McGill

SWATDRAIN

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Development and Evaluation of SWATDRAIN Model for Simulating Hydrology of Agricultural Tile-Drained Watersheds

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Outline

- Introduction
- Objectives
- SWATDRAIN model
- Model evaluation
  - Completely tile-drained watershed
  - Partially tile-drained watershed
- Scenario analysis – controlled drainage on watershed basis
- Conclusions

SWATDRAIN

- SWAT
  - Surface flow
  - Subsurface flow
  - Water table depth
- Modified SWAT - includes tile drainage
  - Hooghoudt and Kirkham approaches
    - Volume drained and WTD relationship
- DRAINMOD
  - Subsurface flow
  - Surface runoff due to different land use practices
- DRAINMOD into SWAT – A WINNING PROPOSITION

Objectives

- Overall goal:
  - Modify SWAT to simulate hydrology and water quality of agricultural tile-drained watersheds
- Specific objectives:
  - SWATDRAIN – incorporate DRAINMOD into SWAT
  - Evaluate SWATDRAIN for fully tile-drained and partially tile-drained watersheds
  - Apply SWATDRAIN to assess impact of controlled drainage systems on watershed hydrology

Model Development

Incorporating DRAINMOD into SWAT

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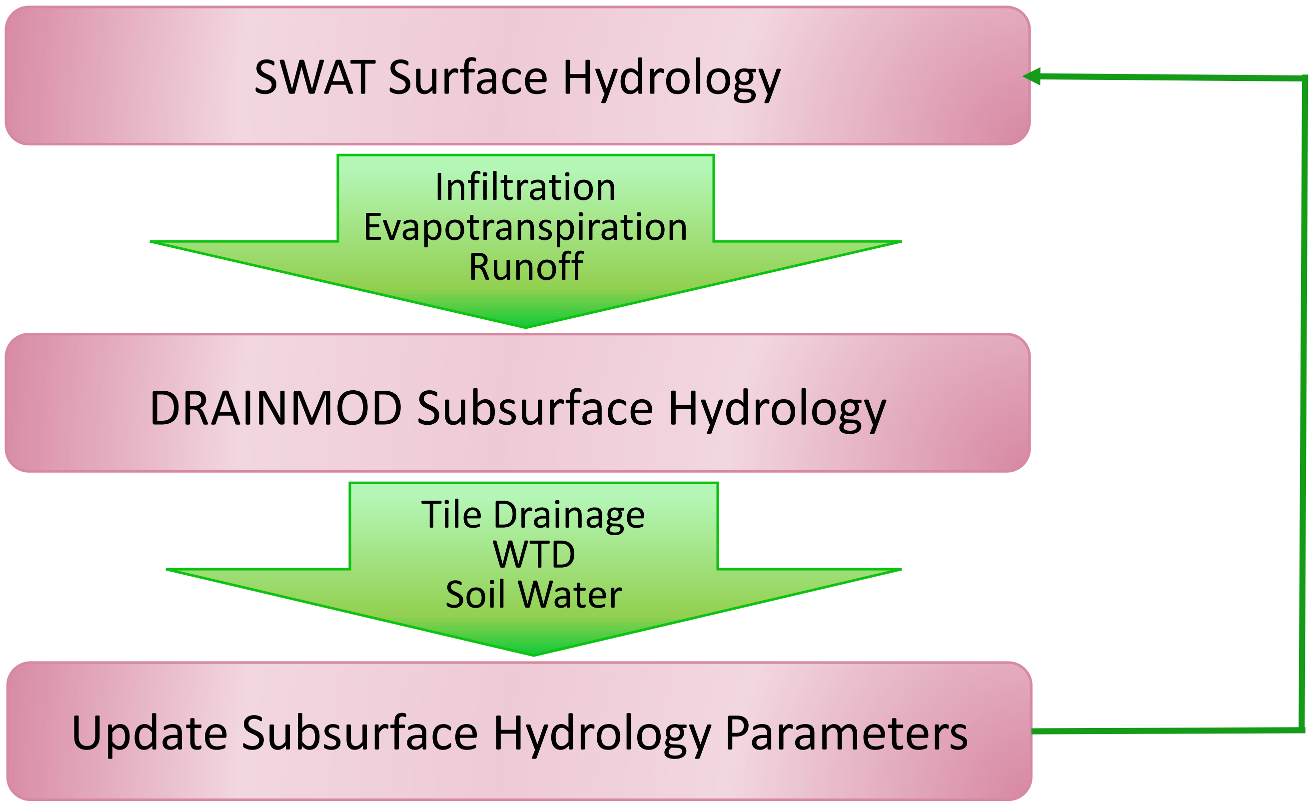
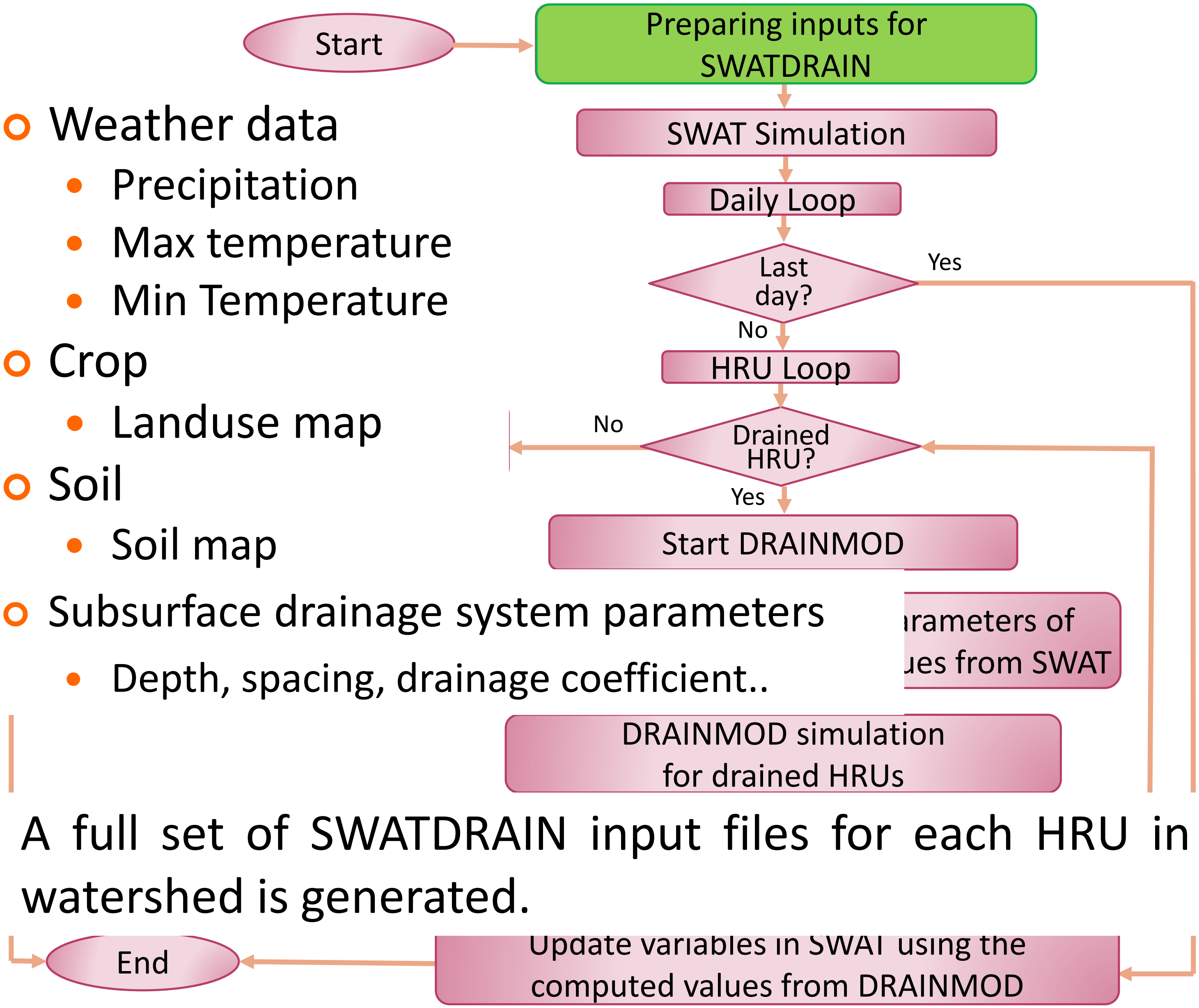
Overall Modeling Approach

DRAINMOD hydrology was fully incorporated into SWAT

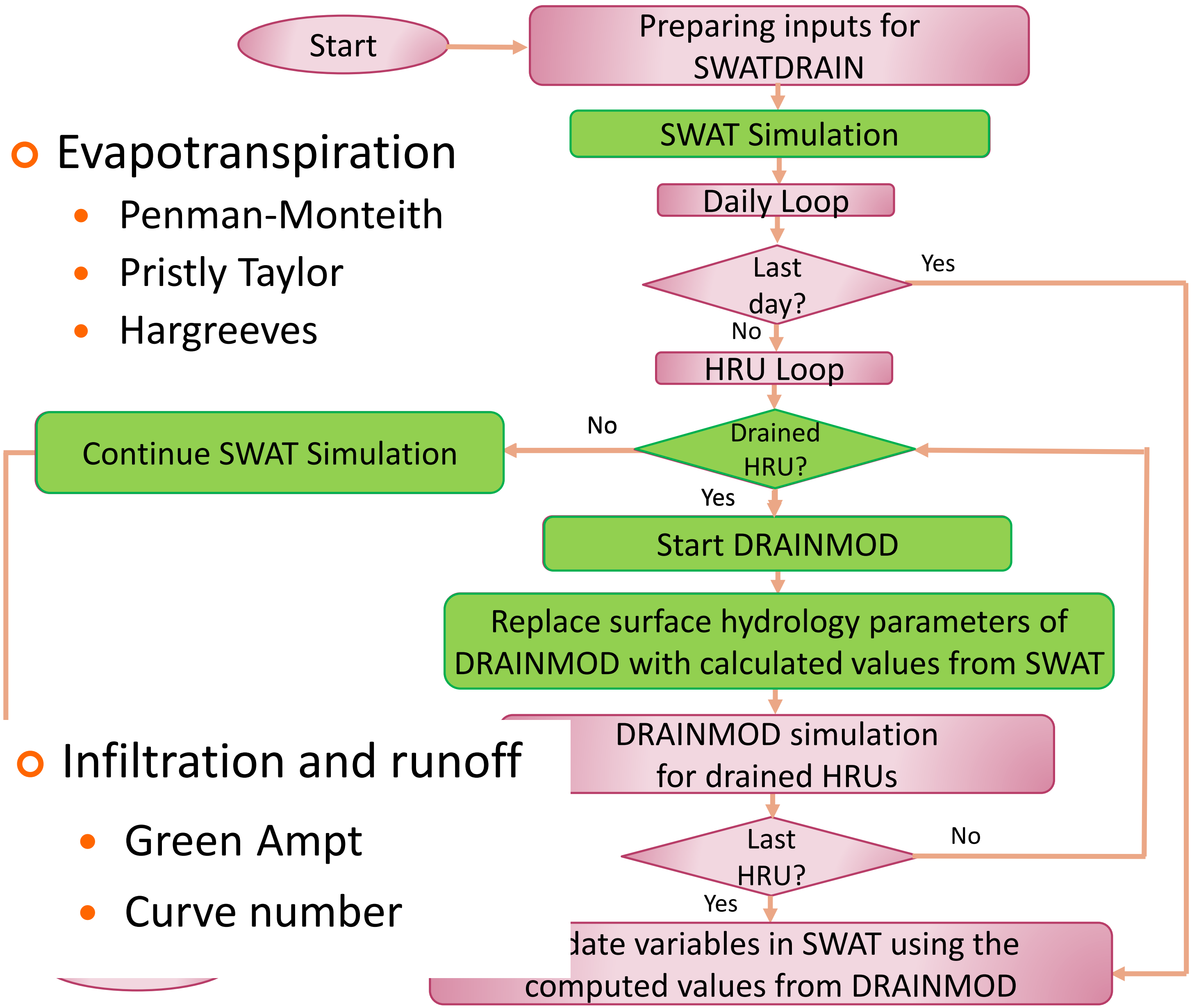


- Weather data
  - Precipitation
  - Max temperature
  - Min Temperature
- Crop
  - Landuse map
- Soil
  - Soil map
- Subsurface drainage system parameters
  - Depth, spacing, drainage coefficient..

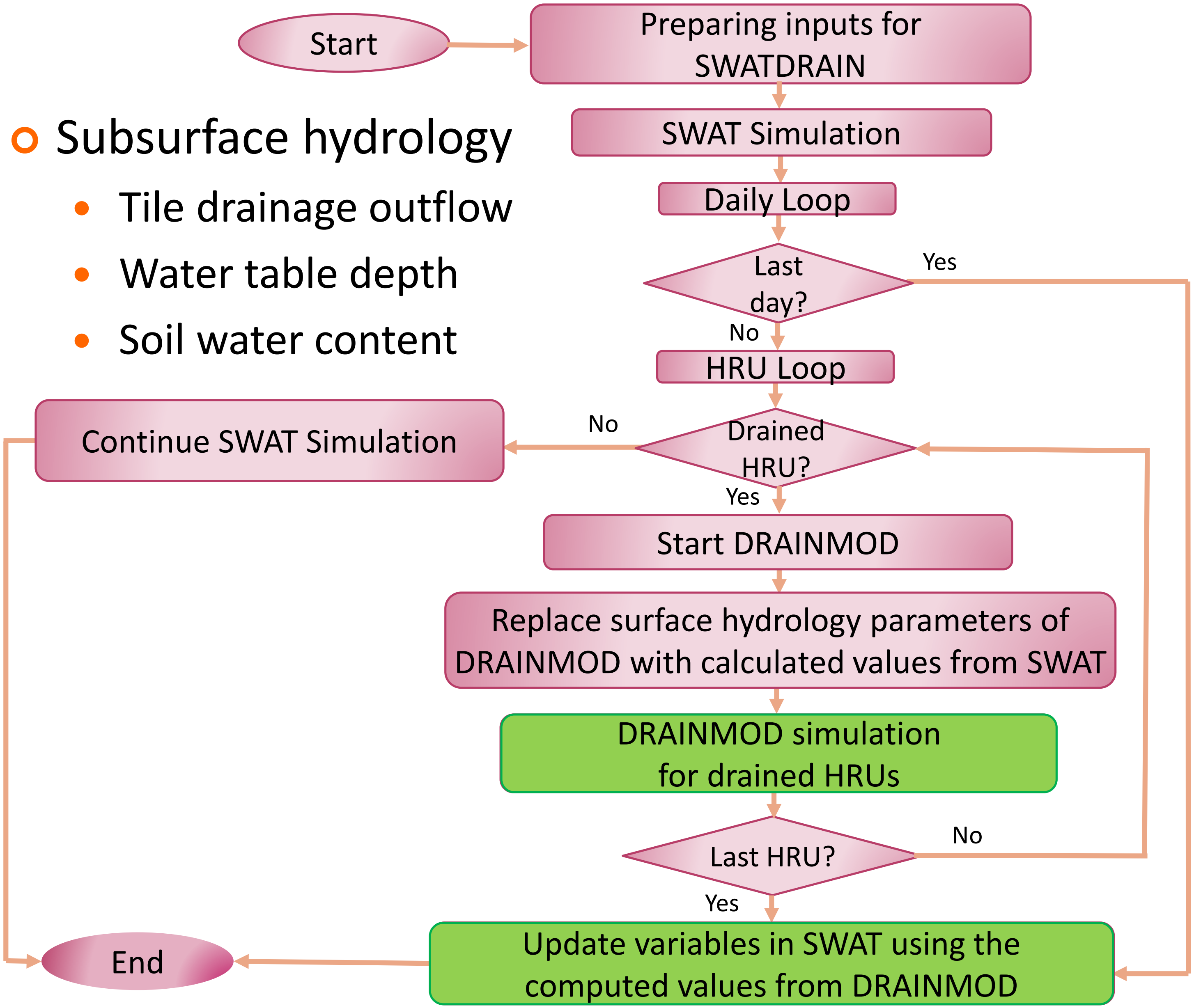


A full set of SWATDRAIN input files for each HRU in the watershed is generated.

- Evapotranspiration
  - Penman-Monteith
  - Pristly Taylor
  - Hargreeves
- Infiltration and runoff
  - Green Ampt
  - Curve number



- Subsurface hydrology
  - Tile drainage outflow
  - Water table depth
  - Soil water content



Options in SWATDRAIN

Algorithm	Tile drainage	Water table depth
SWATDRAIN	ITDRN=2, DRAINMOD ✓	IWTDN=2, DRAINMOD ✓
SWAT (Original)	ITDRN=0	IWTDN=0
SWAT (Modified)	ITDRN=1, incorporates Kirkham and Hooghoudt tile drainage equations	IWTDN=1, drainage volume converted into WTD using a variable water table factor

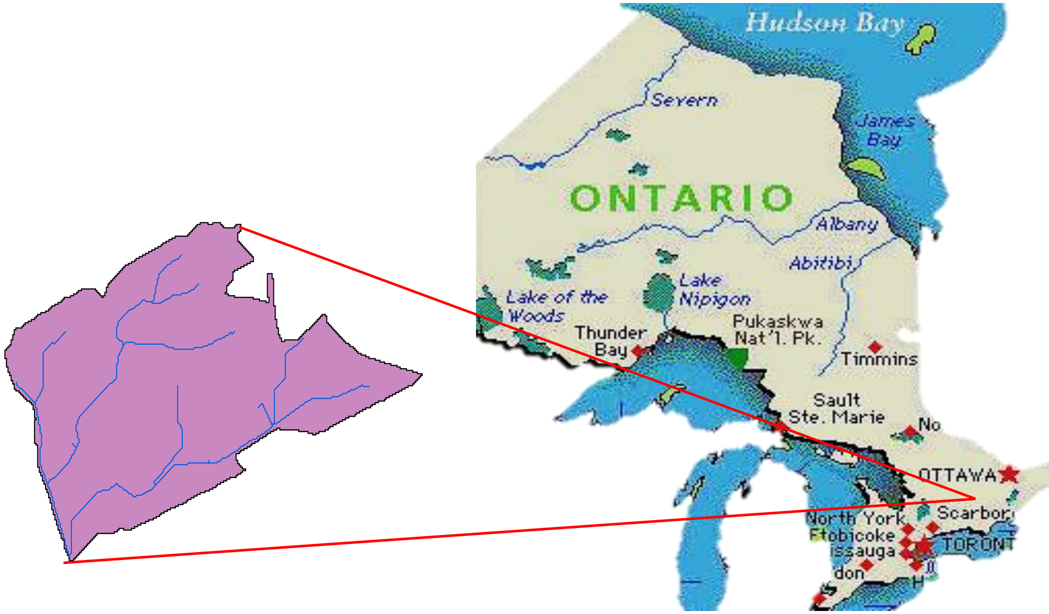
Model Evaluation

Green Belt (fully tile-drained watershed)
Canagagigue Creek (partially tile-drained watershed)


Echo Bay
Northwest Territories
Davis Strait
Watson Lake
Mackenzie
Frobisher Bay
Yellowknife
Great Slave Lake
Rankin Inlet
Hay River
Fort Smith
CANADA
Labrador Sea
Lake Athabasca
Hudson Bay
Reindeer Lake
Churchill
Newfoundland
Alberta
Goose Bay
Nelson
Schefferville
Edmonton
Saskatchewan
Manitoba
Chisasibi (Fort George)
Gander
Saint John's
Island of Newfoundland
Saskatchewan
Lake Winnipeg
Calgary
Saskatoon
Quebec
Lethbridge
Regina
Moosonee
Ontario
Chibougamau
Prince Edward Is.
Saint Pierre and Miquelon (FRANCE)
Sydney
St. Lawrence River
Winnipeg
New Brunswick
Charlottetown
Thunder Bay
Lake Superior
Québec
Fredericton
Halifax
Sherbrooke
Saint John
Nova Scotia
Sudbury
Montréal
Lake Huron
Green Belt
Lake Michigan
Mississippi
Minneapolis
Missouri
Toronto
Lake Ontario
Boston
Salt Lake City
Hamilton
Milwaukee
Detroit
Windsor
Lake Erie
New York
North Atlantic Ocean
Chicago
Philadelphia
Denver
UNITED STATES
Indianapolis
Washington, D.C.
Kansas City
St. Louis
Canagagigue Creek
Province or territory capital
Albuquerque
Oklahoma City
Scale 1:34,500,000
Mississippi
Memphis
Lambert Conformal Conic Projection standard parallels 52°N and 74°N
Atlanta
El Paso
Ciudad Juárez
Dallas
0 200 400 Kilometers

Evaluation of SWATDRAIN - Green Belt

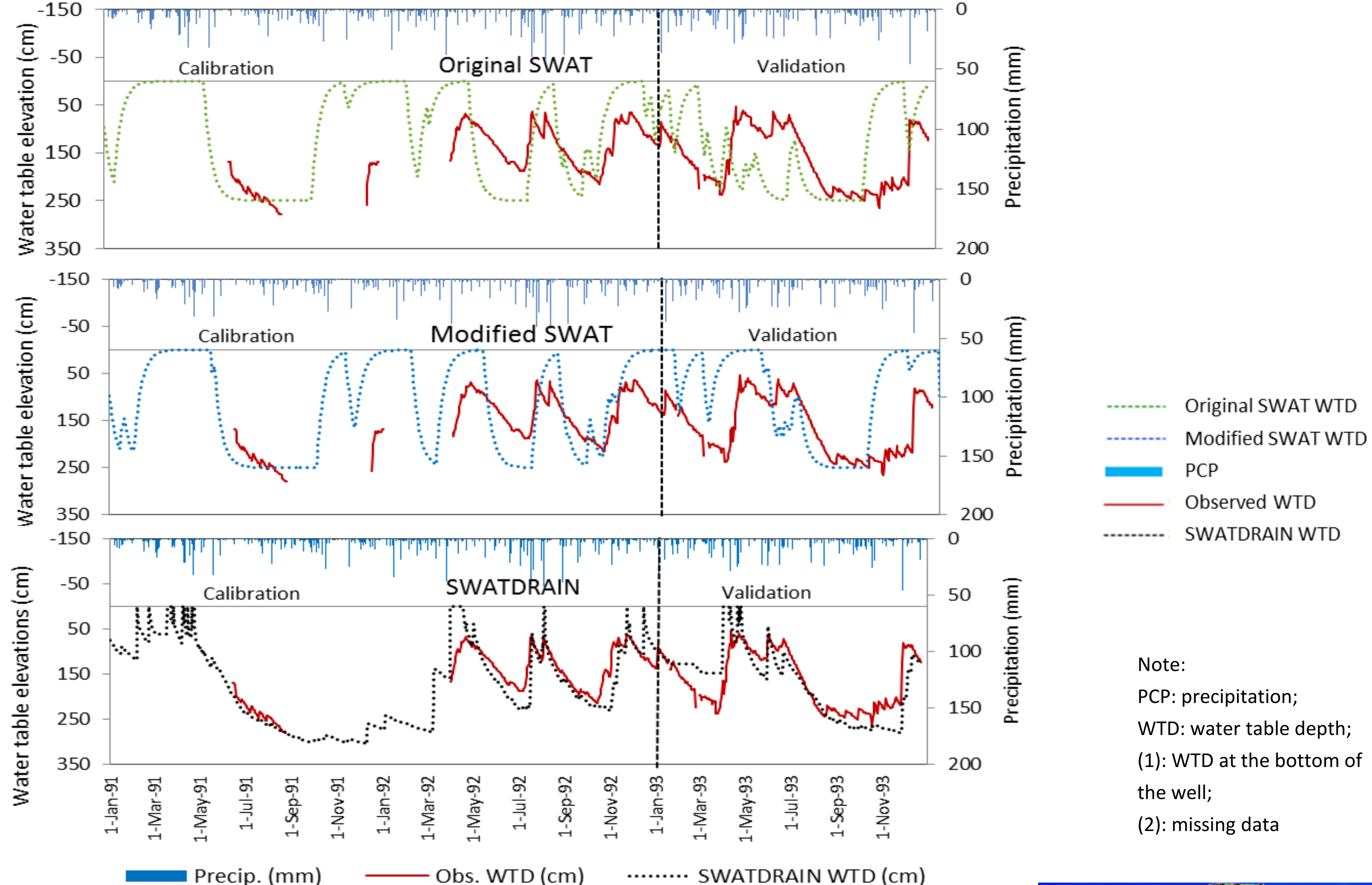
- Green Belt Watershed
  - Area: 14 ha
  - Topography
  - Loam to silty clay
  - Corn



  - Tile drainage systems

    (laterals: 15 m apart and 1 m depth)

Daily Water Table Depth



Note:

PCP: precipitation;

WTD: water table depth;

(1): WTD at the bottom of the well;

(2): missing data

Water Table Depth - Daily and Monthly

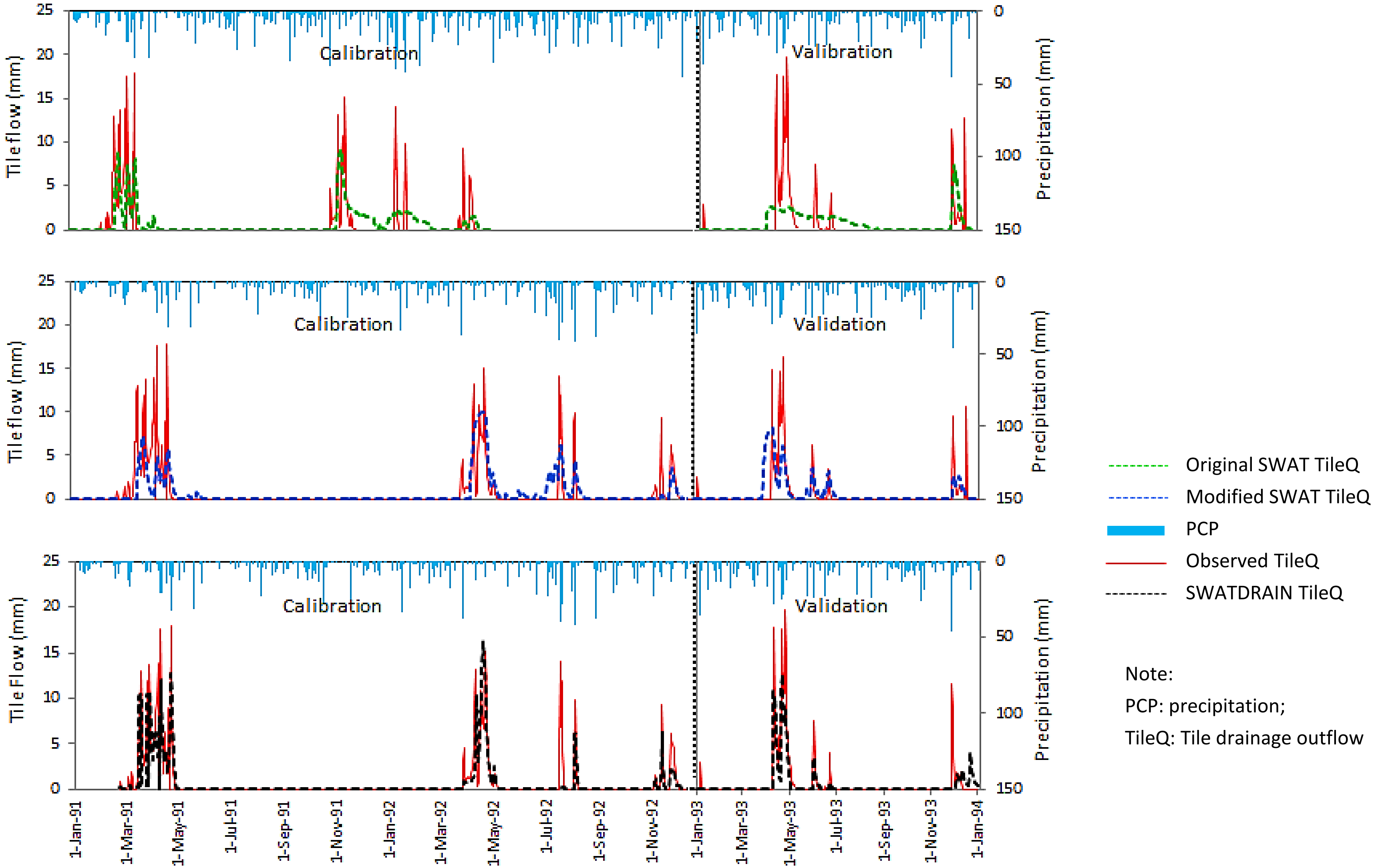
Daily WTD calibration and validation statistics comparing measured and simulated data

Index	Calibration			Validation		
	SWAT (original)	SWAT (Modified)	SWATDRAIN	SWAT (original)	SWAT (Modified)	SWATDRAIN
R^2	0.44	0.57	0.72	0.00	0.13	0.77
PBIAS	-21.20	-13.85	-3.75	9.22	40.26	2.90
NSE	0.42	0.41	0.82	-0.15	0.18	0.72

Monthly WTD calibration and validation statistics comparing measured and simulated data

Index	Calibration			Validation		
	SWAT (Original)	SWAT (Modified)	SWATDRAIN	SWAT (Original)	SWAT (Modified)	SWATDRAIN
R^2	0.24	0.49	0.75	0.00	0.11	0.93
PBIAS	11.03	-18.92	11.59	14.58	47.77	0.11
NSE	0.48	0.35	0.92	-0.33	0.34	0.89

Daily Tile Drainage Outflow



Note:

PCP: precipitation;

TileQ: Tile drainage outflow

Tile Drainage Outflow Statistics – Daily and Monthly

Daily tile flow calibration and validation statistics comparing measured and simulated data

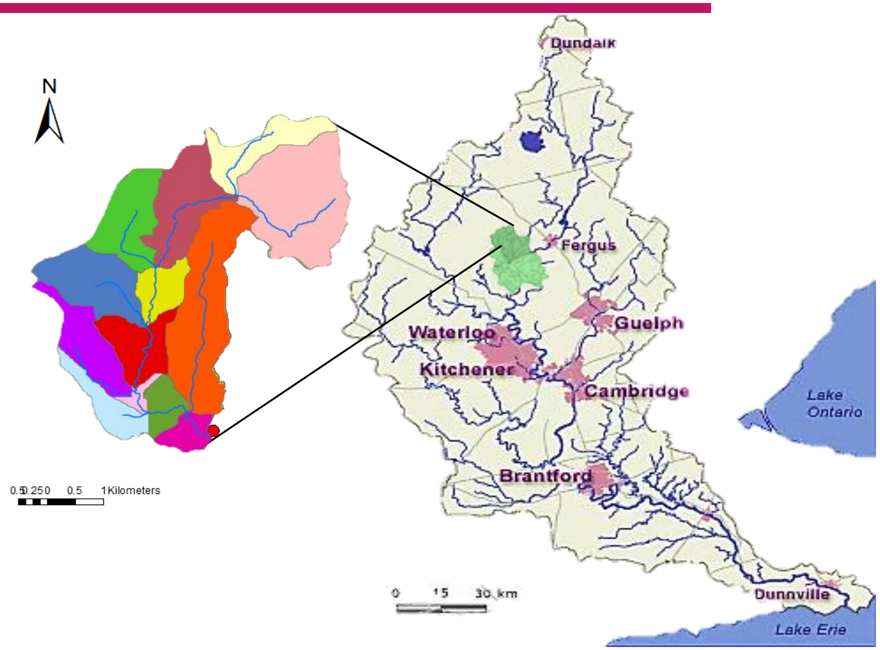
	Calibration			Validation		
Index	SWAT (original)	SWAT (Modified)	SWATDRAIN	SWAT (original)	SWAT (Modified)	SWATDRAIN
R^2	0.35	0.44	0.78	0.19	0.32	0.74
PBIAS	3.53	14.15	18.23	0.21	-18.47	23.85
NSE	0.35	0.42	0.67	0.17	0.38	0.70

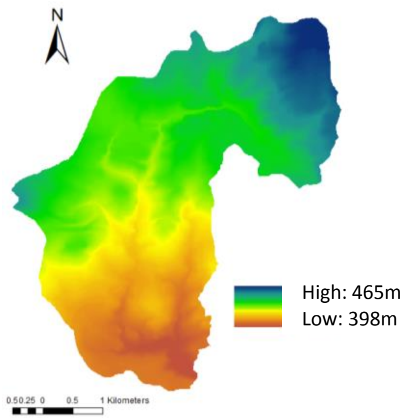
Monthly tile flow calibration and validation statistics of the measured and simulated data

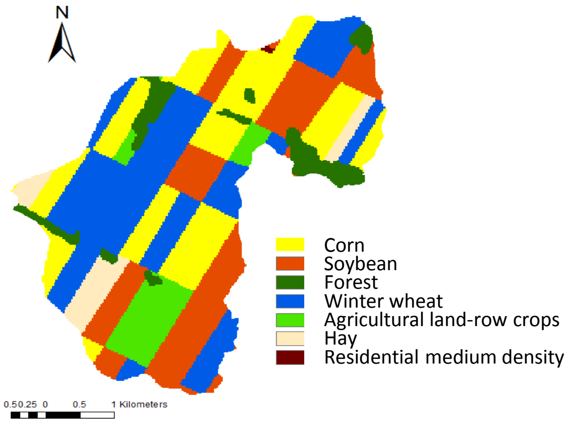
	Calibration			Validation		
Index	SWAT (original)	SWAT (Modified)	SWATDRAIN	SWAT (original)	SWAT (Modified)	SWATDRAIN
R^2	0.75	0.80	0.92	0.45	0.77	0.88
PBIAS	12.34	1.44	9.61	-15.84	-15.04	17.26
NSE	0.65	0.69	0.91	0.42	0.73	0.90

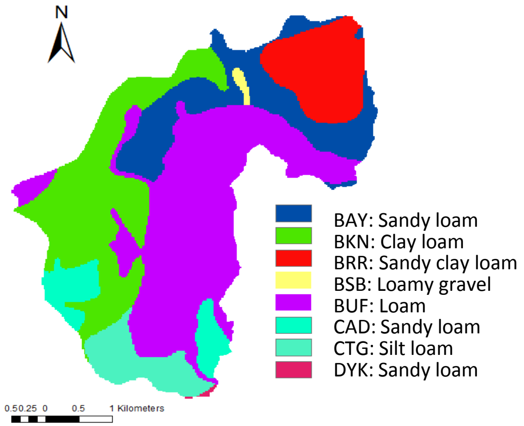
Canagagigue Creek Watershed

- West Canagagigue Creek
- Area: 18 Km^2
- Topography
- Land use: agriculture
- Soil: loam or clay loam
- Tile drainage systems (laterals: 20 m apart and 1m depth)

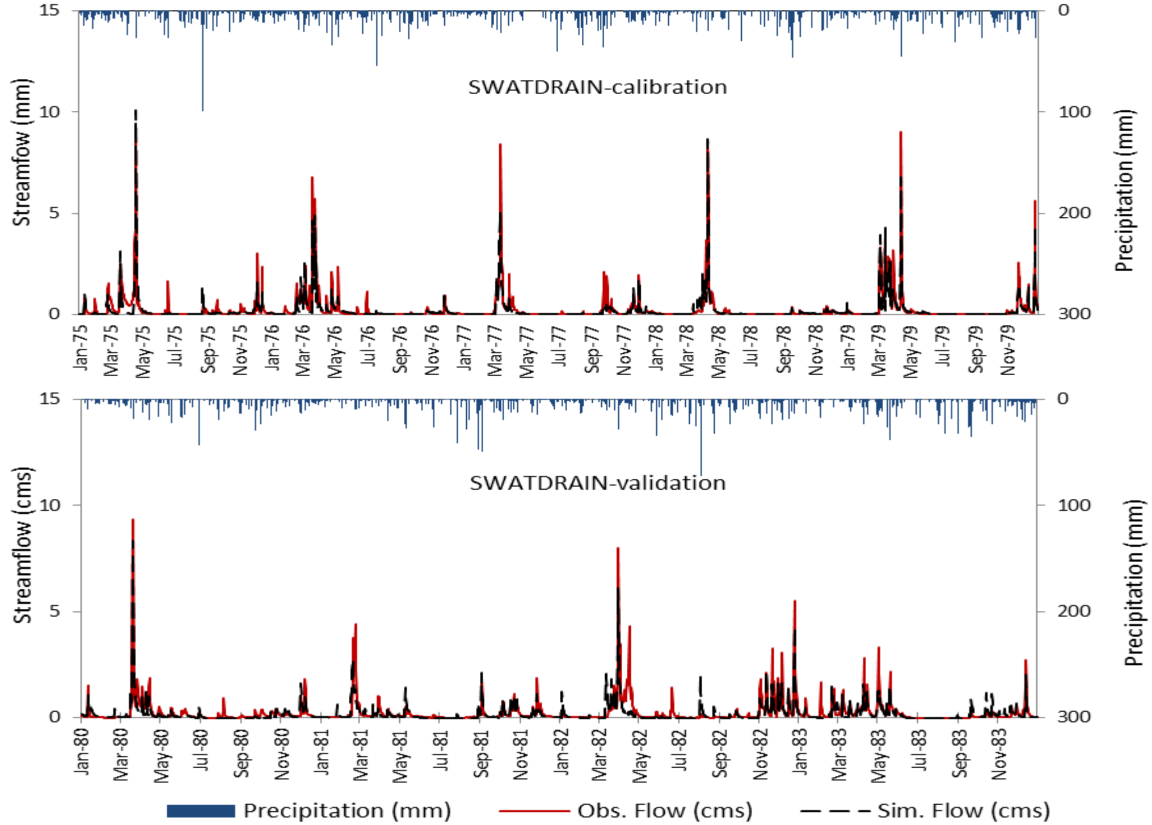








Streamflow



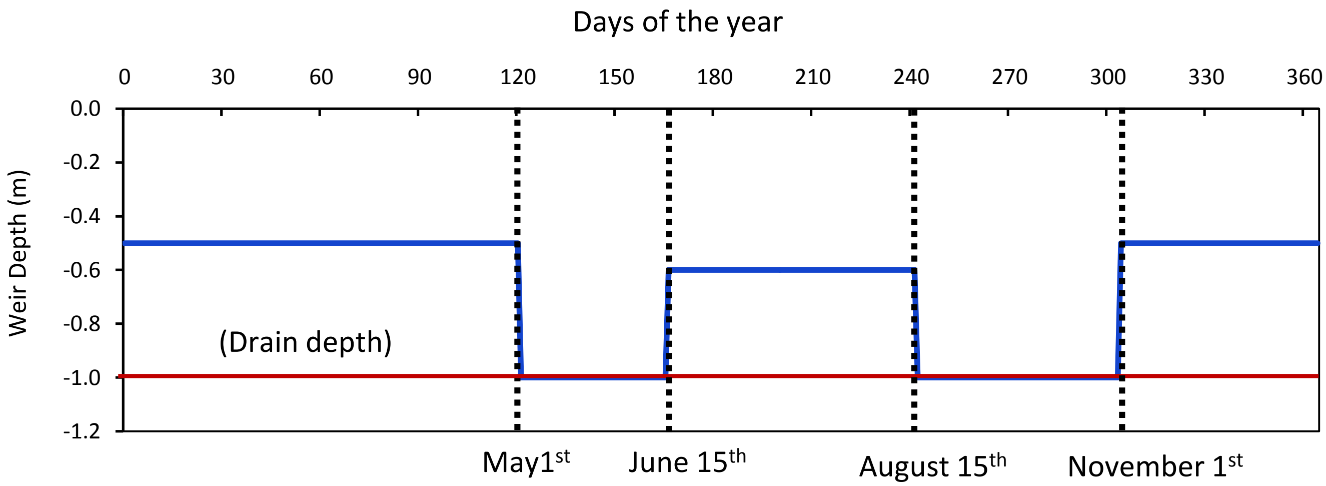
Index	Daily		Monthly	
	Calibration	Validation	Calibration	Validation
R^2	0.74	0.62	0.93	0.75
PBIAS	1.60	17.90	7.30	18.60
NSE	0.72	0.63	0.92	0.73

Application of SWATDRAIN

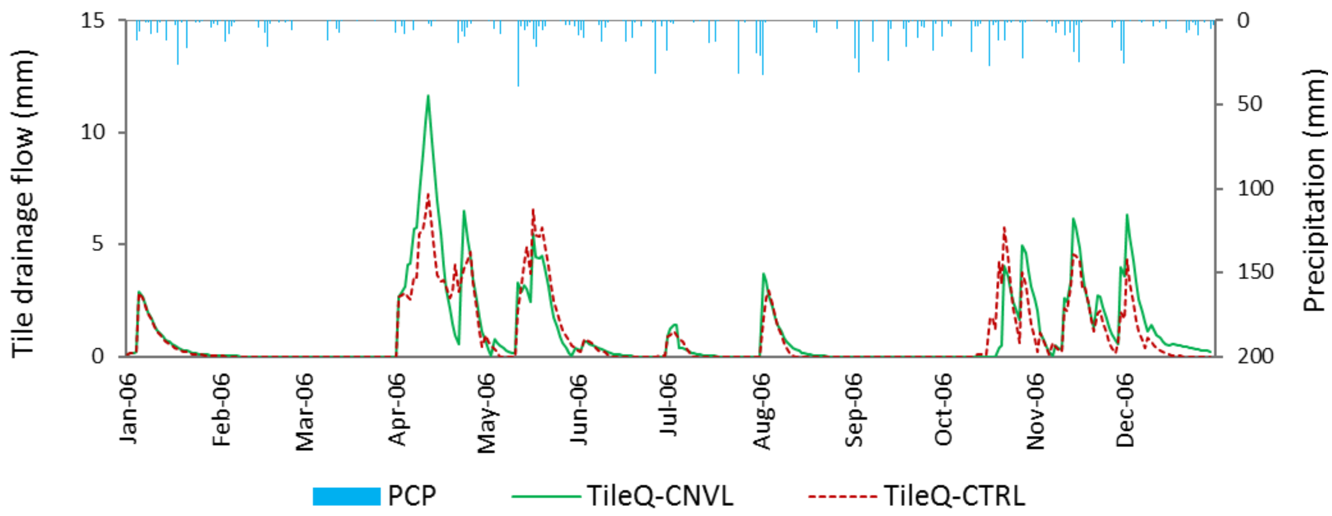
Simulate Effect of Controlled Drainage
on Watershed hydrology

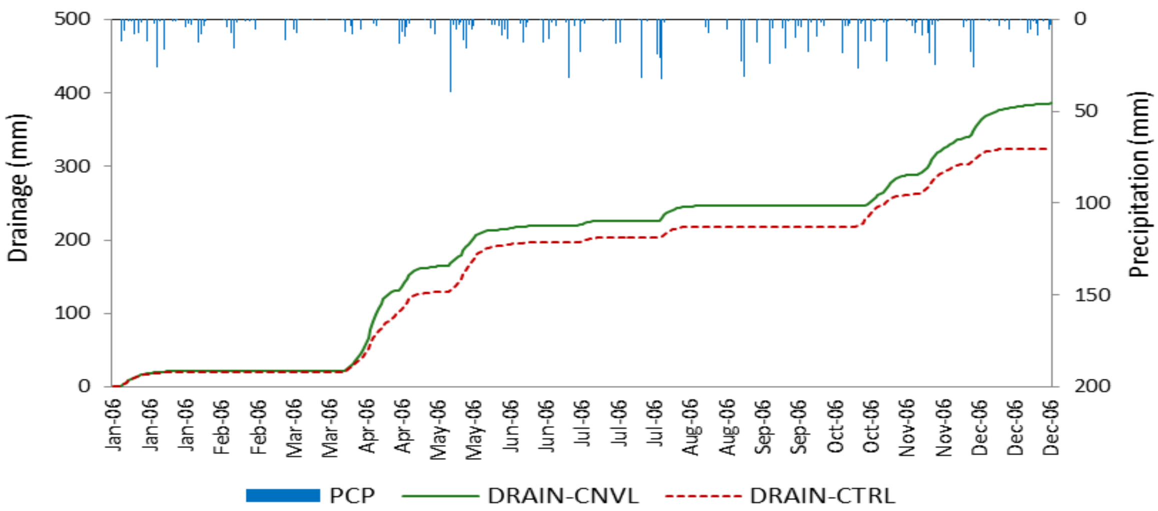
Controlled Drainage Scenario

- Fully tile-drained Green Belt watershed
- Growing season (June 15th to August 15th)
- Winter period (November 1st to May 1st)

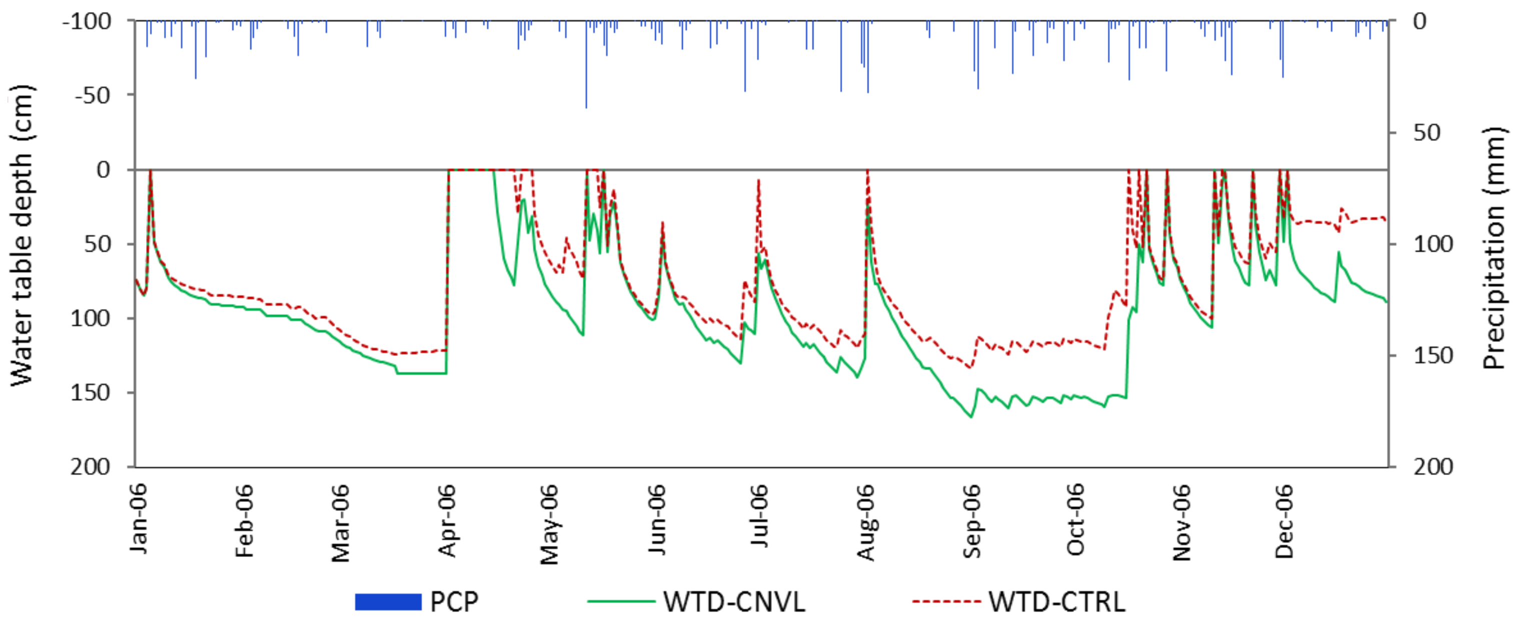


Controlled Drainage Impacts

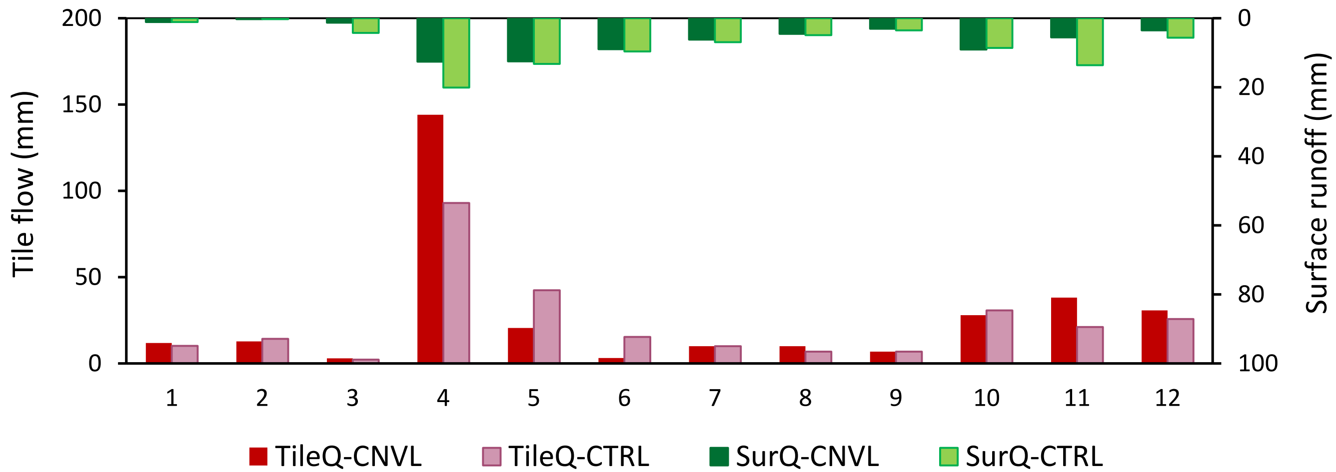




Controlled Drainage Impacts



Effect of Controlled Drainage on Watershed Hydrology



Year	Conventional		Controlled	
	Tile flow (mm)	Surface runoff (mm)	Tile flow (mm)	Surface runoff (mm)
2004	142.2	31.6	136.5	33.4
2005	205.4	64.7	176.1	83.7
2006	385.4	89.7	324.5	139.7
2007	276.3	40.97	249.7	39.5
Average	252.3	56.7	221.7	74.1

Note: CNVL: conventional; CTRL: controlled; SurQ: surface runoff; TileQ: tile drainage

Conclusions

- SWATDRAIN fully incorporates DRAINMOD hydrology into SWAT in order to improve latter's capability to predict subsurface hydrology of agricultural tile-drained watersheds.
- The model appears to do a better prediction of drain outflows and water table dynamics on a watershed scale.
- The model works for both fully drained and partially drained watersheds.

Conclusions

- SWATDRAIN can simulate controlled drainage scenario on a watershed scale.
- Implementing the controlled drainage strategy resulted in a reduction of the average annual drain outflow by 18%, while it increased the surface runoff in the order of 30%.
- Next step is to investigate how improved subsurface hydrology would affect chemical pollution on a watershed scale.

Thank You!