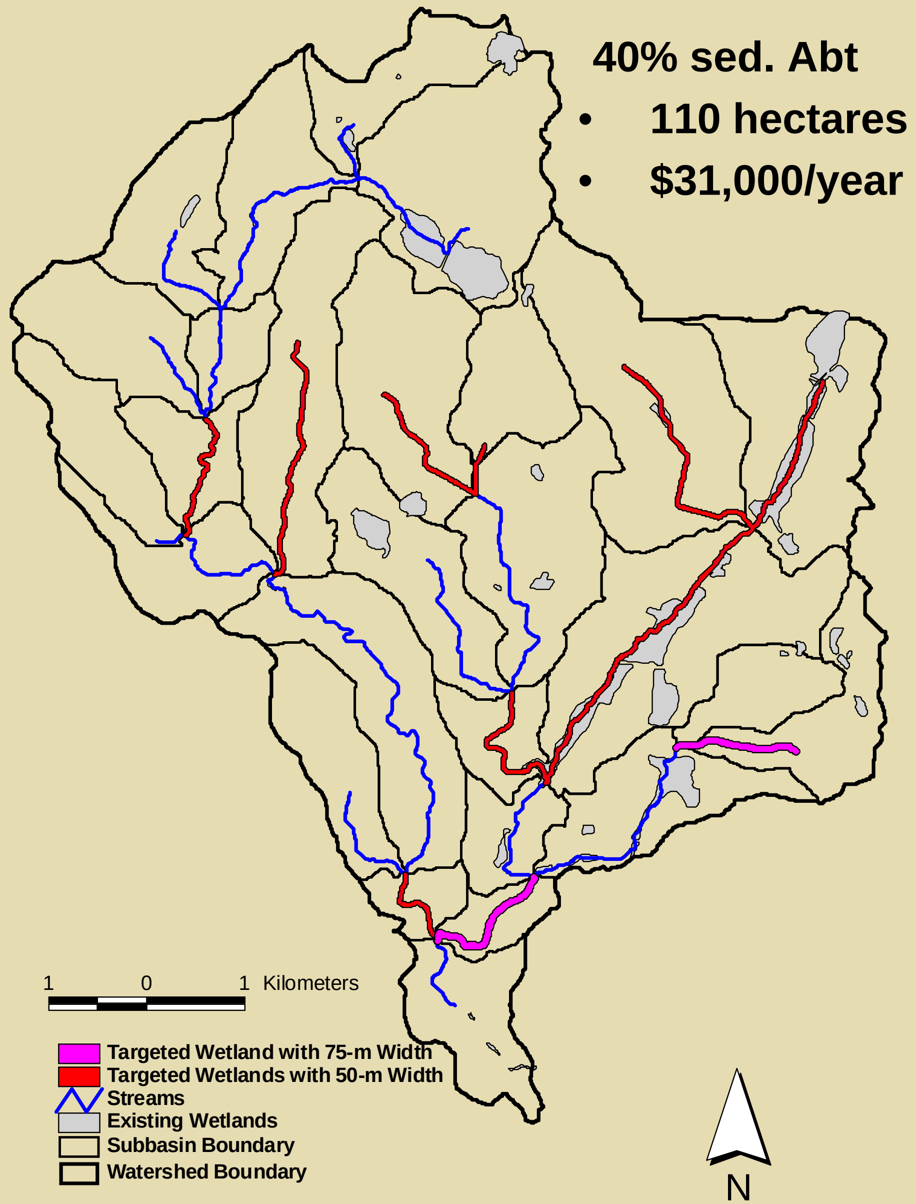
Economic Implications

Spatial Targeting of Wetland Conservation

- **Economic costs:** Forgone cropping returns from wetland conservation or restoration
- **Water quality benefits:** Sediment abatement from wetland conservation or restoration
- **Scenarios:** Wetland with 50, 75, 100, 150, 200 meters of width along reaches in each sub-basin
- **Targeting wetland based on benefit to cost ratios**

Spatial Targeting of Wetland Conservation





Conclusions

- The developed interface can be used to assess efficiency of existing riparian buffers or to design riparian system for a particular location
- Results show considerable reduction of runoff (35 to 45%) and sediment (60 to 90%) is possible by introducing riparian wetland system along the stream.
- Targeting wetland conservation or restoration based on benefit/cost ratios can minimize the economic costs for achieving specific environmental goals

Future Plans

- Evaluation of developed interface
  - Collection of data
- Integration of REMM with SWAT
- Include isolated wetlands in SWAT
  - Hydraulically connected
  - Hydraulically not connected

Acknowledgement

- **Ducks unlimited for funding this project**
- **Grand River Conservation Authority**
- **Ministry of Natural Resources**
- **Ministry of Environment**
- **Southeastern Watershed Research Laboratory of USDA-ARS, Tifton, Georgia**
- **Black land Research Center of USDA-ARS, Temple, Texas**

Thanks

Spatial Distribution of Private Costs and Sediment Abatement Benefits from Wetland Conservation