Adapting SWAT for Riparian Wetlands in Ontario Watershed

Amanjot Singh, Ramesh Rudra and Wanhong Yang

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 Agencies
  – 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

- Hydrology
- Sediment
- Nutrient

- Water, Sediment and Nutrient Budget

- Annual
- Seasonal
- Monthly
- Daily

*SWAT AnnAGNPS HSPF ANSWERS2000 CANWET (AVGWLF) GEO-WEPP MikeShe*

- 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

Grand River Watershed

Canagagigue Creek Watershed
Canagagigue Creek Watershed
## SWAT
Calibrated: Seasonal Water Balance

<table>
<thead>
<tr>
<th>Season</th>
<th>% P</th>
<th>% E</th>
<th>Observed</th>
<th>Simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% Q&lt;sub&gt;s&lt;/sub&gt;</td>
<td>% Q&lt;sub&gt;g&lt;/sub&gt;</td>
<td>% Q&lt;sub&gt;s&lt;/sub&gt;</td>
<td>% Q&lt;sub&gt;g&lt;/sub&gt;</td>
</tr>
<tr>
<td>JFM</td>
<td>21.6</td>
<td>5.6</td>
<td>10.1</td>
<td>7.3</td>
</tr>
<tr>
<td>AMJ</td>
<td>26.7</td>
<td>22.3</td>
<td>5.5</td>
<td>6.5</td>
</tr>
<tr>
<td>JAS</td>
<td>31.5</td>
<td>25.2</td>
<td>2.0</td>
<td>2.4</td>
</tr>
<tr>
<td>OND</td>
<td>23.7</td>
<td>8.2</td>
<td>2.5</td>
<td>4.2</td>
</tr>
</tbody>
</table>
## SWAT Validation: Seasonal Water Balance

<table>
<thead>
<tr>
<th>Season</th>
<th>% P</th>
<th>% E</th>
<th>Observed</th>
<th>Simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>% $Q_s$</td>
<td>% $Q_g$</td>
</tr>
<tr>
<td>JFM</td>
<td>24.9</td>
<td>7.5</td>
<td>11.4</td>
<td>8.0</td>
</tr>
<tr>
<td>AMJ</td>
<td>26.6</td>
<td>23.5</td>
<td>6.2</td>
<td>7.5</td>
</tr>
<tr>
<td>JAS</td>
<td>30.3</td>
<td>23.9</td>
<td>2.4</td>
<td>2.8</td>
</tr>
<tr>
<td>OND</td>
<td>22.7</td>
<td>9.2</td>
<td>2.9</td>
<td>4.9</td>
</tr>
</tbody>
</table>
Simulated and Observed Runoff

Calibration Phase Validation Phase

Amount of runoff (mm)

0 100 200 300 400 500 600 700

Precipitation (mm)

0 20 40 60 80 100 120 140 160 180

Spring, 91
Summer, 91
Fall, 91
Spring, 92
Summer, 92
Fall, 92
Spring, 93
Summer, 93
Fall, 93
Spring, 94
Summer, 94
Fall, 94
Spring, 95
Summer, 95
Fall, 95
Spring, 96
Summer, 96
Fall, 96
Spring, 97
Summer, 97
Fall, 97
Spring, 98
Summer, 98
Fall, 98
Spring, 99
Summer, 99
Fall, 99
Spring, 00
Summer, 00
Fall, 00
Modells 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, however, Effective daily base flow separation technique is required to incorporate with the model
Western Tributary with less wetlands

Eastern Tributary with more wetlands
Riparian Wetland
Canagagigue Creek Watershed

Point of Merger of two Tributaries

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

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 associated with marked sub-basin.
SWAT – REMM Interface
**SWAT Output**

### Sub-Basin 10

- **Rainfall**
- **Runoff (mm)**
- **Sediment (kg/ha)**

![Graph showing rainfall, runoff, and sediment yield over months for Sub-Basin 10.](image-url)
REMMA Input

Zone 1 = 30 m
Zone 2 = 150 m
Zone 3 = 20 m
### REMM Output

#### Runoff (cm)

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

#### Sediment (kg/ha)

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

20% sed. Abt
- 50 hectares
- $12,000/year

40% sed. Abt
- 110 hectares
- $31,000/year
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

Thanks

Thanks

Thanks