Modifications of the Soil Water and Assessment Tool for streamflow modelling in a small, forested watershed on the Canadian Boreal Plain.

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Outline

• FORWARD Project Description
• Data Preparation Protocol
• Model Adaptations
• Results
• Conclusions
FORWARD Project Description

- FORWARD - Forested Watershed and Riparian Disturbance Group
  - Impact of disturbance on water quality and quantity
  - Mitigating effect of buffer riparian zones
  - Compare effect of fire and harvesting
  - Provide a management tool for industry
FORWARD Project Description cont’d

- Group Members
  - University
  - Industry
  - Government

- Other Group Affiliations
  - SWAT group
  - Marcell Experimental Forest
Data Preparation Protocol

- Original data preparation program was developed by A. Rudy with help of I. Whitson & R. McKeown
  - Vegetation
  - Reach
  - Soils
SWAT Code Developed

- Model Development
  - Litter Layer
  - Wetlands
  - Aspect and slope
  - Vegetation
  - Damping factor

- SWATC-2000 Code Framework
Model Adaptation

• Litter layer incorporated for the forested land base

Excess Water 1 is divided between the litter layer and underlying soil layer

Excess Water 2 goes to surface runoff during later winter & early spring conditions

Stored Water remains in the litter layer

Effective Precipitation

Excess Water 1

Excess Water 2

Water Level 1

Water Level 2

Water Level 3

Evapotranspiration

Litter Depth

Litter Saturation

Field Capacity

Stored Water

Soil Layer 1
Wetlands Code

- Wetlands incorporated in a watershed
  - Maximum of one wetland per subbasin

Diagram:
- Upper Organic Layer (UOL)
  - Flow from upslope HRU litter layer
  - Excess water from UOL
  - Evaporation from UOL
  - Transpiration from LOL
  - Partitioned excess water from UOL
  - Root zone
  - Precipitation

- Lower Organic Layer (LOL)
  - Flow from upslope HRU soils & groundwater
  - Excess water in LOL
  - Revap
  - Seepage to shallow aquifer

- Lateral flow out of LOL to reach
- Excess water from UOL to reach
Soil Temperature Code

• Aspect & Slope
  ▪ The aspect and slope was included to reduce incoming solar radiation

• Vegetation
  ▪ Equation was based on Beers Law of light extinction

• Damping Effect
  ▪ An equation was developed to represent the damping effect due to the litter layer
Model Setup: Delineation

Outlets
- Linking stream added Outlet
- Streams
- Watershed

Mask
- 1

Watershed
- Streams
- Subbasins
- Outlets

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Model Setup: Soils

Streams

Soil Class

PA231
PA234
PA237
PA238
PA239
PA241
PA242
State Soil

N

S

W

E
Model Setup: Land Cover
Results: Daily Flow 2002

[Diagram showing daily flow and precipitation with measurements and code information]
Results: Daily Flow 2003

Measured & Estimated Data
SWATC-2000 code
SWAT2000 code
Precipitation
Results: Daily Flow 2004

- **Discharge (mm)**
  - Measured Data
  - SWATC-2000 code
  - SWAT2000 code
  - Precipitation

- **Precipitation (mm)**
  - Mar-04 to Oct-04
Conclusions

• The data preparation protocol and SWAT code completed to date are a significant improvement for both data management and modelling in a forested setting.

• As data becomes available, additional SWAT code improvements include litter layer growth, wetlands freeze & thaw, refined damping effect equation, and the development of an improved radiation reduction equation.
Meteorological Data

Goose Mountain
Firetower

Eagle Ridge
Firetower

Sak A
W2

Willow
W3

Kashka
W4

Pierre
W1

Environment Canada
Weather Station

Imperial
Firetower

Whitecourt
Firetower
Model Adaptation

- Equation used for proportioning

\[ Pptn = \left( \frac{K_{sat\_ly1} \times 1}{K_{sat\_ly1} \times 1} \right) + \left( K_{sat\_litter} \times Slope \right) \]
Wetlands Code

- **Inflows**
  - **Flow from upslope**
    - The volume of water released from the upslope hru(s) – surface flow (if applicable), litter layer, groundwater flow and lateral flow enters the wetland.

\[
V_{\text{flowin}} = \sum_{hru=1}^{n} \left[ f_{pot, hru} \times 10 \times \left( Q_{surf, hru} + Q_{gw, hru} + Q_{lat, hru} + Q_{litter, hru} \right) \times area_{hru} \right]
\]
Wetlands Code

- Precipitation
  - Enters litter layer first and excess water is partitioned as per the litter code

- Revap
  - Water moves upward from the shallow groundwater
Outflows

- Litter flow downslope
  - Excess flow is calculated, lagged and then fed directly to the reach. The amount of litter flow released each day is determined using the kinematic storage model.

- Lateral flow out via soil
  - This flow is limited by the downslope soil Ksat values. The flow is then lagged to the stream using the kinematic storage model.
Wetlands Code

- **Seepage**
  - The Ksat of the underlying soil limits the seepage. The water then passes through the soil horizons as with other hru’s.

- **Excess Water in Wetland**
  - Water that exceeds the capacity of the wetland is sent to the litter layer and routed as per the litter code.

- **Evaporation**
  - This occurs from the litter layer if the litter has sufficient excess water.
Transpiration

- limited by the root depth of the vegetation growing within the wetland hru.
- the equation is the same as that used in SWAT2000

\[
E_t = \frac{E_o \times \text{LAI}}{3.0} \quad 0 \leq \text{LAI} \leq 3.0
\]

\[
E_t = E_o \quad \text{LAI} > 3.0
\]
Soil Temperature Code

• Aspect & Slope
  - The aspect and slope are included to reduce incoming solar radiation

\[
G_a = G_m \left[ R_d \left( 1 - K_r \right) + f_\beta K_r + 0.2 \left( 1 - f_\beta \right) \right]
\]

\[
R_d(\varphi, \delta, \beta, b) = \left( \frac{\sin \Phi^*}{\sin \Phi} \right) \left( \frac{d - \sin d \cos e \cos g}{\cos w^*} \right) \frac{\omega_s - \tan \omega_s}{\omega_s}
\]
Soil Temperature Code

- Vegetation
  - Equation used is based on Beers Law of light extinction

\[ G_f = G_a \times e^{(-K \times LAI)} \]
Soil Temperature Code

• Damping Effect
  
  ▪ An equation was developed to represent the damping effect due to the litter layer

\[
b_{cv}^{\text{forest}} = \frac{D_{LL}}{D_{LL} + \exp(-2.598 + 0.845 \times D_{LL})}
\]