The New SWAT-2005 model: Sensitivity analysis, auto-calibration and modeling of hydrology, sediment, phosphorus and nitrogen mobility in the Walbridge Creek watersheds

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Introduction

Water quality monitoring in river basins needs an understanding of the physical system and its interaction with the environment as a prerequisite for effective planning and management of the area in order to have a sustainable system.

In recent years, cyanobacteria blooms, triggered by an excess of phosphorus, have caused the degradation of the Missisquoi Bay, in Lake Champlain. The phosphorus (P) concentration exceeds the target levels by 40% and it is estimated that around 80% of the P exports originate from diffuse agricultural sources.

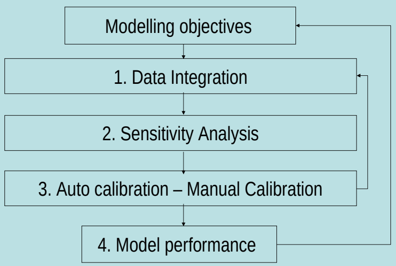
The poster presents the SWAT-2005 model, and its built-in sensitivity analysis and auto-calibration tools. The sensitivity and predictive capacity of SWAT are being tested at a small scale using the Walbridge (7 km²) sub-basins, which present contrasting landscape attributes.

Objectives:

The objective of this study is to carry out a modeling exercise in order to understand the dynamics of water, sediments, phosphorus and nitrogen transport in the Pike River basin, using SWAT.

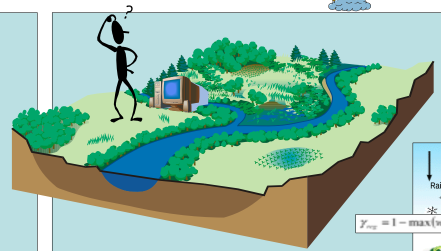
Furthermore, the model will allow devising best management scenarios that would permit a pollution reduction that would meet the target load set by the Québec-Vermont agreement.

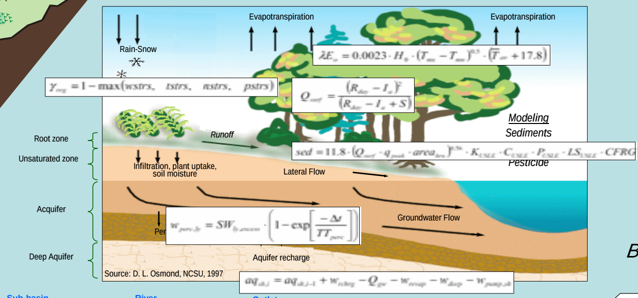
Methodology



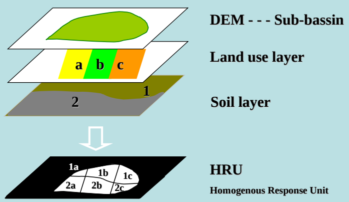
SWAT Model

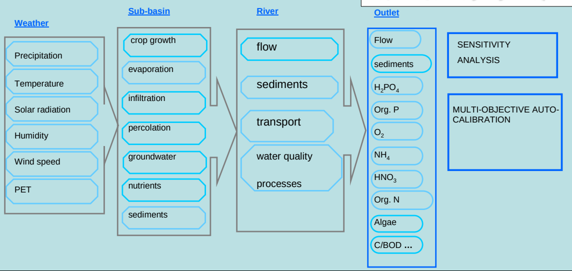
The Soil Water Assessment Tool (SWAT) is a physically based continuous event hydrologic model developed to predict the impact of land management practices on water, sediment, and agricultural chemical yields in large, complex watersheds with varying soils, land use, and management conditions over long periods of time





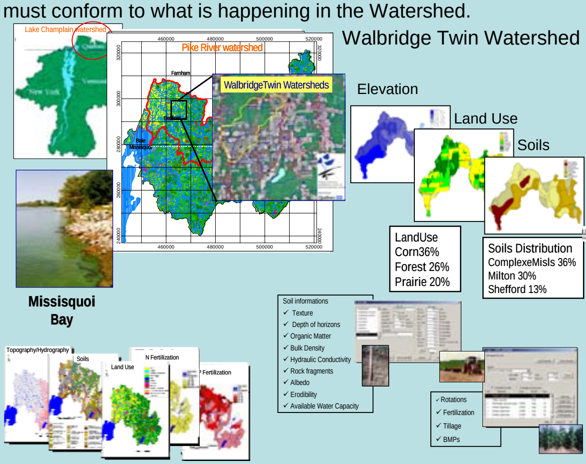
Base unit : HRU





1. Data Integration:

To accurately predict the movement of sediments, nutrients, or pesticides the hydrologic cycle as simulated by the model must conform to what is happening in the Watershed.



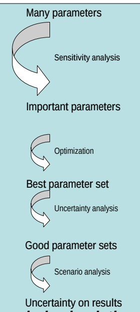
2. Sensitivity analysis

Aim: Estimate the rate of change in the output of a model with respect to changes in model inputs.

Parameter's sensitivity

What are the most sensitive parameters concerning the hydrological system, sediment transport and nutrient supply towards the streams?

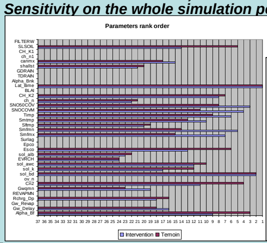
The LH-OAT sensitivity analysis method is a combination of the LH (Latin Hypercube) and the OAT (One-factor-At-a-Time). The LH sampling ensures that the full range of all parameters has been sampled and the OAT design deals with the changes in the output for each model run and attributes that to the input changed in a simulation.

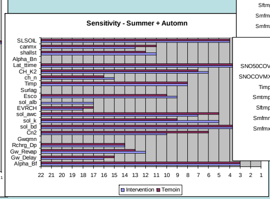


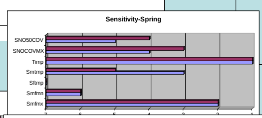
Parameters	Min	Max	Definition
Alpha_Bf	0	1	Base flow alpha factor(days)
Alpha_Bnk	0	1	alpha factor for bank storage recession curve(days)
BLAI	-50	50	Leaf area index for crop*
canmx	0.001	10	maximum canopy storage(mm H2O)
CH_K2	0	150	Effective hydraulic conductivity in main channel alluvium (mm/h)
ch_n	-20	20	Manning coefficient for channel
Cn2	-35	35	SCS runoff curve number for moisture condition II*
DDRAIN	-10	50	depth to the sub-surface drain (mm)
Epco	0.01	1	plant evaporation compensation factor
Esco	0	1	plant evaporation compensation factor*
EVRCH	0	1	Reach evaporation adjustment factor.
FILTERW	-50	50	filter strip width for bacteria transport (m)
GDRAIN	-50	900	drain tile lag time(hrs)
Gw_Delay	0	50	Groundwater delay (days)
Gw_Revap	0.02	0.2	Groundwater "revap" coefficient
Gwqmn	0	5000	Threshold depth of water in th shallow aquifer required for return flow to occur (mm)
Lat_ttime	0.01	20	lateral flow travel time (days)
ov_n	-50	50	Manning's "n" value for overland flow
Rchrg_Dp	0	1	Goundwater recharge to deep aquifer
REVAPMN	0	500	Threshold depth of water in tha shallow aquifer required for "revap" to occur (mm)
Sftmp	-1.5	1	Snowfall temperature (deg C)
shallst	0.5	6000	depth of water in shallow aquifer (mm H2O)
SLSOIL	0	0.6	slope length for lateral subsurface flow (m)
Smfmn	1	7	Minimum melt rate for snow during year (Dec. 21) where deg C refers to the air temperature (mm/deg C/day)
Smfmx	1	7	Maximum melt rate for snow during year (June 21) where deg C refers to the air temperature (mm/deg C/day)
Smtmp	-2	3	Snow melt base temperature(deg C)
SNO50COV	0.01	0.94	Fraction of SNOCOVMX that corresponds to 50% snow cover
SNOCOVMX	0	50	Minimum snow water content that corresponds to 100% snow cover (mm H2O)
sol_alb	-50	50	bulk density of the soil (Mg/m**3)
sol_awc	-50	50	available water capacity of soil layer (mm H20/mm soil)
sol_bd	-50	50	albedo when soil is moist
sol_k	-50	50	saturated hydraulic conductivity of soil (mm/hr)
sol_z	-50	50	depth to bottom of soil layer (mm)
Sol_zmx	0.001	3500	maximum rooting depth (mm)
Surlag	0	10	Surface runoff lag time.(days)
TDRAIN	-50	0	time to drain soil to field capacity (hrs)
Timp	0.01	1	Snow pack temperature lag factor

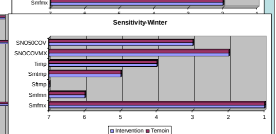
*Relative percent change

Sensitivity on the whole simulation period









3. Auto calibration – Manual calibration

3.1. Auto calibration

Supported by techniques of sensitivity analysis

Objective function

Sum of the squared of the residuals (SSQ) aims at matching a simulated series to a measured time series.

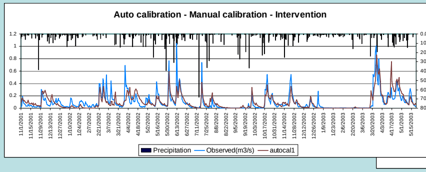
$$SSQ = \sum_{i=1,n}\left[X_{i,measured} - X_{i,simulated}\right]^2$$

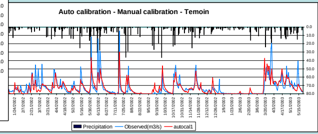
Parasol (Parameter Solutions method) method - **Automatic Optimization**

- Use of Algorithms that optimize an objective function by systematically searching the parameter space according to a fixed set of rules.
- Optimum corresponds to minimization of errors, expressed by the system

3.2. **Manual calibration**

Aim: to bring the optimized values to better estimated ones that allow the model to represent the real conditions of the area.





4. Model performance

Pearson Correlation Coefficient

$$R = \frac{\frac{1}{n}\sum_{i=1}^{n}(Q_i - \mu_{Q_i}) - (Q'_i - \mu_{\bar{Q}_i})}{\sigma_x * \sigma_y}$$

Nash-Sutcliffe Coefficient

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(Q_i - Q'_i)^2}{\sum_{i=1}^{n}(Q_i - u)^2}$$

Deviation

$$D_v(\%) = \frac{V - V^*}{V} * 100$$

Results

Performance criteria	Intervention	Temoin
CORR	0.8	0.8
N-S	0.6	0.6
DEV	-0.75%	-3.71%

Conclusion

- ✓ The focus on sensitive parameters leads to a better understanding of the system.
- ✓ The results of auto calibration brought the parameters to a good adjustment and helped the manual calibration process to a better estimation of the parameter values.
- ✓ Based on the satisfying results on the Walbridge experimental sub basins, parameter values will be applied to the rest of the Pike river sub basins.
- ✓ The future results at the Pike Watershed scale will enable a better targeting and implementation of appropriate pollution reduction strategies.

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