Effect of climate change on low-flow conditions in Ruscom River watershed, Ontario

by

Tirupati Bolisetti

Co-Authors:

M. Rahman and R. Balachandar

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Introduction

- Climate change refers to the persistent change in climate over long periods of time due to either natural or as a result of man-made activity.
- Changes in future climate will affect the hydrological cycle and impact the water resources in terms of quantity and quality.
- The Ruscom River within the Essex County, Ontario sometimes experiences very low-flow conditions during dry season.
- Understanding of future low-flow conditions of the watershed is required for the sustainable watershed management and maintaining watershed ecosystem.
The objective of this study is to investigate the effect of climate change on low-flow conditions in Ruscom River watershed; specifically to:

- simulate streamflow from the watershed considering likely changes in future climate
- perform flow frequency analysis and predict the impact on low-flow conditions in the watershed due to possible climate change
Study Area - Index Map

Image source: Flash Earth (2009)
Study Area - Map

Image source: Flash Earth (2009)
Study Area

- **Watershed area:** About 175 km²
- **Topography:** Level to slightly undulating
- **Soils:** Predominantly clayey
- **Natural drainage:** Poor category
- **Artificial drainage:** Extensively tile drains are used
- **Climate:** Favorable to agriculture when compared to other parts of Ontario
- **Land use:** Agricultural land (93 %), Orchard (3 %), Urban (2 %) and Woodland (2 %)
- **Major crops:** Soybeans, Wheat and Corn
Methodology

- Canadian Regional Climate Model (CRCM) simulated outputs under SRES A2 scenario (2041-2070) was used
- A stochastic weather generator, LARS-WS was applied to generate daily future weather data from CRCM outputs for base (1961-1990) and future periods
- Soil and Water Assessment Tool (SWAT) was used for predicting streamflows over the base and future periods
- Flow frequency analysis was performed using HEC-SSP
SWAT Model

- SWAT is a physically based, continuous time model
- Developed by the USDA Agricultural Research Service (ARS) in the early 1990s
- Predicts the impact of management and climate on hydrology and non-point source pollution
- Upland components: Hydrology, weather, erosion/sedimentation, soil temperature, plant growth, nutrients, pesticides, and land and water management
- Routing components: Channel and reservoir routing
GIS Layers Used in the Modelling

- DEM
- Soil Map
- Landuse map
DEM was utilized to divide the watershed into subwatersheds

Pre-digitized stream network was used in locating the streams
Weather, soils, landuse and land management database was developed for the model.

The model was calibrated for streamflow by adjusting model parameters.

Monthly observed discharge data for a period of 5 years each were used to calibrate and validate the model.

The calibrated SWAT model was used to simulate streamflows generated from the watershed for the base (1961-1990) and future (2041-2070) periods.
Annual Flow Calibration and Validation

### Calibration

- **Streamflow (m$^3$/s)**: 1112, 673, 1010, 728, 730
- **Prec.**, **Obs. Q**, **Sim. Q**

### Validation

- **Streamflow (m$^3$/s)**: 760, 738, 678, 670, 960
- **Prec.**, **Obs. Q**, **Sim. Q**
Monthly Flow Calibration and Validation

<table>
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<tr>
<th>Period:</th>
<th>Calibration</th>
<th>Validation</th>
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<td>Coefficient of determination:</td>
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<td>Nash-Sutcliffe model efficiency:</td>
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<td>Index of agreement:</td>
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Changes in Future Temperatures

Monthly maximum temperature

![Graph showing monthly maximum temperature for base period (1961-1990) and future period (2041-2070).]

Monthly minimum temperature

![Graph showing monthly minimum temperature for base period (1961-1990) and future period (2041-2070).]
Changes in Future Precipitation

Average monthly precipitation

Relative change in duration of wet and dry spell
Frequency Analysis

Based on annual minimum monthly flow

Lognormal Distribution

Log Pearson III Distribution
## Frequency Analysis (Contd.)

### Changes in annual minimum monthly flows

<table>
<thead>
<tr>
<th>Distribution</th>
<th>Return period</th>
<th>Base period flow (m³/s)</th>
<th>Future period flow (m³/s)</th>
<th>Relative change</th>
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<td>0.013</td>
<td>0.010</td>
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<td>0.001</td>
<td>-50%</td>
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</table>
Seasonal Flow Duration Curves

Winter: Dec, Jan, Feb and Mar

Summer: Jun, Jul, Aug and Sep

Spring: Apr and May

Fall: Oct and Nov
Box Plot of Monthly Streamflow

- 1st Quartile
- Minimum
- Median
- Maximum
- 3rd Quartile

Base period (1961-1990)
Future period (2041-2070)
Monthly Flow Frequency Analysis

Monthly streamflow equaled or exceeded 90% of the time

Monthly streamflow equaled or exceeded 95% of the time
Conclusions

- Model performance indicate that SWAT reasonably simulated streamflows from the Ruscom river watershed.

- Under the projected climate scenario for the period, 2041-2070, the future mean monthly minimum and maximum temperatures can be increased by 3.2 °C and 3.6 °C, respectively compared to the temperatures in base period, 1961-1990.

- As a consequence of climate warming the average annual precipitation in future could be increased by 8%.

- Low-flows in the Ruscom River would be increased in winter but decreased in fall due to the possible climate change.
Annual minimum monthly streamflow of 2-yr return period can be reduced by more than 20% and the conditions would be worse for higher return periods.

Since uncertainties are involved with the future climate predictions, further study can be performed with multiple future climate scenarios for understanding the range of climate change impact on low-flow conditions in the Ruscom River watershed.
Essex Region Conservation Authority, Ontario is gratefully acknowledged for providing necessary support.
Thank you!
<table>
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<tr>
<th>Experiment</th>
<th>Model Version</th>
<th>Domain &amp; Resolution</th>
<th>Driving Atmos. Data (and ocean data if different) &amp; Nesting Strategy</th>
<th>GHG+ A Evolution</th>
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<th>Period End</th>
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http://loki.ouranos.ca/DAI/mrcc_exp-e.html
These simulations were performed with the Canadian Regional Climate Model (CRCM). In the current period (also referred to as recent climate), CRCM is driven either by NCEP/NCAR or by ECMWF-ERA40 global atmospheric reanalysis data, or by Global Climate Model (GCM) data. Both reanalysis datasets were used at a 2.5x2.5 global latitude/longitude resolution, every 6 hours. In recent climate simulations, the CRCM follows observed greenhouse-gas and aerosol (GHG+A) concentrations. In future climate projections, the CRCM can use various GHG+A scenarios from the IPCC (i.e. IS92a, A2, etc.), following that of the driving GCM data. Regional climate change can be estimated from future and recent climate simulations produced with the same configuration. It is preferable to use an ensemble of simulations to evaluate the spread of the expected climate change.