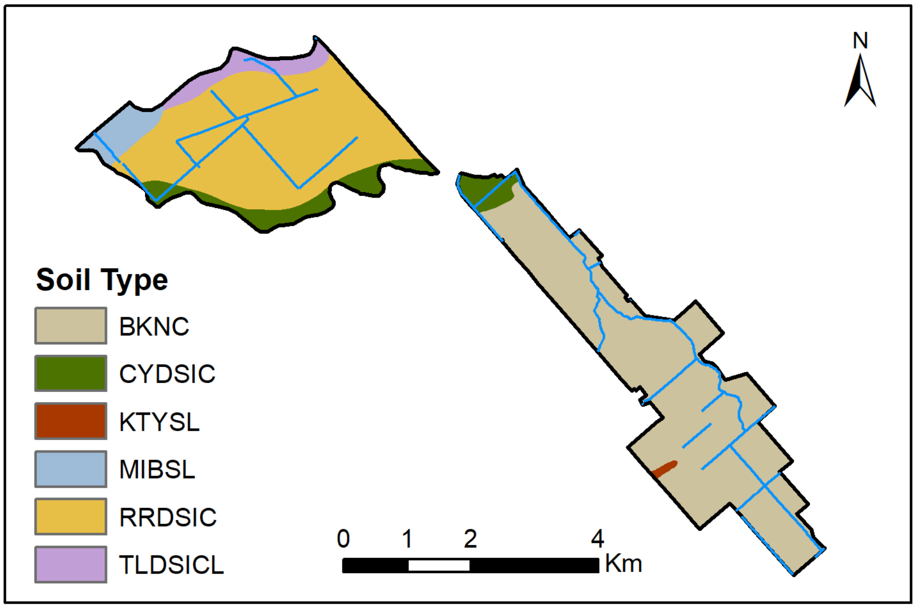

ONFARM

# Modelling Report – Jeannette's Creek

June 28, 2023

Prepared by:

The Watershed Evaluation Group

University of Guelph

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## 1.0 INTRODUCTION

The Jeannette's Creek subwatershed in the service area of the Lower Thames Valley Conservation Authority (LTVCA) is a representative lakeshore watershed of the Lake St. Clair Basin. It has a relatively flat landscape and is dominated by agricultural landuse activities. Evident sediment and nutrient transport from these lakeshore watersheds has become one of the major identified concerns to near shore water quality. In response to this growing concern over the adverse environmental effects of agriculture, farmers, conservation authorities and governments have worked together to promote and implement "Best/Beneficial Management Practices" or BMPs that focus on maintaining agricultural activity and farm profitability while protecting the environment.

From 2015 to 2018, the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) and the Ontario Soil and Crop Improvement Association (OSCIA) jointly implemented the Great Lakes Agricultural Stewardship Initiative (GLASI). In GLASI, the Jeannette's Creek subwatershed was selected as one of the six priority subwatersheds for BMP establishment and study. By building upon LTVCA's previous BMP initiatives and monitoring program, the GLASI program invested in establishing a monitoring system for evaluating existing and newly-established BMPs in the study area, primarily conservation tillage, fertilizer incorporation, cover cropping, and vegetative buffer strip. As a component of the GLASI, Soil and Water Assessment Tool (SWAT) modelling of the Jeannette's Creek subwatershed was conducted to evaluate the water quality effects of various BMP scenarios (Rudra et al., 2019).

The On-Farm Applied Research and Monitoring (ONFARM) program, administered by OMAFRA and OSCIA from 2019 to 2023, further developed soil health and water quality research on farms across Ontario. ONFARM extended previous work under the GLASI priority subwatersheds to evaluate BMP effects on soil health and water quality. In the ONFARM project, LTVCA colleagues continued their efforts on BMP experiments and data collection including completing farmer land management surveys and water monitoring. Watershed modelling for BMP assessment was also one of the key components of the ONFARM project.

The purpose of the ONFARM modelling project was to apply the Integrated Modelling for Watershed Evaluation of BMPs (IMWEBs) tool to evaluate the environmental effectiveness and cost effectiveness of three key agricultural BMPs (conservation tillage or no-till, cover cropping, and fertilizer/manure incorporation) in the six priority subwatersheds including the Jeannette's Creek subwatershed. Specifically, the modelling project had the following objectives:

1). Collect and prepare IMWEBs modelling input data;

2). Set up and calibrate IMWEBs modelling to simulate the watershed's historical/existing conditions;

3). Apply IMWEBs modelling to evaluate the environmental effectiveness (including P loss reduction efficacies) and cost effectiveness of the three key BMPs of interest (cover cropping, conservation tillage/no-till, and fertilizer/manure incorporation following application) presently existing or being applied in the study watersheds – referred to in this report as the "existing actual BMP" scenario.

4). Apply IMWEBs modelling to evaluate the environmental effectiveness and cost effectiveness of the three key agricultural BMPs of interest (cover cropping, conservation tillage/no-till, and fertilizer/manure incorporation following application) under different implementation levels and placement strategies across the watershed.

## 2.0 STUDY AREA

### 2.1 Location

The Jeannette's Creek subwatershed is located in southwestern Ontario, about 14 km southwest of the city of Chatham (Figure 2-1). The Jeannette's Creek subwatershed is composed of two smaller subwatersheds that each drain to Jeannette's Creek. Jeannette's Creek drains to the Thames River, about 3.5 km upstream of the Thames River outlet to Lake St. Clair. The two smaller subwatersheds forming the Jeannette's creek subwatershed study area cover a drainage area of about 1,867 ha.

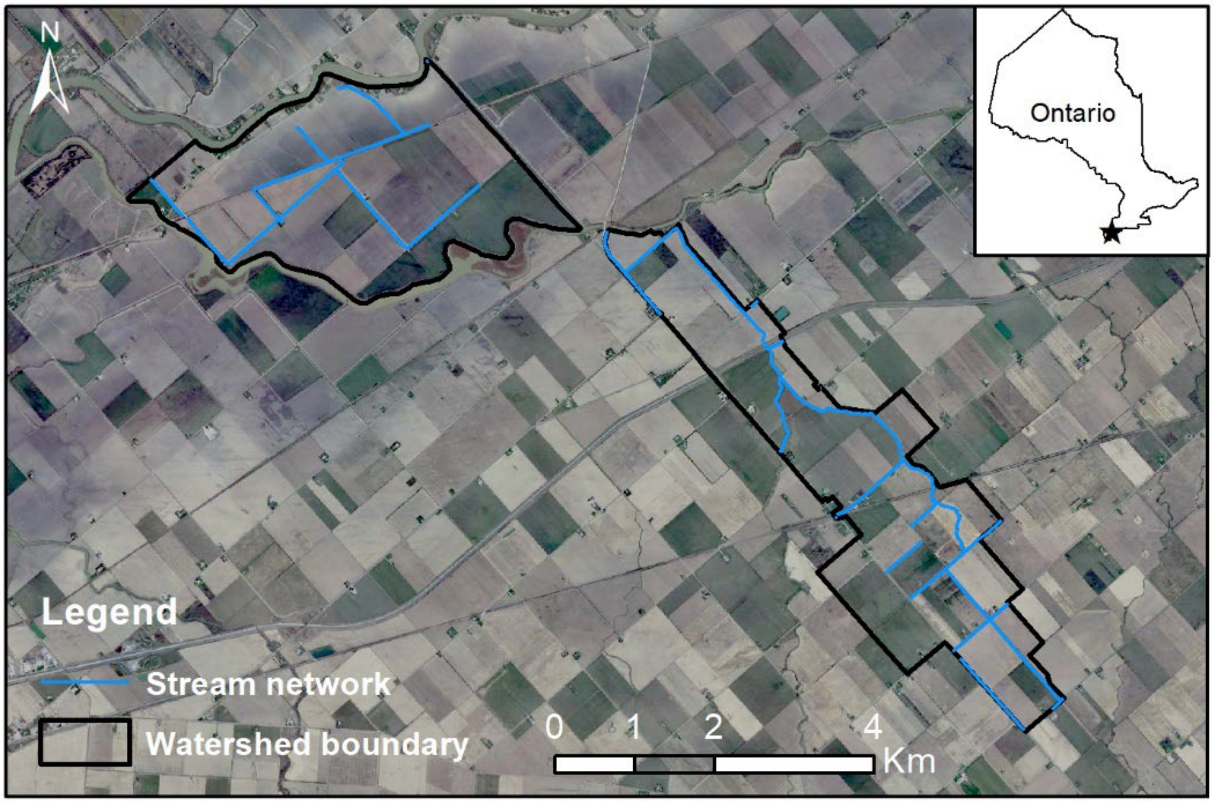

Figure 2-1. The Jeannette's Creek subwatershed within southwestern Ontario

### 2.2 Topography, soil, and landuse

The Jeannette's Creek subwatershed has very flat topography, ranging from the highest elevation of 185 m in the southeast, to the lowest elevation of 172 m at the Dauphin pump station outlet (Figure 2-2). The average slope (according to the 1-m pixel resolution LiDAR DEM) is 1.82%, with a minimum of 0.00% in flat areas, and up to 115% (49 degrees) a drainage ditch banks (Figure 2-3). About 95% of the watershed has slopes less than 4.5% (Table 2-1).

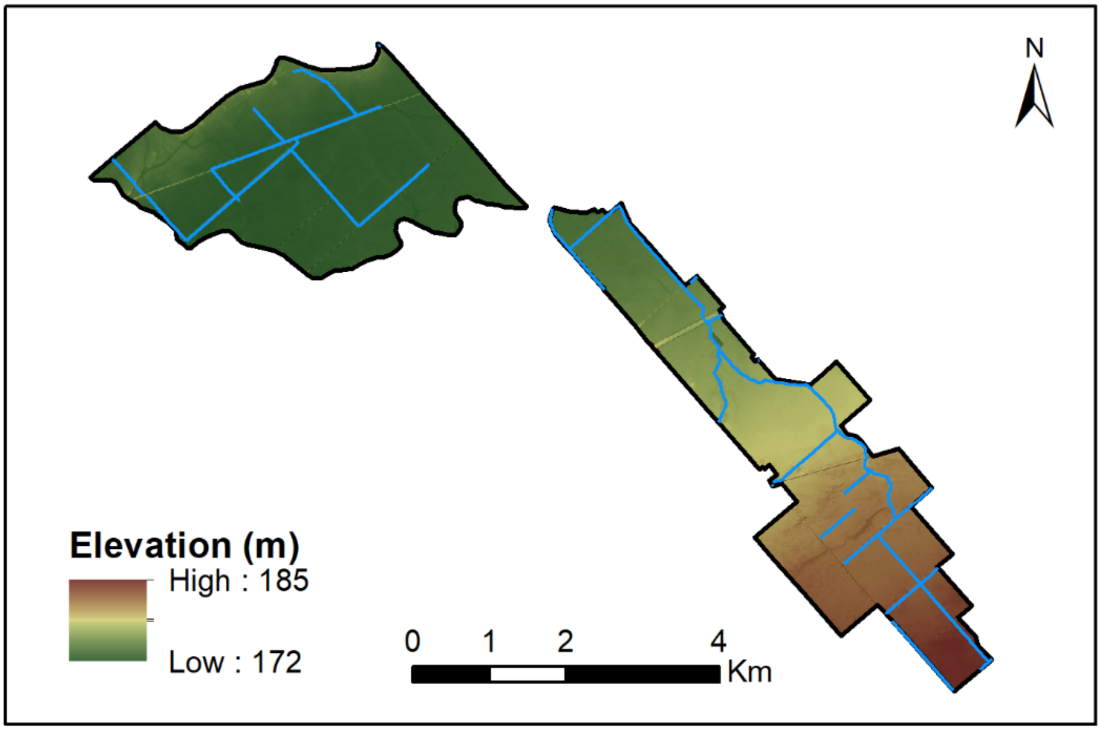

Figure 2-2. Elevation of the Jeannette's Creek subwatershed

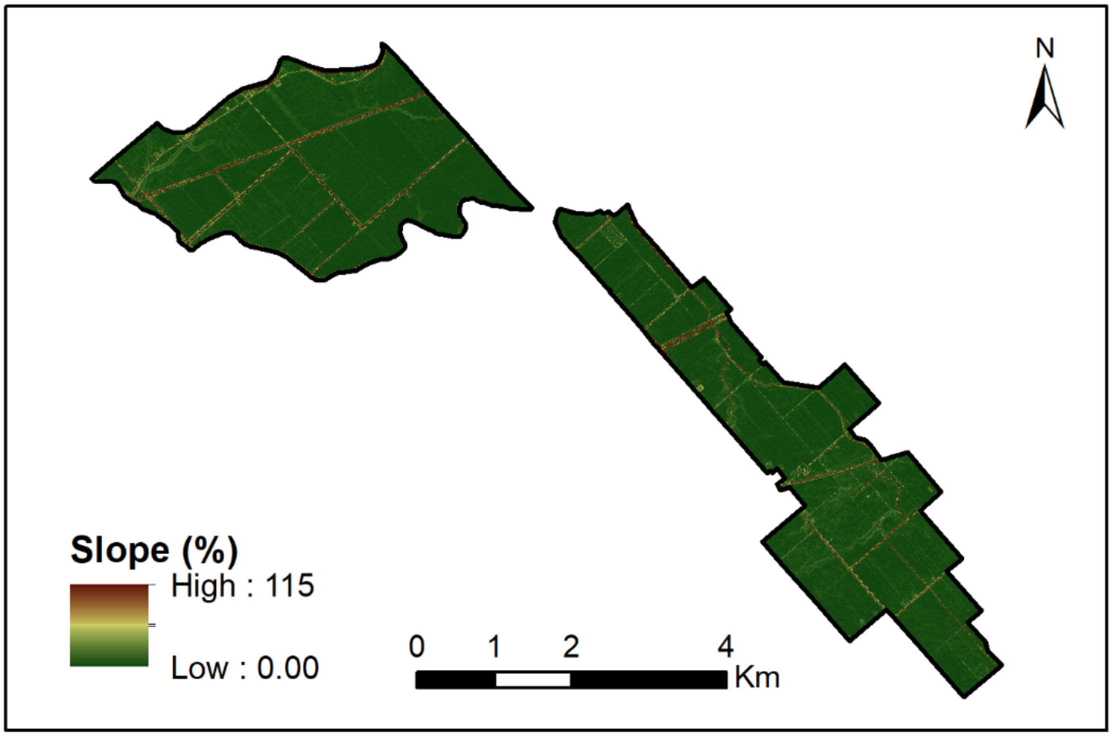

Figure 2-3. Slope of the Jeannette's Creek subwatershed

Table 2-1. Elevation and slope areal extent in the Jeannette's Creek subwatershed

| Class | Elevation (m) | Area extent |  | Slope (%) | Area extent |  |
|---|---|---|---|---|---|---|
|  |  | (km$^2$) | (%) |  | (km$^2$) | (%) |
| 1 | 172 - 175 | 7.76 | 41.6 | 0.00 - 4.51 | 17.6 | 94.5 |
| 2 | 176 - 177 | 3.41 | 18.3 | 4.52 - 16.2 | 0.504 | 2.70 |
| 3 | 178 - 179 | 2.75 | 14.7 | 16.3 - 32.0 | 0.255 | 1.37 |
| 4 | 180 - 182 | 3.09 | 16.6 | 32.1 - 50.0 | 0.191 | 1.02 |
| 5 | 183 - 185 | 1.65 | 8.84 | 50.1 - 115 | 0.081 | 0.436 |
| Average/sum | 177 | 18.7 | 100 | 1.82 | 18.7 | 100 |

The map of soil type distribution based on OMAFRA Soil Survey Complex is shown in Figure 2-4. The soil names and areal extents corresponding to each soil type within the Jeannette's Creek subwatershed are shown in Table 2-2. The southern subwatershed is dominated by Brookston Clay soil (48.5%), while the northwestern subwatershed is primarily composed of Rivard Silty Clay soil (36.4%).

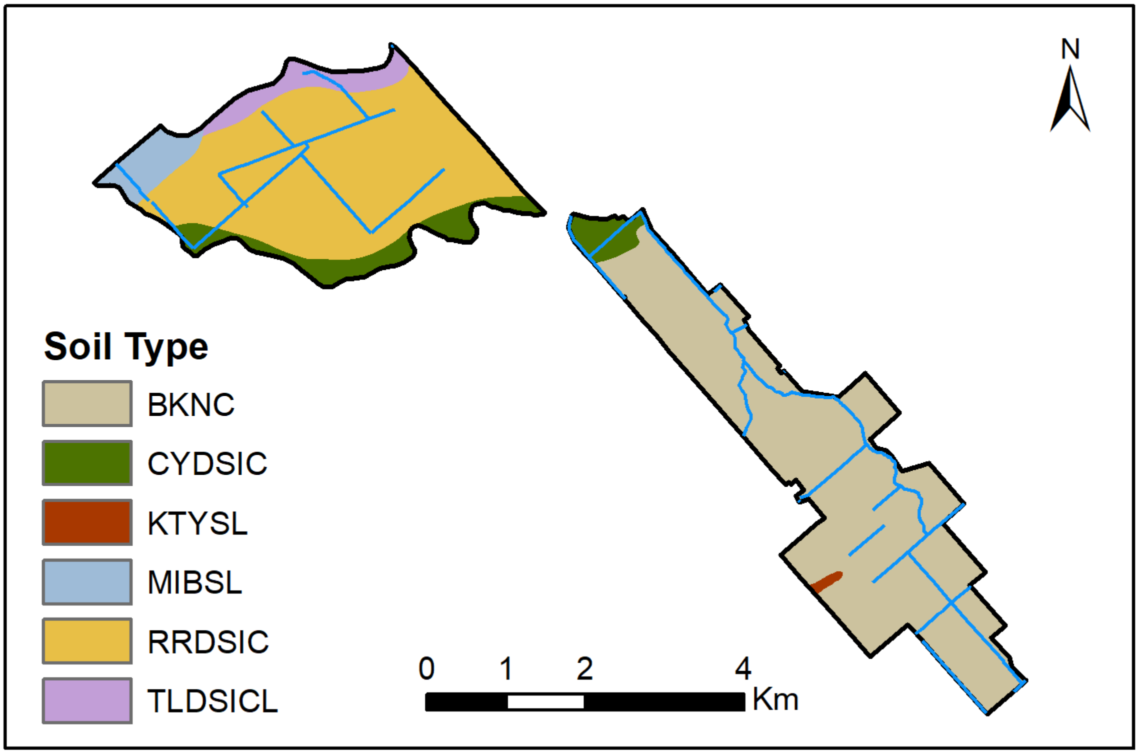

Figure 2-4. Soil types in the Jeannette's Creek subwatershed, based on OMAFRA soil survey data

Table 2-2. Soil types and areal extent in the Jeannette's Creek subwatershed

| Soil code | Soil type | Hydrologic group | Soil texture | Area (ha) | Watershed area (%) |
|---|---|---|---|---|---|
| BKNC | Brookston Clay | D | C | 905 | 48.5 |
| CYDSIC | Clyde Silty Clay | D | SiC | 141 | 7.58 |
| KTYSL | Kintyre Sandy Loam | B | SL | 5.32 | 0.285 |
| MIBSL | Mitchell's Bay Sandy Loam | D | SL | 61.8 | 3.31 |
| RRDSIC | Rivard Silty Clay | D | SiC | 679 | 36.4 |
| TLDSICL | Toledo Silty Clay Loam | D | SiCL | 74.2 | 3.97 |
| Total | | | | 1,867 | 100 |

Figure 2-5 presents the landuse distribution within the Jeannette's Creek subwatershed based on ONFARM field boundaries and a landuse layer generated under the previous GLASI study. The landuse names and associated areas and percentages within the Jeannette's Creek subwatershed are listed in Table 2-3. Approximately 90% of the land is agricultural, while 4.7% is forest or grassland, 4.7% is urban (i.e., residential or transportation), and less than 1% is open water.

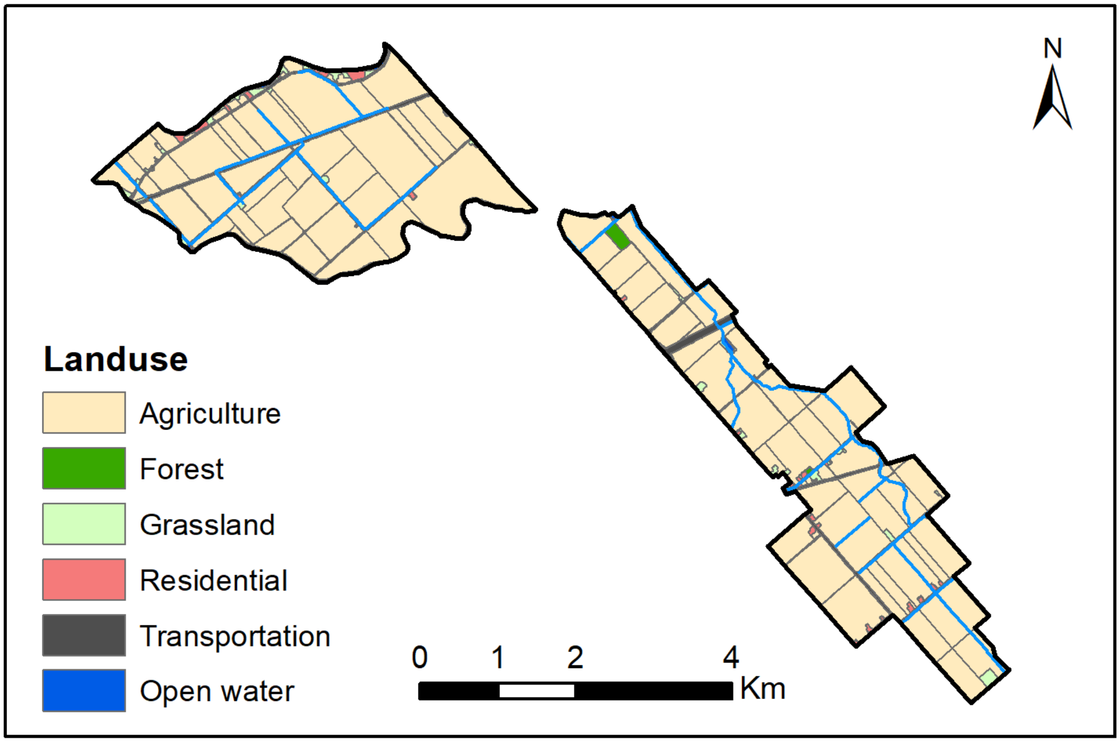

Figure 2-5. Landuse in the Jeannette's Creek subwatershed based on ONFARM field boundaries and GLASI landuse layer

Table 2-3. Landuse and areal extent of the Jeannette's Creek subwatershed

| Land use type | Area (ha) | Percent (%) |
|---|---|---|
| Agriculture | 1,673 | 89.6 |
| Forest | 6.32 | 0.338 |
| Grassland | 82.2 | 4.40 |
| Residential | 14.9 | 0.801 |
| Transportation | 73.4 | 3.93 |
| Open water | 17.3 | 0.926 |
| Total | 1,867 | 100 |

## 2.3 Climate and hydrology

The input climate data (i.e., daily precipitation, maximum and minimum temperature, solar radiation, wind speed, wind direction, and relative humidity) were collected from five Lower Thames Valley Conservation Authority (LTVCA) and nine Environment and Climate Change Canada (ECCC) stations (Figure 2-6, Table 2-4). Wind speed, relative humidity, and solar radiation were also downloaded from the website of NASA Prediction of Worldwide Energy Resources based on the latitude and longitude of the ECCC and LTVCA climate stations to supplement the available climate data. A synthesized climate dataset from 1970-01-01 to 2022-06-30 was developed for the IMWEBs simulation.

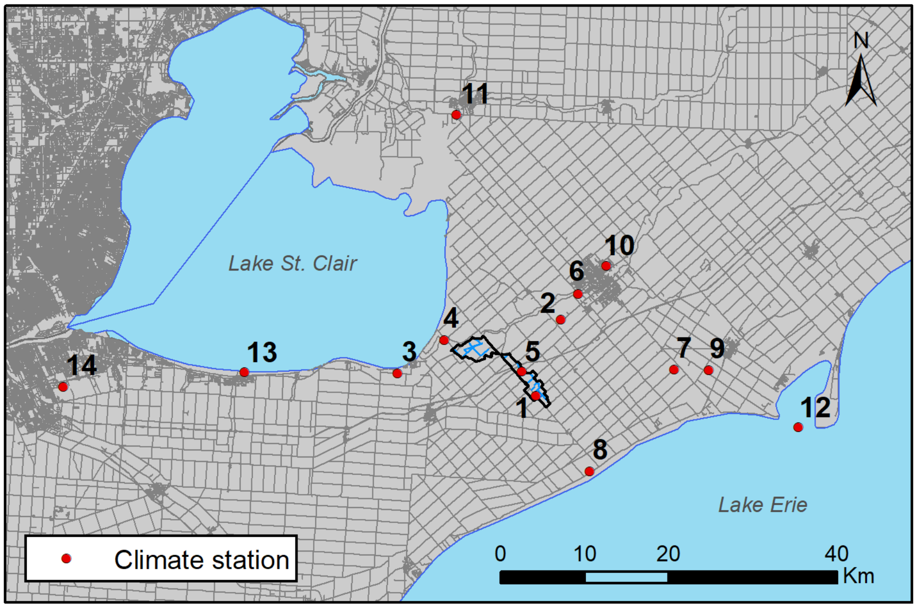

Figure 2-6. Climate monitoring stations for the Jeannette's Creek subwatershed IMWEBs modelling (Please refer to Table 2-4 for station names). Note that stations 12, 13, and 14 were only used for wind direction data

Table 2-4. Climate stations for the Jeannette's Creek subwatershed IMWEBs modelling

| ID | Name | Latitude | Longitude | Elevation | Frequency | Period | Parameters |
|---|---|---|---|---|---|---|---|
| 1 | MerlinB (LTVCA) | 42.28 | -82.279 | 184 | 15 Minutes | 2016-05-19 to 2022-06-30 | TMP, PCP, RH, SLR, WS, WD |
| 2 | Chatham WIN (LTVCA) | 42.362 | -82.244 | 179 | 15 minutes | 2007-05-15 to 2022-06-30 | TMP, PCP, RH, SLR, WS, WD |
| 3 | Lighthouse Cove (LTVCA) | 42.302 | -82.479 | 177 | 15 minutes | 2007-01-01 to 2017-08-08 | TMP, PCP, RH, WS*, SLR* |
| 4 | Poppe Rd TLBY (LTVCA) | 42.338 | -82.412 | 177 | Daily | 2014-01-01 to 2020-12-31 | TMP, PCP, RH, WS, WD, SLR* |
| 5 | Deary Upstream (LTVCA) | 42.306 | -82.30 | 178 | 15 minutes | 2019-09-03 to 2022-06-30 | PCP, WS*, RH*, SLR* |
| 6 | Chatham WPCP (ECCC) | 42.39 | -82.22 | 180 | Daily | 1983-06-01 to 2019-01-11 | TMP, PCP, WS*, RH*, SLR* |
| 7 | Chatham Kent (ECCC) | 42.31 | -82.08 | 197 | Hourly & Daily | 2014-04-03 to 2022-06-30 | TMP, PCP, RH, WS, WD, SLR* |
| 8 | Port Crewe (ECCC) | 42.20 | -82.20 | 195 | Daily | 1988-06-08 to 1994-08-31 | TMP, PCP, WS*, RH*, SLR* |
| 9 | Blenheim 1 (ECCC) | 42.31 | -82.03 | 200 | Daily | 2006-05-15 to 2009-12-29 | TMP, PCP, WS*, RH*, SLR* |
| 10 | Chatham Waterworks (ECCC) | 42.42 | -82.18 | 183 | Daily | 1970-01-01 to 1983-05-25 | TMP, PCP, WS*, RH*, SLR* |
| 11 | Wallaceburg (ECCC) | 42.58 | -82.40 | 177 | Daily | 1970-05-13 to 1997-04-30 | TMP, PCP, WS*, RH*, SLR* |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 12 | Erieau AUT (ECCC) | 42.25 | -81.90 | 178 | Hourly & Daily | 1994-02-01 to 2022-06-30 | This station was only used for WD |
| 13 | Belle River (ECCC) | 42.30 | -82.70 | 184 | Hourly & Daily | 1994-02-01 to 2005-03-06 | This station was only used for WD |
| 14 | Windsor A (ECCC) | 42.28 | -82.96 | 190 | Hourly & Daily | 1970-01-01 to 2014-09-22 | This station was only used for WD |

Note: PCP means precipitation, TMP means temperature, WD means wind direction, WS means wind speed, RH means relative humidity, SLR means solar radiation. * in 'Notes' column indicates the data are taken from NASA by specifying the latitude and longitude of the ECCC or LTVCA climate station because NASA data are grid based.

The Jeannette's Creek subwatershed has a climate with pronounced seasonal variations. The growing season begins in late April and ends in mid October with an annual average of about 170 frost free days. At station 2 (LTVCA Chatham WIN), the average annual precipitation was 824 mm from 2008 – 2021 with a standard deviation of 134 mm. The maximum annual precipitation of 1,172 mm occurred in 2011, and the minimum was 668 mm, occurring in 2012. The maximum daily precipitation was 83 mm, recorded on July 29, 2016. The average annual temperature was 9.7 °C from 2008 – 2021, ranging from 11.0 °C in 2012 to 7.9 °C in 2014 with a standard deviation of 0.87 °C. Figure 2-7 presents annual precipitation and average temperature from 2008 – 2021 at station 2 (LTVCA Chatham WIN). Annual precipitation is on average decreasing, while annual average temperature is increasing from 2008 – 2021 (Figure 2-7).

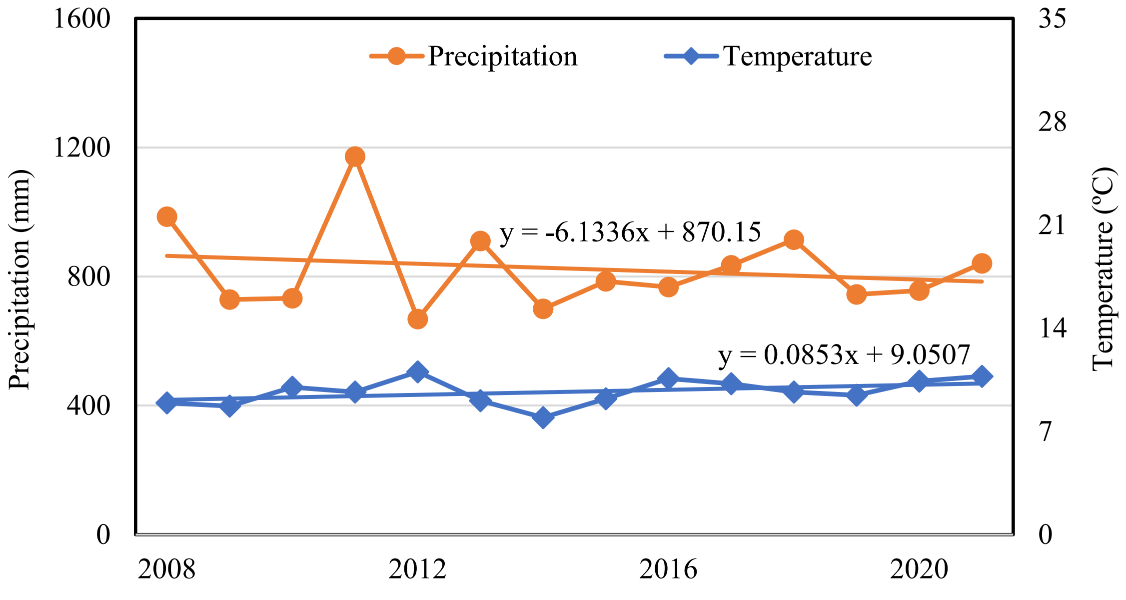

Figure 2-7. Variation of yearly precipitation and average temperature at station 2 (LTVCA Chatham WIN) from 2008-01-01 to 2021-12-31

Temperature is highest in the summer months from June to September, and lowest in the winter months from December to March in the Jeannette's Creek subwatershed (Figure 2-8 and Table 2-5). Precipitation also varies seasonally, with July having the highest monthly precipitation of 113 mm and January the lowest monthly precipitation of 36.3 mm (Figure 2-8 and Table 2-5).

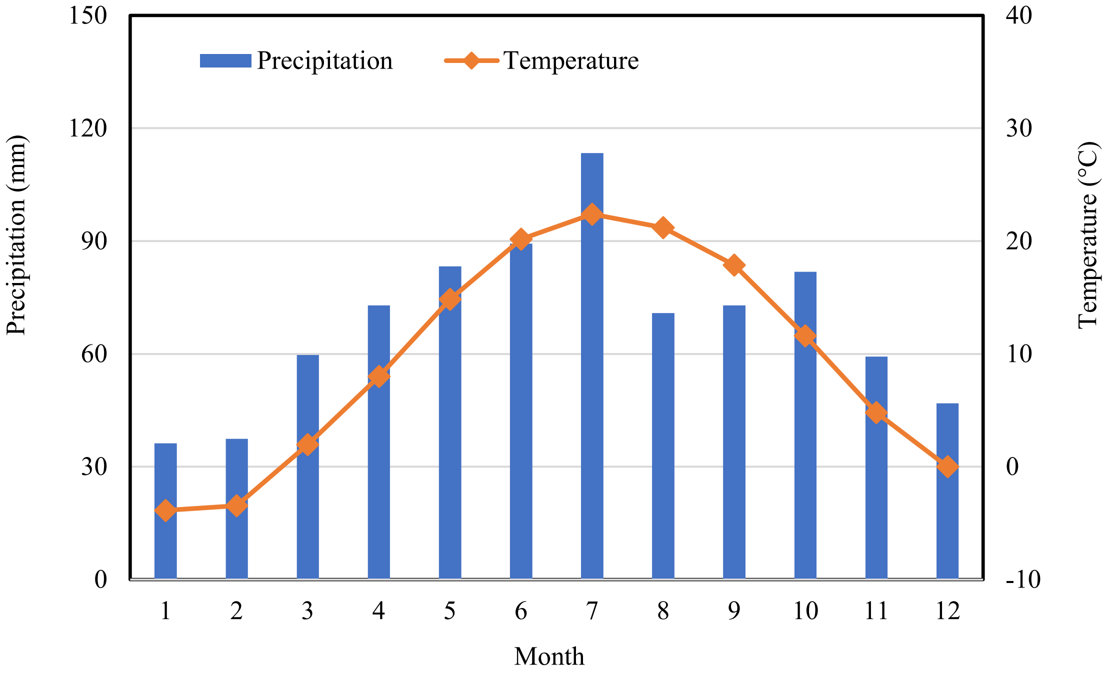

Figure 2-8. Average monthly precipitation and average temperature variation at station 2 (LTVCA Chatham WIN) from 2008-01-01 to 2021-12-31

Figure 2-9 presents baseflow separation for the Deary Upstream station from 2017 – 2022. Based on the SWAT Baseflow Separation tool, baseflow contributed about 31% of total streamflow at the Deary Upstream station from 2017-11-18 to 2022-06-30. Table 2-6 presents average monthly precipitation, runoff, and baseflow for the Deary Upstream streamflow monitoring station from 2018-01-01 to 2021-12-31. Runoff is highest in the winter months from December to February due to frozen soils and snowmelt, and lowest in the summer months from July to September due to higher temperatures and evapotranspiration (Figure 2-10).

Table 2-5. Average monthly precipitation and temperature at station 2 (LTVCA Chatham WIN) from 2008-01-01 to 2021-12-31

| Month | T_max (°C) | T_min (°C) | T_avg (°C) | Precipitation (mm) |
|---|---|---|---|---|
| 1 | -0.211 | -7.52 | -3.87 | 36.3 |
| 2 | 0.577 | -7.47 | -3.45 | 37.4 |
| 3 | 6.48 | -2.56 | 1.96 | 59.7 |
| 4 | 13.4 | 2.67 | 8.01 | 72.9 |
| 5 | 20.6 | 9.06 | 14.8 | 83.3 |
| 6 | 25.7 | 14.7 | 20.2 | 89.3 |
| 7 | 28.0 | 16.8 | 22.4 | 113 |
| 8 | 26.7 | 15.7 | 21.2 | 70.9 |
| 9 | 23.4 | 12.3 | 17.9 | 72.9 |
| 10 | 16.2 | 6.97 | 11.6 | 81.8 |
| 11 | 8.68 | 0.931 | 4.80 | 59.3 |
| 12 | 3.15 | -3.16 | -0.002 | 46.9 |
| Ave/Sum | 14.4 | 4.87 | 9.63 | 824 |
| Max | 28.0 | 16.8 | 22.4 | 113 |
| Min | -0.211 | -7.52 | -3.87 | 36.3 |
| STDV | 10.5 | 8.94 | 9.71 | 22.4 |

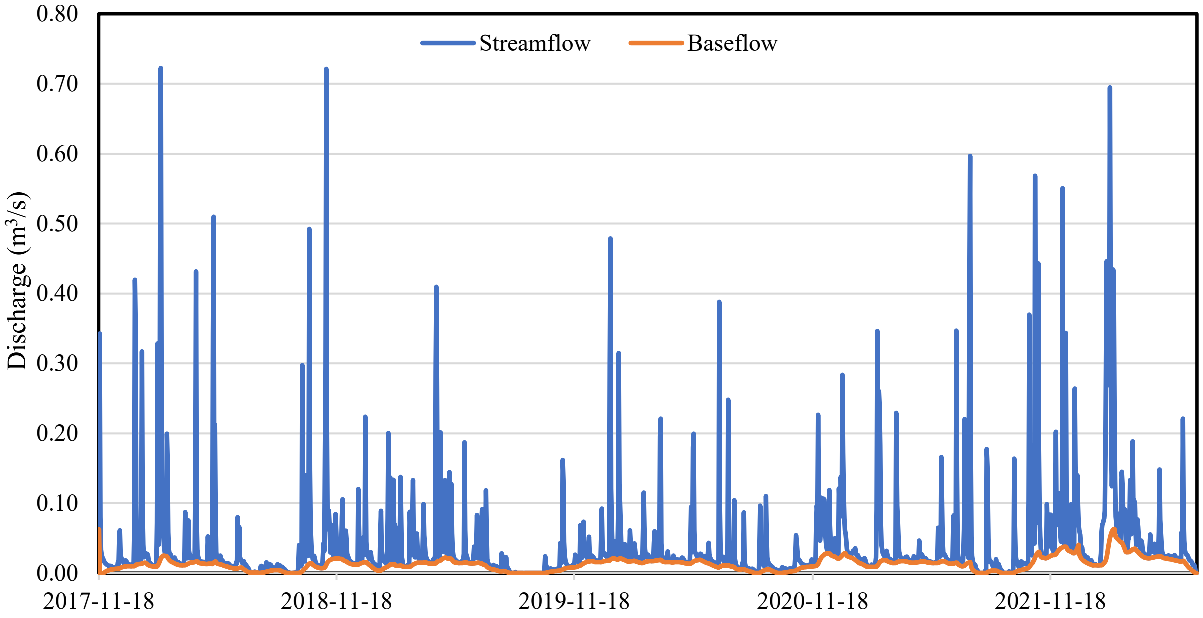

Figure 2-9. Baseflow separation at Deary Upstream station over the period of 2017 – 2022

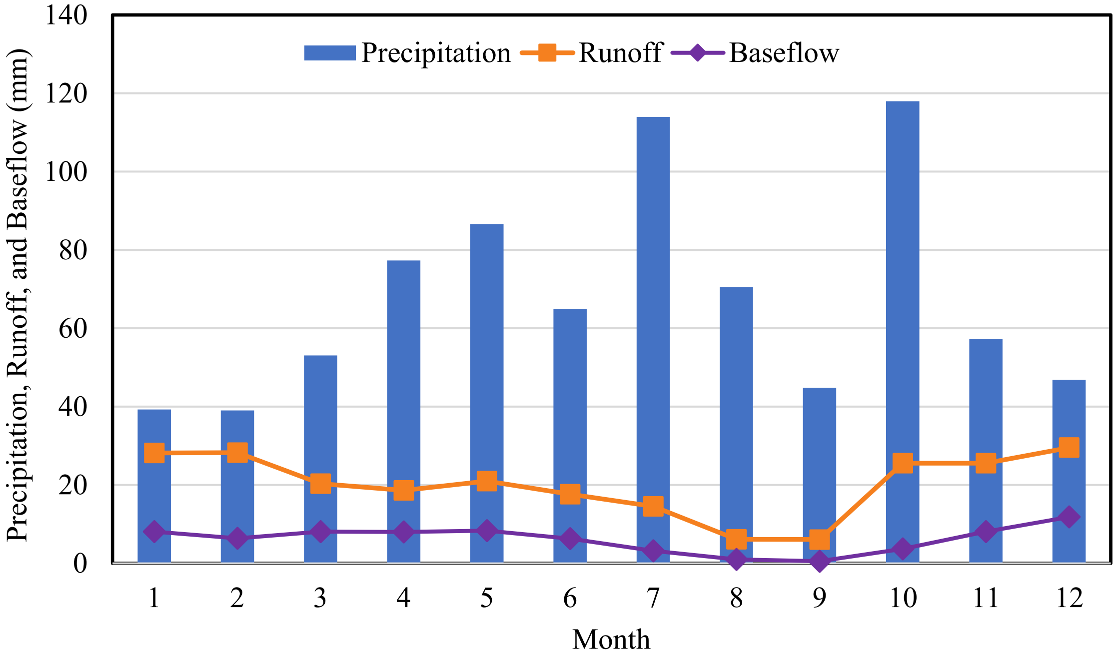

Figure 2-10. Average monthly precipitation, runoff, and baseflow at Deary Upstream station over the period of 2018 – 2021

Table 2-6. Average monthly precipitation, runoff, and baseflow at Deary Upstream station over the period of 2018 – 2021

| Month | Precipitation | Runoff | | | Baseflow | | |
|---|---|---|---|---|---|---|---|
| | (mm) | ($m^3$/s) | (mm) | (% of Precipitation) | ($m^3$/s) | (mm) | (% of Runoff) |
| 1 | 39.3 | 0.052 | 28.2 | 71.8 | 0.015 | 8.09 | 28.7 |
| 2 | 39.1 | 0.058 | 28.3 | 72.4 | 0.013 | 6.42 | 22.7 |
| 3 | 53.1 | 0.038 | 20.3 | 38.3 | 0.015 | 8.10 | 39.8 |
| 4 | 77.3 | 0.036 | 18.7 | 24.2 | 0.015 | 8.02 | 43.0 |
| 5 | 86.7 | 0.039 | 21.0 | 24.2 | 0.016 | 8.36 | 39.8 |
| 6 | 65.0 | 0.034 | 17.7 | 27.2 | 0.012 | 6.30 | 35.7 |
| 7 | 114 | 0.027 | 14.5 | 12.8 | 0.006 | 3.19 | 21.9 |
| 8 | 70.6 | 0.011 | 6.18 | 8.76 | 0.002 | 1.04 | 16.9 |
| 9 | 44.9 | 0.012 | 6.11 | 13.6 | 0.001 | 0.557 | 9.12 |
| 10 | 118 | 0.048 | 25.6 | 21.7 | 0.007 | 3.70 | 14.4 |
| 11 | 57.3 | 0.049 | 25.6 | 44.6 | 0.016 | 8.14 | 31.8 |
| 12 | 46.9 | 0.055 | 29.5 | 63.0 | 0.022 | 11.8 | 40.1 |
| Sum/Ave | 812 | 0.038 | 242 | 35.2 | 0.012 | 73.8 | 28.7 |
| Max | 118 | 0.058 | 29.5 | 72.4 | 0.022 | 11.8 | 43.0 |
| Min | 39.1 | 0.011 | 6.11 | 8.76 | 0.001 | 0.557 | 9.12 |
| STDV | 27.0 | 0.015 | 8.04 | 22.9 | 0.006 | 3.37 | 11.5 |

# 3.0 DATA COLLECTION AND PREPARATION

## 3.1 GIS Data

Geospatial data required for IMWEBs model setup include topography, soil, landuse, stream network, and others (Table 3-1). These data were prepared using data from LTVCA, OMAFRA, and other sources.

Table 3-1. GIS data available for the Jeannette's Creek subwatershed

| Data | Format | Source | Use |
|---|---|---|---|
| LiDAR DEM (1x1 m) | TIFF | UoG WEG | Model setup |
| Soil | Shape | OMAFRA | Model setup |
| Land use | Shape | LTVCA & Rudra et al. (2019) | Model setup |
| Crop inventory 2011-2021 | TIFF (30x30 m) | AAFC & LTVCA | Crop rotation |
| Stream network | Shape | LTVCA | Watershed delineation |
| Boundary | Shape | LTVCA | Watershed delineation |
| Existing BMPs | Shape | LTVCA | Model setup |
| Climate, flow, and water quality stations | Shape | LTVCA, ECCC, NASA | Model setup |
| Field boundary | Shape | LTVCA | Model setup |
| Tile drain | Shape | OMAFRA | Model setup |
| Transportation | Shape | MNRF | Presentation purpose |

Note: LTVCA stands for Lower Thames Valley Conservation Authority, UoG WEG stands for University of Guelph Watershed Evaluation Group, OMAFRA stands for Ontario Ministry of Agriculture, Food and Rural Affairs, AAFC stands for Agriculture and Agri-Food Canada, ECCC stands for Environment and Climate Change Canada, NASA stands for National Aeronautics and Space Administration, and MNRF stands for Ministry of Natural Resources and Forestry.

## 3.2 Climate Data

The IMWEBs requires daily precipitation, minimum temperature, maximum temperature, relative humidity, wind speed, wind direction, and solar radiation as input for the model. Climate data were prepared for 1970-01-01 to 2022-06-30 using LTVCA, ECCC, and NASA climate data. See section 2.3 for more details on the climate data.

## 3.3 Flow and Water Quality Data

Data used in IMWEBs model calibration includes stream flow (discharge), sediment concentration and load, and nutrient (nitrogen and phosphorus) concentration and load at a daily scale. These data were prepared from LTVCA monitoring stations (Table 3-2). The locations of these stations are shown in Figure 3-1.

Table 3-2. Water Quality and Flow monitoring stations within the Jeannette’s Creek subwatershed

| Name | Description | Drainage Area (km$^2$) | Flow | Sediment | Nutrient |
|---|---|---|---|---|---|
| Deary Pump Station | Pump station site | 6.96 | 2017 - 2022 | 2016 - 2022 | 2016 - 2022 |
| Boudreau Pump Station | Pump station site | 1.44 | 2016 - 2022 | 2016 - 2022 | 2016 - 2022 |
| Dauphin Pump Station | Pump station site | 8.77 | 2016 - 2022 | 2016 - 2022 | 2016 - 2022 |
| Dauphin Upstream | Grab sample site | 4.74 | - | 2016 - 2022 | 2016 - 2022 |
| Boudreau Upstream | Grab sample site | 1.32 | - | 2016 - 2022 | 2016 - 2022 |
| Deary Upstream | Main stream | 4.97 | 2017 - 2022 | 2016 - 2022 | 2016 - 2022 |
| MerlinA Plot 2 Tile | Edge of field site | 0.342 | 2017 - 2022 | 2017 - 2022 | 2017 - 2022 |
| MerlinA Plot 3 Tile | Edge of field site | 0.088 | 2017 - 2022 | 2017 - 2022 | 2017 - 2022 |
| MerlinA Surface | Edge of field site | 0.342 | 2019 - 2022 | 2019 - 2022 | 2019 - 2022 |
| MerlinB Plot 1 Tile | Edge of field site | 0.055 | 2017 - 2022 | 2017 - 2022 | 2017 - 2022 |
| MerlinB Plot 2 Tile | Edge of field site | 0.312 | 2017 - 2022 | 2017 - 2022 | 2017 - 2022 |
| MerlinB Surface | Edge of field site | 0.312 | 2021 - 2022 | 2021 - 2022 | 2021 - 2022 |

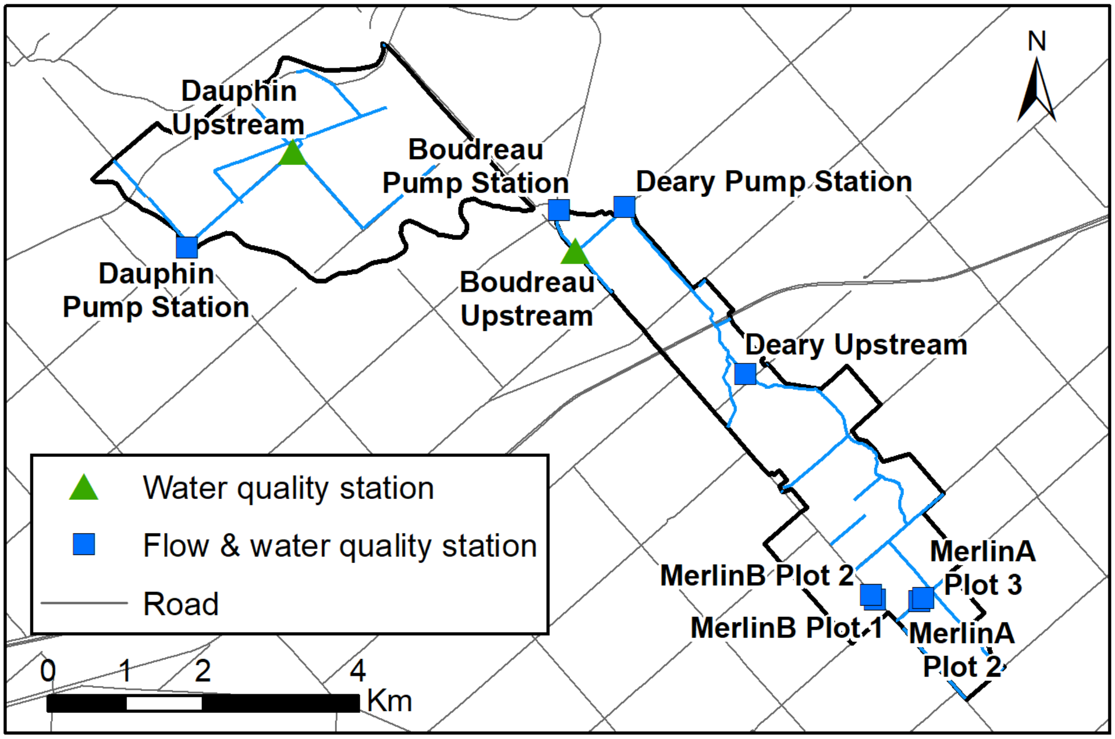

Figure 3-1. Flow and water quality monitoring stations in the Jeannette's Creek subwatershed

### 3.4 Land Management Data

LTVCA staff conducted land management surveys for the ONFARM project in 2022. Table 3-3 describes the key parameters included in the land management dataset. LTVCA staff also collected windshield surveys including the GLASI survey for several years in 2015 – 2021 that describe the crop grown, spring tillage type, fall tillage type, and the presence of an overwintering cover crop. AAFC annual crop inventories were used to fill any gaps that existed after compiling the ONFARM land management survey and the windshield surveys. These datasets were combined to establish a land management database spanning 2011 – 2021 for the Jeannette's Creek subwatershed IMWEBs modelling. Figure 3-2 shows the field boundary layer used for the collection of land management data.

Table 3-3. Land management parameters surveyed under the ONFARM program in the Jeannette's Creek subwatershed.

| Items | Description |
|---|---|
| Land features | Land ID, area and physical location |
| Crop | Crop name |
| Fall tillage | Tillage type, number of tillage passes, and date for each tillage pass |
| Spring tillage | Tillage type, number of tillage passes, and date for each tillage pass |
| Planting | Seeding week and month |

| | |
|---|---|
| Harvest | Harvest week and month |
| Straw management | Type of straw management, crop residue after straw management |
| Fertilizer, Nitrogen | Rate and date applied, and how applied |
| Fertilizer, Phosphate | Rate and date applied, and how applied |
| Manure | Manure type, rate and date applied, and how applied |
| Tile drainage | Tile drain type, spacing, and depth |

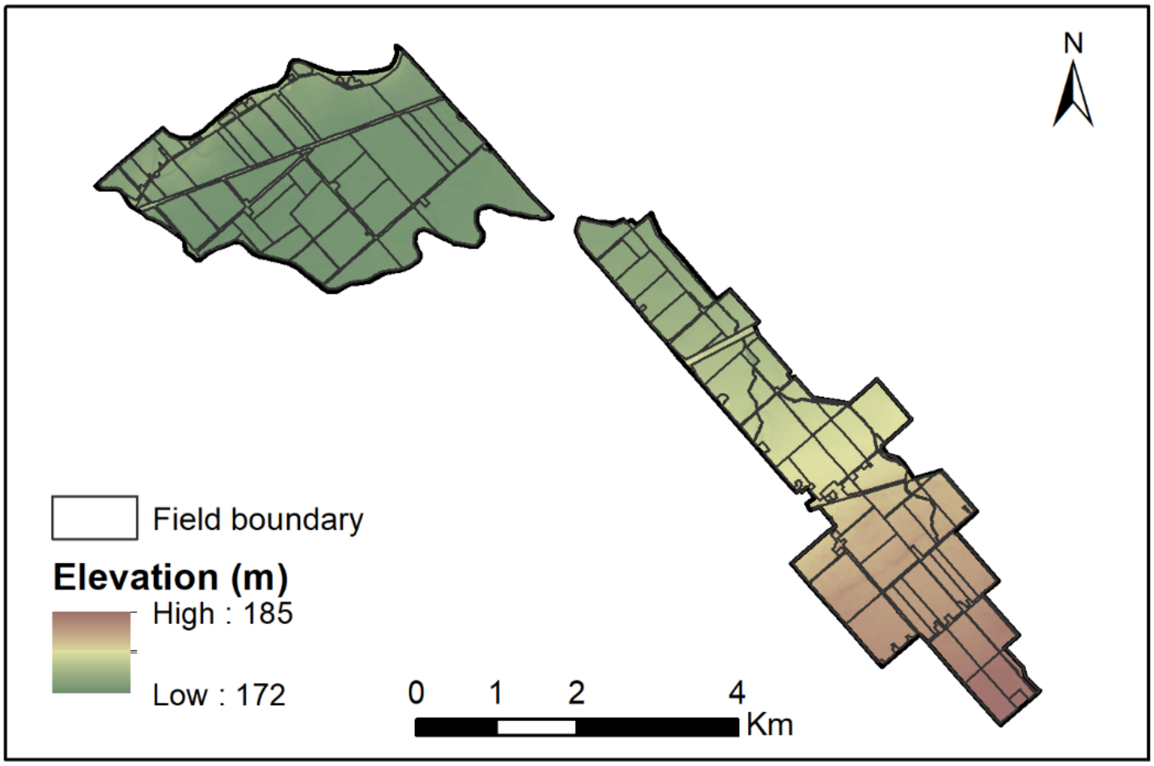

Figure 3-2. Field boundaries for the Jeannette's Creek subwatershed IMWEBs modelling

### 3.5 Existing BMPs

There was one existing riparian buffer described by Rudra et al. (2019), which was included in the Jeannette's Creek subwatershed IMWEBs model. Figure 3-3 shows the location of the existing riparian buffer.

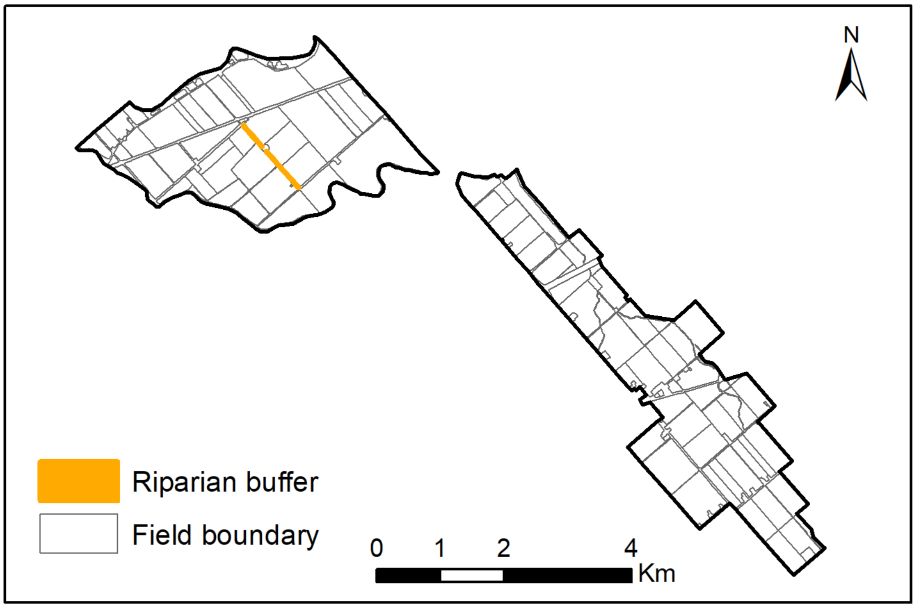

Figure 3-3. Existing riparian buffer in the Jeannette's Creek subwatershed

# 4.0 IMWEBS MODEL SETUP

## 4.1 Overview of the IMWEBs model

The Integrated Modelling for Watershed Evaluation of BMPs (IMWEBs) tool, developed by the Watershed Evaluation Group (WEG) of the University of Guelph with funding from Agriculture and Agri-Food Canada, Environment and Climate Change Canada, Alberta Agriculture and Forestry, Alberta Environment and Parks, Alberta Innovates, ALUS, and other organizations, is a cell-based hydrologic model specifically designed for conducting location-specific BMP assessment. The IMWEBs spatial units are further aggregated from cells to subareas in order to reduce computational time for model simulation while maintaining detailed characterization of land management practices and BMPs. The subarea layer can be defined by intersecting the farm field boundary layer with the subbasin layer and other layers such as slope class and soil type layers, if necessary. Similar to SWAT/CanSWAT, a relatively coarse resolution can be made of the watershed for the purpose of characterizing BMPs in the context of large watersheds. What is unique about the IMWEBs tool, however, is that it has a cell-based and subarea-based structure, rather than a subbasin/HRU structure, allowing the potential for landscape features including agricultural lands, wetlands, and riparian buffers to be partitioned by fine-resolution grid cells and subareas, enabling location-specific representation within the model. The IMWEBs model is a fully-fledged hydrologic model with characterization of landscape processes including climate, water balance, plant/crop growth, as well as sediment and nutrient fate. The IMWEBs is the only model in Canada that is designed for evaluating water quantity and quality effects of agricultural BMPs over a variety of modelling scales from the site, field, and farm to the watershed scales.

## 4.2 Watershed delineation

The IMWEBs model uses the Digital Elevation Model (DEM) and stream network to delineate the watershed boundary. The watershed was delineated by burning the stream network into the DEM to ensure accurate flow routing. The flow and water quality monitoring stations were specified as subbasin outlets. The stream initiation threshold was set to 5 ha, in order to delineate subbasins for the monitoring stations with the smallest contributing areas. Figure 4-1 shows the delineated watershed for the Jeannette's Creek subwatershed IMWEBs modelling, which contains 267 subbasins.

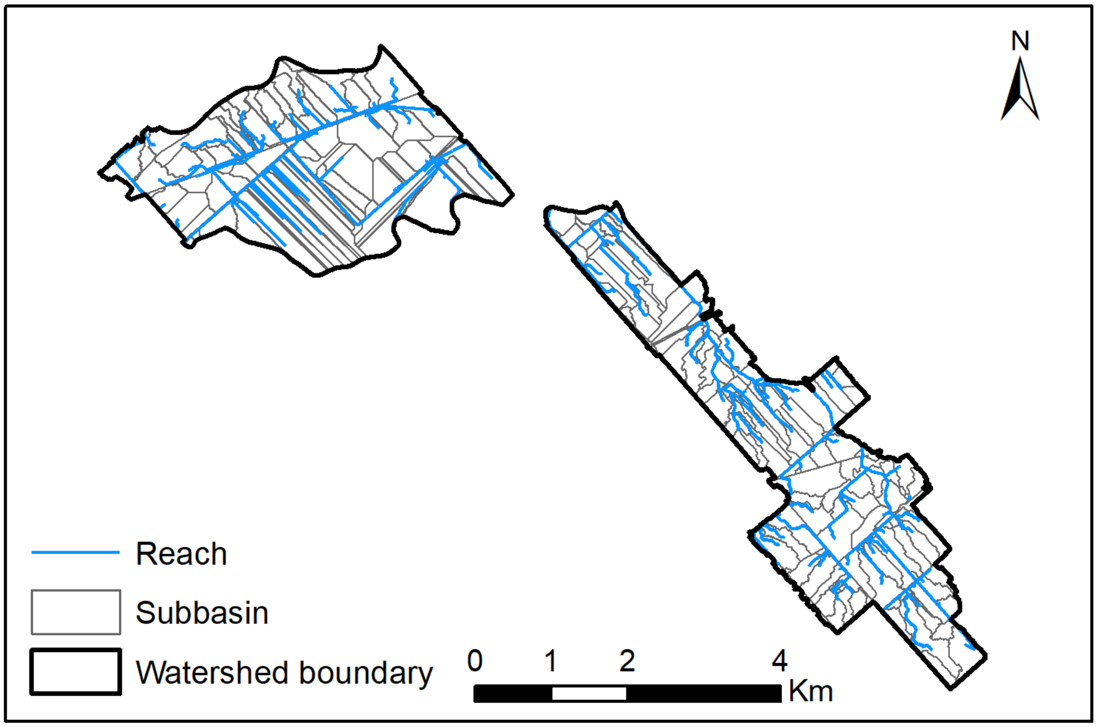

Figure 4-1. Delineated watershed boundary, subbasins, and reaches for the Jeannette's Creek subwatershed IMWEBs modelling

### 4.3 Soil characterization

Soil properties are important factors in controlling infiltration and soil water movement, and play a key role in surface runoff, groundwater recharge, evapotranspiration, soil erosion, and the transport of chemicals. The OMAFRA Soil Survey Complex was used to define soil type distribution and key soil parameters for the Jeannette's Creek subwatershed IMWEBs modelling. A summary of soil characterization for the Jeannette's Creek subwatershed IMWEBs modelling is provided in Table 2-2.

### 4.4 Landuse characterization

The IMWEBs model has a detailed land cover classification including 98 plant types and eight urban landuses. For the Jeannette's Creek subwatershed, a total of six distinct landuse types were identified based on the landuse data. The landuse types and associated areas and percentages within the Jeannette's Creek subwatershed are listed in Table 2-3.

### 4.5 Subarea definition

The IMWEBs model uses subareas to reduce the computer processing times associated with the cell-based IMWEBs model. Subareas are the smallest management unit for defining land management operations and structural BMPs. The subarea layer was created by intersecting the field boundary layer with the subbasin layer. Figure 4-2 presents the subarea layer for the Jeannette's Creek subwatershed modelling, which contains 1,388 subareas.

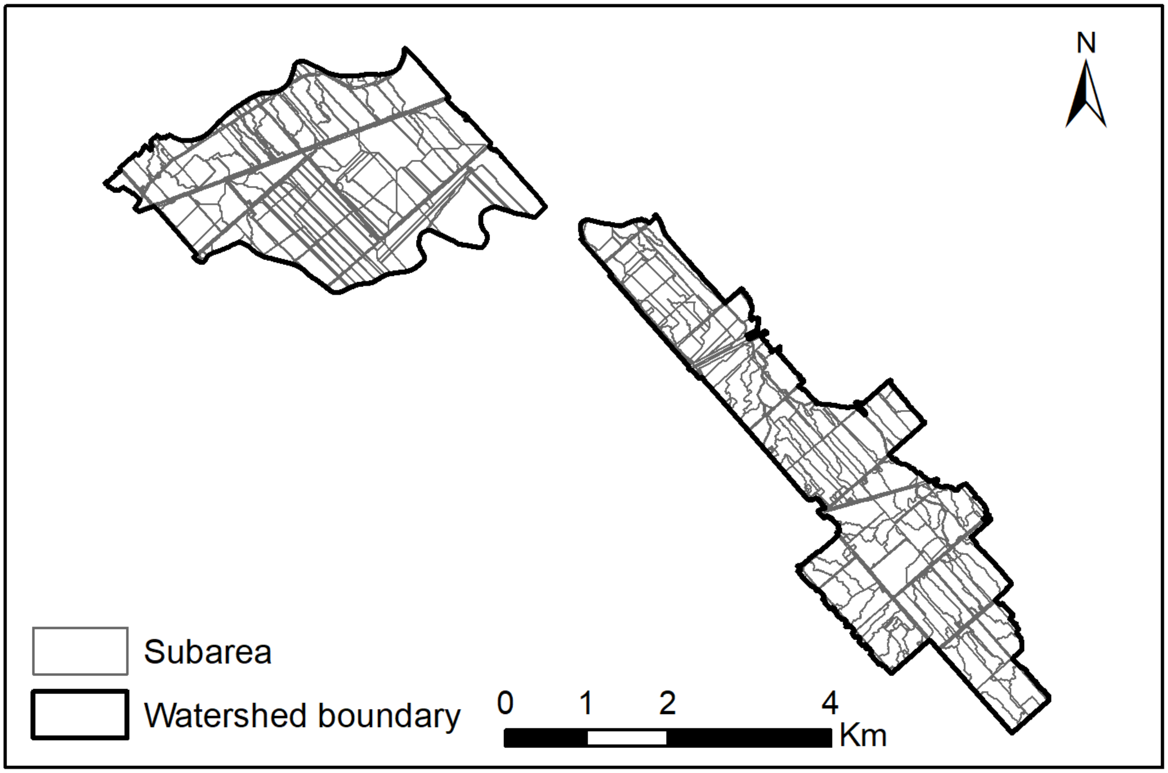

Figure 4-2. Subarea layer for the Jeannette’s Creek subwatershed IMWEBs modelling

### 4.6 Land management operations

Land management operations are a critical input for the IMWEBs model. Land management operations affect plant growth, nutrient availability, and nutrient and sediment transport throughout the watershed. LTVCA staff conducted ONFARM and GLASI land management surveys and windshield surveys in the Jeannette’s Creek subwatershed, which were used to establish an 11-year land management dataset spanning from 2011 – 2021. Table 3-3 describes the key parameters included in the land management dataset.

### 4.7 Tile drain characterization

All fields were assumed to be tile drained in the Jeannette’s Creek subwatershed based on information provided by LTVCA. The ONFARM land management survey contained tile drain spacing and tile depth data, which were incorporated into the IMWEBs model. For fields that did not have tile drain spacing and depth data listed in the survey, the dominant depth and spacing from the survey was assumed. Table 4-1 presents tile drain parameters for the Jeannette’s Creek subwatershed, including the ONFARM survey data on tile radius, spacing, and dominant tile spacing and tile depth for each smaller subwatershed. Note that we also added the parameters for simulating controlled tile drain in IMWEBs setup which include start and end months for controlled tile drain and depth of controlled tile drain.

Table 4-1. Tile drain parameters for the Jeannette's Creek subwatershed IMWEBs modelling.

| Subwatershed | Start month for controlled tile drain | End month | Radius (mm) | Spacing (mm) | Tile drain depth (mm) | Controlled tile drain depth (mm) |
|---|---|---|---|---|---|---|
| Dauphin | April | October | 50 | 9,754 | 762 | 500 |
| Deary & Boudreau | April | October | 50 | 6,096 | 610 | 500 |

### 4.8 Reservoir characterization

Because the Thames River flows at a higher grade than the surrounding landscape in the Jeannette's Creek subwatershed, there are three pumping station outlets, the Dauphin outlet, Deary outlet, and Boudreau outlet, which are used to move water from the municipal drain network to the watercourse. The pumping stations service their respective upstream canal or ditch system, and each canal/ditch can be considered as a reservoir with pumping the primary means for generating outflow from these reservoirs. The pumping stations have been manually operated historically. The Dauphin and Deary pumping stations, however, were recently outfitted with automatic pumping infrastructure. Given that flow leaving the watershed is dictated by the operation of the pump schemes, the Jeannette's subwatershed is a particularly challenging system to model with standard hydrologic modelling tools. To represent these unique pumping station outlets, the IMWEBs reservoir module with target release method was used. The target release method triggers reservoir outflow as a function of the desired target storage. The target release approach tries to mimic general release rules that may be used by reservoir operators. Although this approach is relatively simplistic and cannot account for all decision criteria made by the real-world system operators or automatic pump trigger systems, it can realistically simulate major outflow and low flow periods.

LTVCA provided pump station depth and outflow data which were used to define monthly maximum daily flow and monthly target volume discharges for each reservoir (Table 4-2, Table 4-3). LTVCA staff estimated the length of canal that generally holds ponding water. This information was used in conjunction with engineering design reports to estimate the reservoir surface area and water storage volume at principal water levels and at the water level matching each ditch/reservoir's emergency spillway (Table 4-4).

Table 4-2. Monthly maximum daily flow for the Dauphin, Deary, and Boudreau pump station outlets.

| Pump station name | Maximum average daily outflow ($m^3/s$) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Dauphin | 0.689 | 1.009 | 0.720 | 0.823 | 0.863 | 0.599 | 0.330 | 0.142 | 0.113 | 0.624 | 0.505 | 0.511 |
| Boudreau | 0.098 | 0.110 | 0.117 | 0.083 | 0.097 | 0.048 | 0.037 | 0.019 | 0.041 | 0.057 | 0.081 | 0.097 |
| Deary | 0.498 | 0.372 | 0.617 | 0.567 | 0.702 | 0.121 | 0.229 | 0.047 | 0.113 | 0.258 | 0.462 | 0.295 |

Table 4-3. Monthly target reservoir volume for the Dauphin, Deary, and Boudreau pump station outlets.

| Pump station name | Target reservoir volume ($10^4$ $m^3$) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Dauphin | 11.6 | 13.8 | 13.9 | 14.1 | 12.7 | 12.8 | 13.7 | 13.8 | 14.3 | 13.5 | 9.2 | 10.2 |
| Boudreau | 0.250 | 0.280 | 0.274 | 0.279 | 0.273 | 0.283 | 0.284 | 0.304 | 0.324 | 0.356 | 0.295 | 0.283 |
| Deary | 2.13 | 1.90 | 1.66 | 1.60 | 1.60 | 2.04 | 1.95 | 2.28 | 1.93 | 2.06 | 1.77 | 1.75 |

Table 4-4. Surface area and volume at principal and emergency spillway for the Dauphin, Deary, and Boudreau pump station outlets.

| Pump station name | Surface area at emergency spillway (ha) | Volume at emergency spillway ($10^4$ $m^3$) | Surface area at principal water levelspillway (ha) | Volume at principal water level ($10^4$ $m^3$) |
|---|---|---|---|---|
| Dauphin | 6.69 | 30.1 | 6.08 | 21.2 |
| Boudreau | 0.265 | 1.50 | 0.241 | 1.12 |
| Deary | 1.59 | 7.40 | 1.45 | 5.28 |

## 5.0 IMWEBs MODEL CALIBRATION

### 5.1 Overview of IMWEBs model calibration

Calibrating the IMWEBs model involves adjusting model inputs and parameters to optimize the agreement between measured data and model simulation results for realistically characterizing watershed historical/existing observed conditions. A simulation period of 2016 to 2022 was used for model calibration. Observed data from the Dauphin Pumping Station (DauphinPS), Boudreau Pumping Station (BoudreauPS), Deary Pumping Station (DearyPS) and Deary Upstream (DearyUP) streamflow monitoring site were used for flow calibration. Observed data from the four sites and also the Dauphin Upstream (DauphinUP) and Boudreau Upstream (BoudreauUP) water quality monitoring sites were used for water quality calibration. The water quality data collected at the other stations were used as reference during model calibration. The model was calibrated firstly for flow; followed by sediment, particulate P, and particulate N; and lastly dissolved P and dissolved N.

IMWEBs calibration was evaluated graphically and also statistically based on three indicators, Nash–Sutcliffe coefficient (NSC), Percent bias (PBIAS), and correlation coefficient (CORR). The Nash-Sutcliffe coefficient (Nash and Sutcliffe, 1970) describes how well the model simulates the observed values and is calculated by comparing the variance of the differences between simulated and observed values to the variance of observed values.

$$NSC = 1 - \sum_{i=1}^{N}(Qo_i - Qs_i)^2 \Big/ \sum_{i=1}^{N}\left(Qo_i - \overline{Qo}\right)^2$$

where NSC is the Nash-Sutcliffe efficiency, $Qoi$ and $Qs_i$ and are the observed and simulated values on day i (m$^3$/s), $\overline{Qo}$ is the mean of observed values, and N is the number of days over the simulation period. The NSC value can range from a negative value to 1. A NSC value below zero indicates that average measured stream flow would have been a better predictor of stream flow than that predicted by the model. A perfect model prediction has NSC value of 1 with higher positive value indicating better match of simulated flow with observed flow. PBIAS measures the relative mean difference between predicted and observed values.

$$PBIAS = \sum_{i=1}^{N}(Qo_i - Qs_i) * 100 \Big/ \sum_{i=1}^{N} Qo_i$$

The optimal value of PBIAS is 0.0, with lower values indicating more accurate model simulation. Positive values indicate model underestimation bias, and negative values indicate model overestimation bias. CORR measures the degree of dependence of one variable upon another.

$$CORR = \frac{\sum_{i=1}^{n}\left(Qo_i - \overline{Qo}\right)\left(Qs_i - \overline{Qs}\right)}{\sqrt{\sum_{i=1}^{n}\left(Qo_i - \overline{Qo}\right)^2 \sum_{i=1}^{n}\left(Qs_i - \overline{Qs}\right)^2}}$$

Where $\overline{Qo}$ and $\overline{Qs}$ are means of observed and simulated values. A higher CORR indicates a higher correlation between observed and simulated values. In contrast to continuous flow monitoring data, most Total Suspend Solid (TSS), Nitrogen(N) and Phosphorus (P) monitoring data have limited samples, which are not suitable for calculating NSC. Therefore, only PBIAS and CORR are used for measuring the performance on IMWEBs calibration of TSS, N and P.

## 5.2 Flow calibration

We conducted flow calibration for three drain outlet monitoring sites (DauphinPS, BoudreauPS, DearyPS) and the one upstream streamflow monitoring site (DearyUP). Observed flow data from other monitoring sites were used as further reference data. Table 5-1 presents the parameters used for water balance and flow routing calibration and Table 5-2 lists the performance statistics for flow calibration at the four major monitoring sites. Figures 5-1, 5-2, 5-3, and 5-4 show the graphs of measured vs. simulated flow at the four major monitoring sites. A satisfactory flow calibration was achieved at the four major monitoring sites resulting in a NSC of 0.49 to 0.75, a model bias of -16.0% to 16.0%, and a CORR of 0.45 to 0.65 based on the criteria outlined in Moriasi et. al (2007).

Table 5-1 Calibrated water balance and flow routing parameters for the Jeannette's Creek Subwatershed IMWEBs model

| Parameter | Definition | Value |
|---|---|---|
| **runoff_co** | Potential runoff coefficient | 0.15* |
| **K_pet** | Correction factor for PET | -0.46 |
| **Surface_lag** | Surface lag coefficient | -0.1 |
| **kg** | Baseflow recession coefficient | 0.075 |
| **base_ex** | Baseflow recession exponent | 0.5 |
| **gwmax** | Maximum groundwater storage | 100 |
| **gw0** | Initial groundwater storage, DEEPST | 100 |
| **Moist_in** | Initial soil moisture | 0.15* |
| **K_run** | Runoff exponent when net rainfall approaches to zero | -1.5 |
| **P_max** | Maximum rainfall intensity | -15 |
| **soil_ta0** | Empirical coefficient for estimating soil temperature | 0.0 |
| **T_Snow** | Snowfall temperature, SFTMP | -1.5 |
| **T0** | Snowmelt temperature | -3.5 |
| **swe0** | Initial snow water equivalent | 30 |
| **K_rain** | Rainfall impact factor | -1.5 |
| **SHC_crop** | Snow holding capacity of cropland | 10 |
| **s_frozen** | Frozen moisture relative to porosity with no infiltration | -0.45 |
| **t_soil** | Soil freezing temperature | 1.5 |

[*] Ratio of relative parameter change, e.g. porosity_layer1 modified = porosity_layer1-0.13× porosity_layer1

Table 5-2. Model performance for flow simulation at four major monitoring sites in the Jeannette's Creek subwatershed

| **Station** | **Period** | **NSC** | **PBIAS** | **CORR Monthly NSC** |
|---|---|---|---|---|
| DauphinPS | 2016-2022 | 0.58 | 16.0% | 0.48 |
| BoudreauPS | 2016-2022 | 0.57 | -16.0% | 0.65 |
| DearyPS | 2017-2022 | 0.75 | 0.34% | 0.62 |
| DearyUP | 2017-2022 | 0.49 | -6.51% | 0.45 |

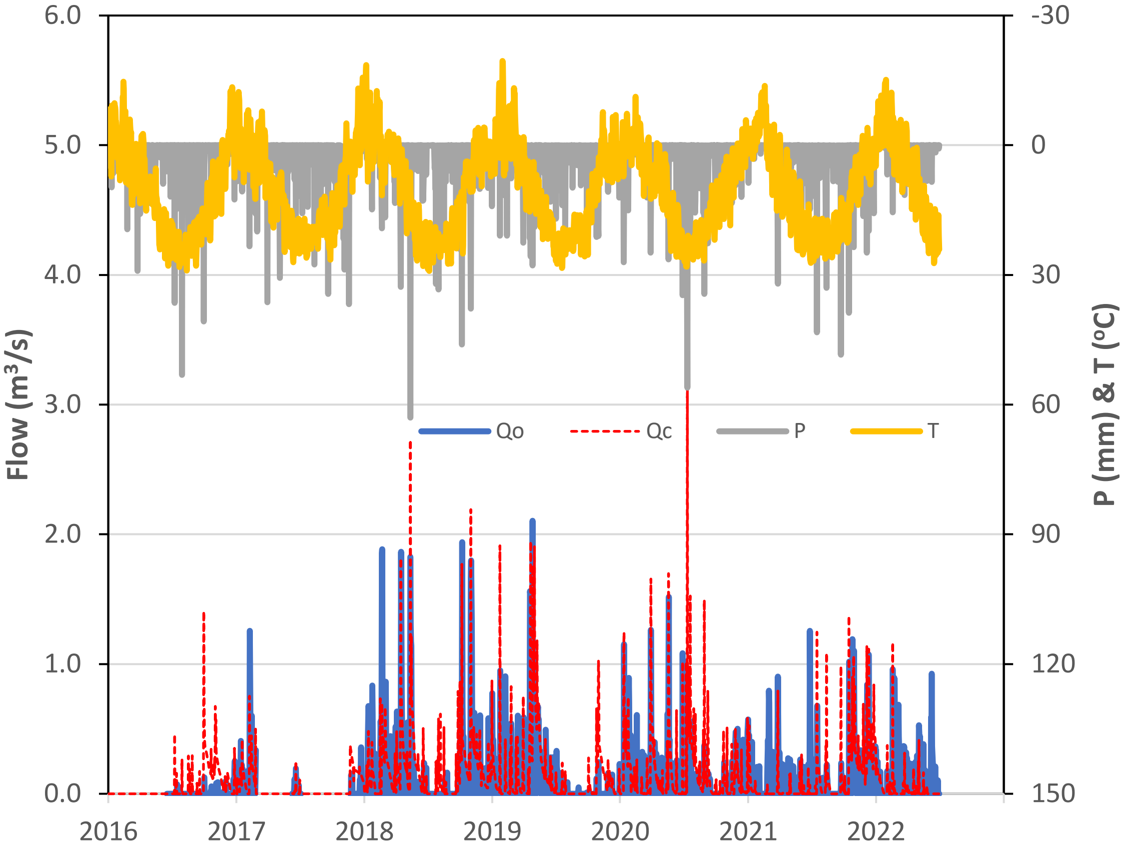

Figure 5-1. Measured vs. simulated flow at the DauphinPS site

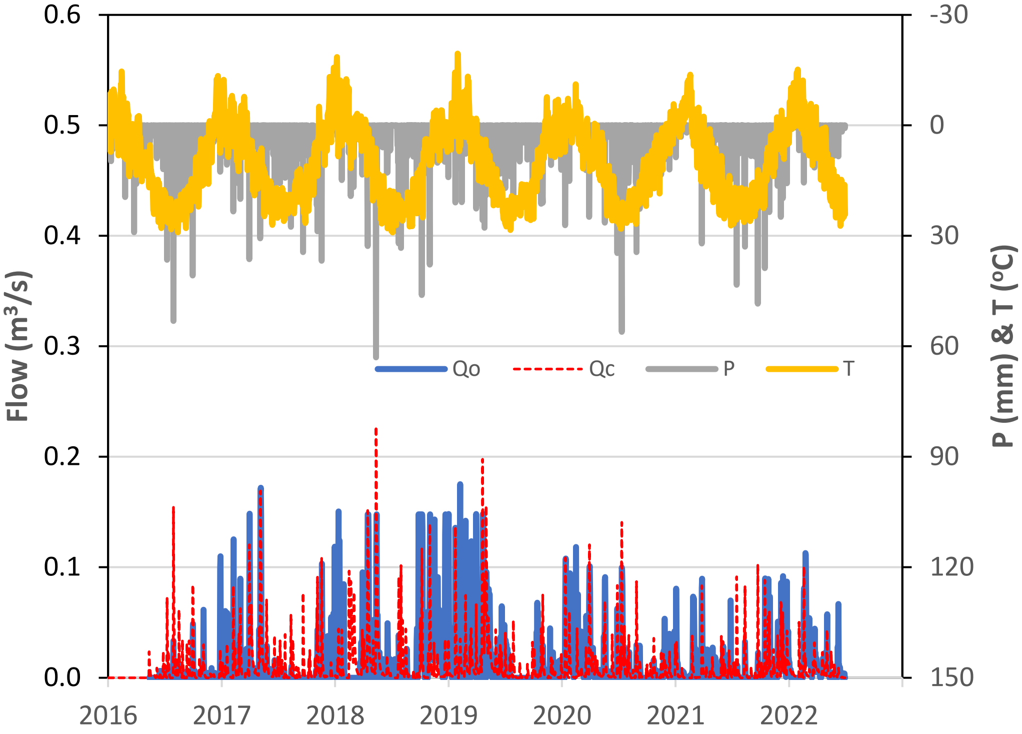

Figure 5-2. Measured vs. simulated flow at the BoudreauPS site

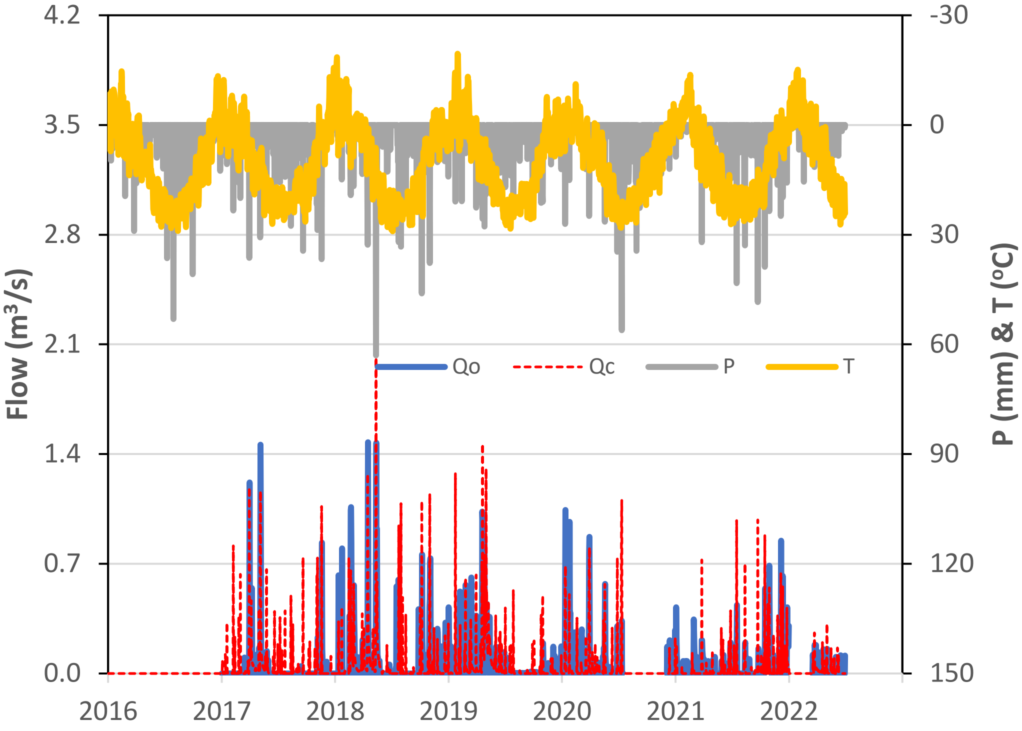

Figure 5-3. Measured vs. simulated flow at the DearyPS site

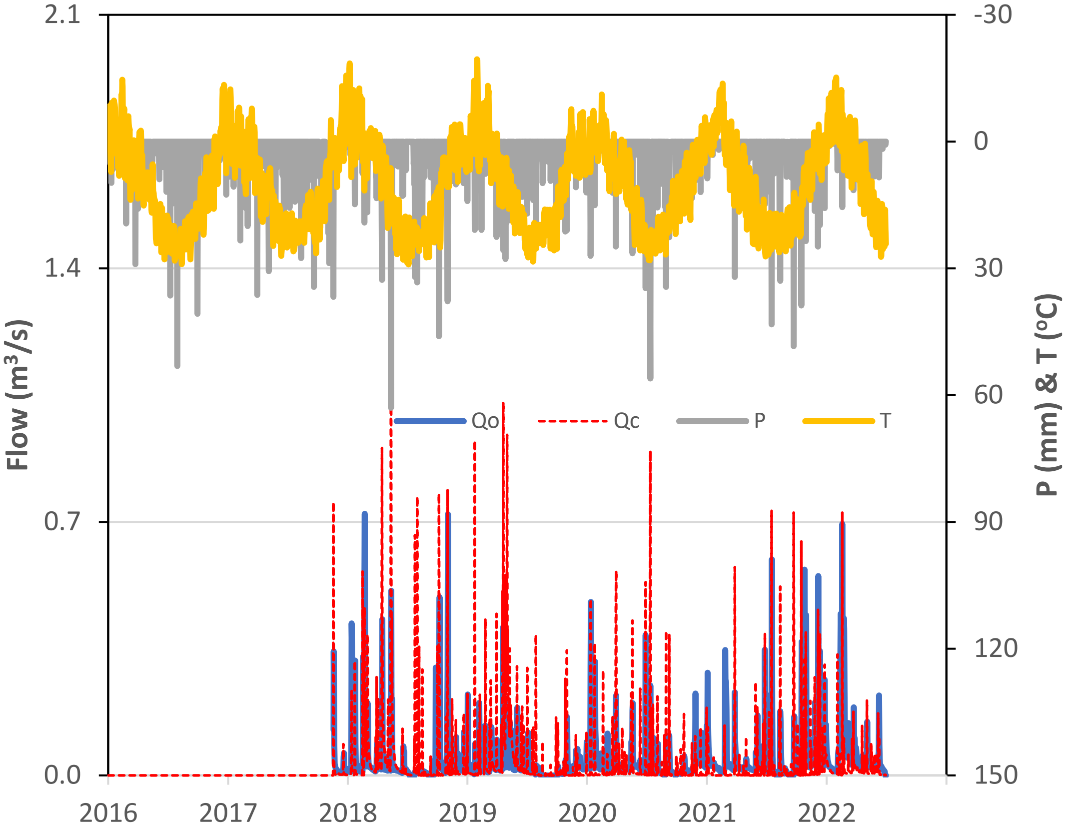

Figure 5-4. Measured vs. simulated flow at the DearyUP site

## 5.3 Sediment calibration

Sediment load/concentration calibration was completed for six major water quality monitoring sites: DauphinPS (load), DauphinUP (concentration), BoudreauPS (load), BoudreauUP (concentration), DearyPS (load), and DearyUP (load), and the observed data from other water quality monitoring sites were used as references. Load calibration was conducted when both observed flow and concentration data were available and concentration calibration was conducted when only observed concentration data were available. Table 5-3 presents the parameters adjusted for soil erosion and sediment transport calibration and Table 5-4 lists the performance statistics for sediment concentration load calibration at the six major monitoring sites. Figures 5-5, 5-6, 5-7, 5-8, 5-9 and 5-10 show the graphs of measured vs. simulated sediment load/concentration at the six major monitoring sites. A satisfactory to acceptable sediment load/concentration calibration was achieved at the six major monitoring sites resulting in a model bias of -24.3% to 57.7%, and a CORR of 0.30 to 0.74 based on the criteria outlined in Moriasi et. al (2007).

Table 5-3. Calibrated soil erosion and sediment transport parameters for the Jeannette's Creek Subwatershed IMWEBs model

| Parameter | Definition | Value |
|---|---|---|
| **USLE_K_layer1** | K-factor for MUSLE | -0.07* |
| **USLE_C** | C-factor for MUSLE | -0.07* |
| **USLE_P** | The erosion control practice factor | -0.15* |
| **spexp** | Exponent in sediment transport equation | 1.0 |
| **spcon** | Coefficient in sediment transport equation | 0.1 |
| **vcrit** | Critical velocity for sediment deposition | -0.1 |

Note: * ratio of relative parameter change, e.g. USLE_C modified = USLE_C-0.07×USLE_C

Table 5-4. Model performance for sediment load/concentration simulation at six major monitoring sites in the Jeannette's Creek subwatershed

| Station | Period | PBIAS | CORR Monthly NSC |
|---|---|---|---|
| DauphinPS (load) | 2016-2020 | 5.4% | 0.66 |
| DauphinUP (concentration) | 2016-2020 | 57.7% | 0.52 |
| BoudreauPS (load) | 2016-2020 | -16.2% | 0.39 |
| BoudreauUP (concentration) | 2016-2020 | 23.6% | 0.53 |
| DearyPS (load) | 2016-2020 | -24.3% | 0.30 |
| DearyUP (load) | 2018-2020 | 14.5% | 0.74 |

Note: Calibration using load when both observed flow and concentration data were available. Calibration using concentration when only concentration data were available.

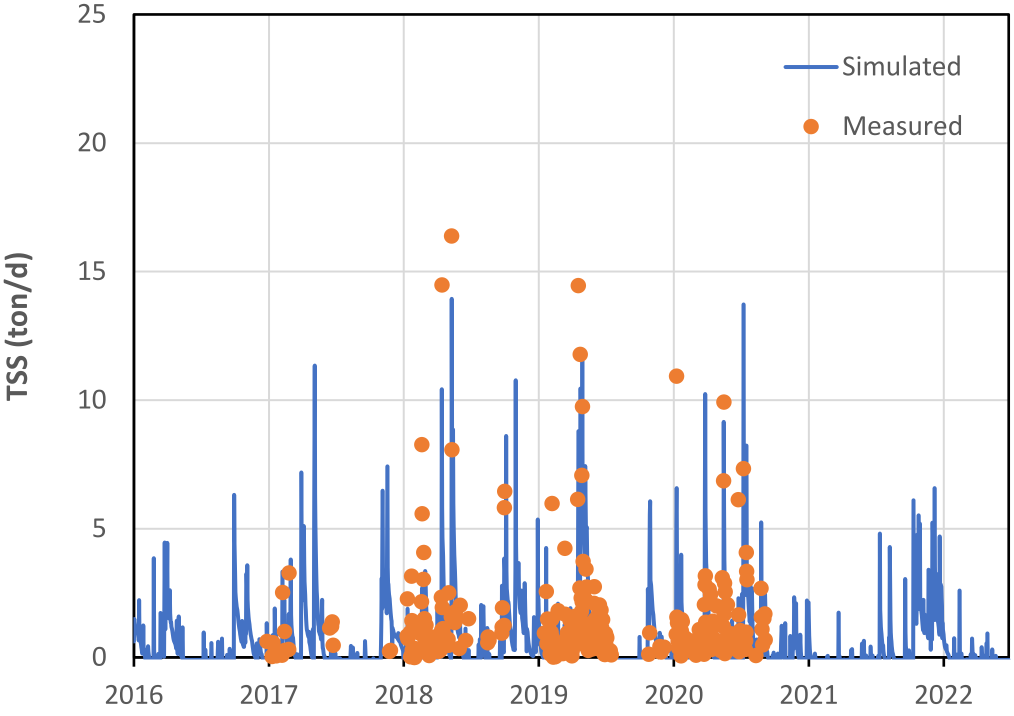

Figure 5-5. Measured vs. simulated sediment load at the DauphinPS site

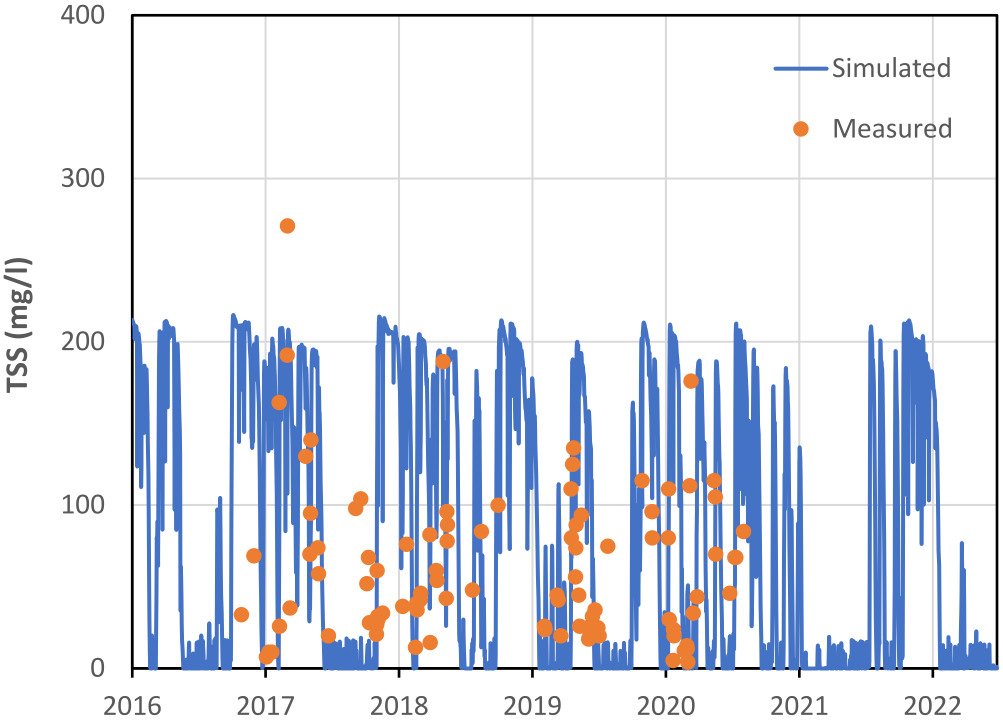

Figure 5-6. Measured vs. simulated sediment concentration at the DauphinUP site

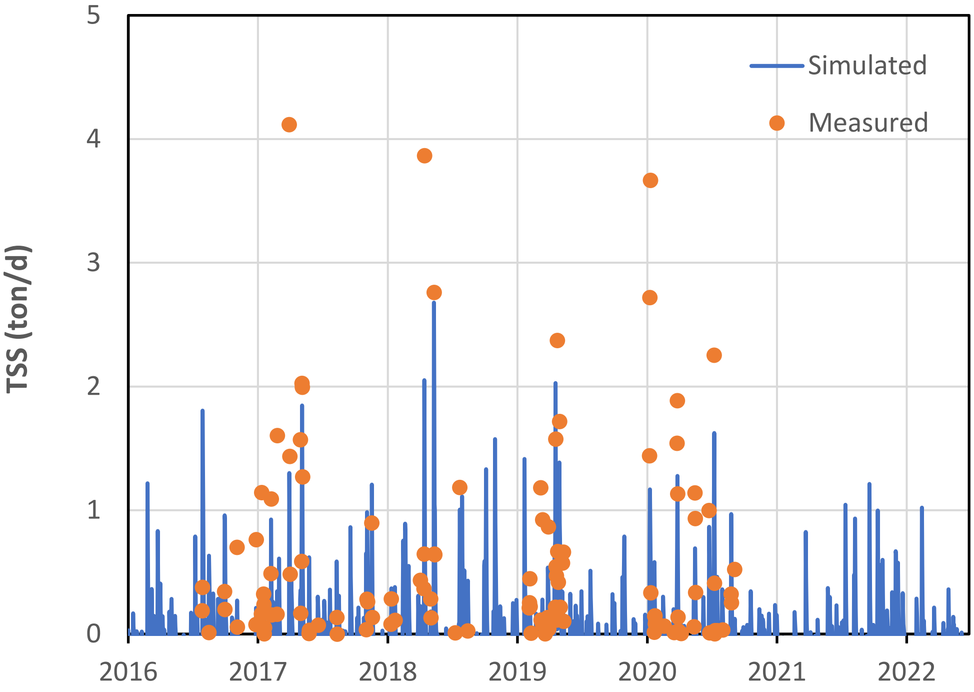

Figure 5-7. Measured vs. simulated sediment load at the BoudreauPS site

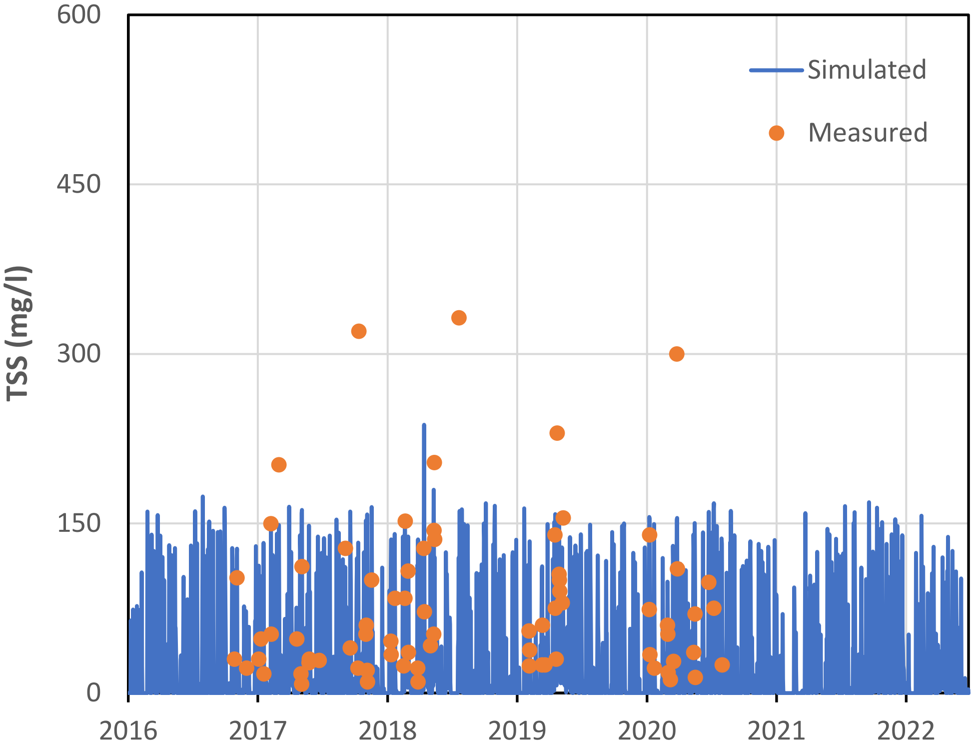

Figure 5-8. Measured vs. simulated sediment concentration at the BoudreauUP site

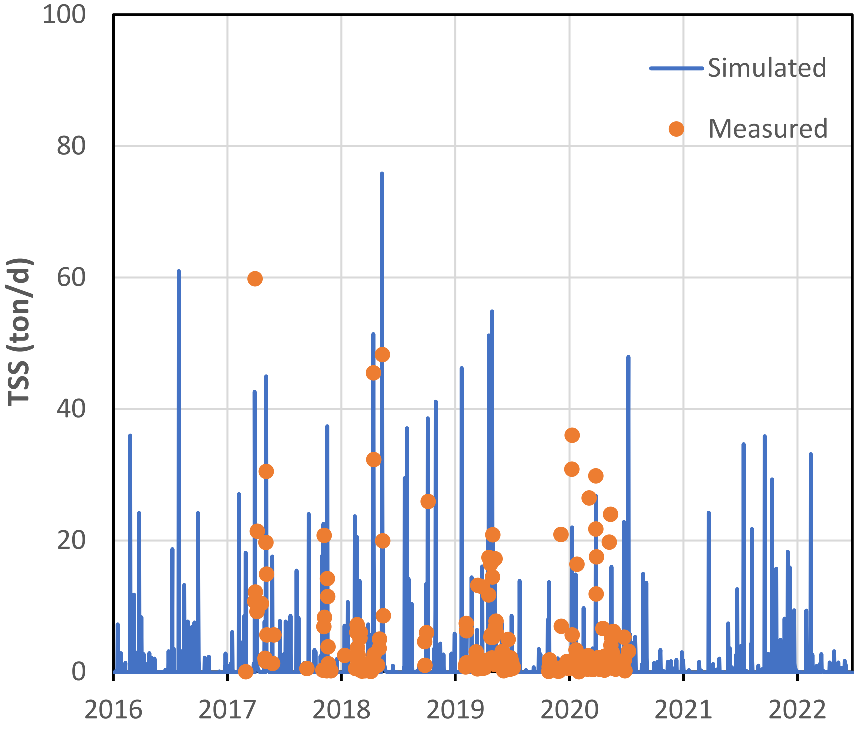

Figure 5-9. Measured vs. simulated sediment load at the DearyPS site

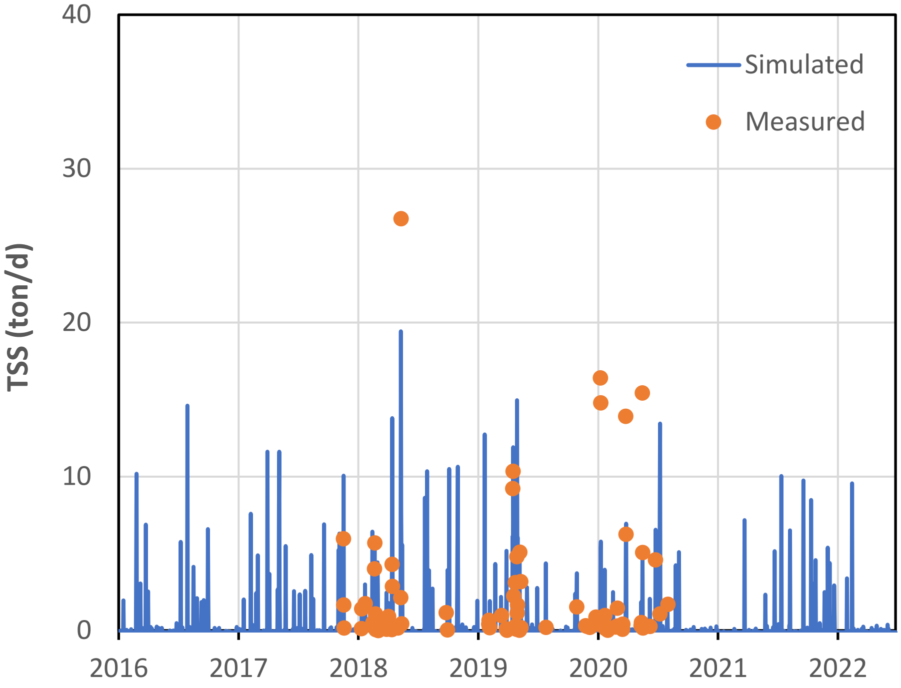

Figure 5-10. Measured vs. simulated sediment load at the DearyUP site

## 5.4 Nutrient calibration

Particulate, dissolved, and total phosphorus load/concentration calibration was conducted for six major water quality monitoring sites: DauphinPS (load), DauphinUP (concentration), BoudreauPS (load), BoudreauUP (concentration), DearyPS (load), and DearyUP (load), and the observed data from other water quality monitoring sites were used as references. Load calibration was conducted when both observed flow and concentration data were available and concentration calibration was conducted when only observed concentration data were available. Table 5-5 presents the parameters adjusted for dissolved and particulate phosphorus load/concentration calibration and Table 5-6 lists the performance statistics for total phosphorus load/concentration calibration at the six major monitoring sites. Figures 5-11, 5-12, 5-13, 5-14, 5-15 and 5-16 showed the graphs of measured vs. simulated total phosphorus load/concentration at the six major monitoring sites. A satisfactory total phosphorus load/concentration calibration was achieved at the six major monitoring sites resulting in a model bias of -2.8% to 19.8%, and a CORR of 0.54 to 0.82 based on the criteria outlined in Moriasi et. al (2007).

Table 5-5. Calibrated phosphorus parameters for the Jeannette's Creek Subwatershed IMWEBs model

| Parameter | Definition | Value |
|---|---|---|
| **initialSoilOrganicP** | Initial organic P concentration in soil, SOL_ORGP | 10.0 |
| **initialSoilSolutionP** | Initial soluble P concentration in soil,SOL_SOLP | 10.0 |
| **organicP_coefficient** | Organic phosphorus adjustment coefficient | 6.5 |
| **phosphrusPartiCo** | Phosphorus partitioning coefficient | -30 |
| **phosphrusPercoCo** | Phosphorus percolation coefficient | 3.0 |
| **gwOrganicP** | Organic P concentration in groundwater loading to reach | 0.005 |
| **P_enrich** | Phosphorus enrichment ratio | -2.0 |

Table 5-6. Model performance for total phosphorus load/concentration simulation at six major monitoring sites in the Jeannette's Creek subwatershed

| | Period | PBIAS | CORR Monthly NSC |
|---|---|---|---|
| DauphinPS (load) | 2016-2020 | 16.1% | 0.80 |
| DauphinUP (concentration) | 2016-2020 | 17.5% | 0.66 |
| BoudreauPS (load) | 2016-2020 | 9.5% | 0.73 |
| BoudreauUP (concentration) | 2016-2020 | 18.0% | 0.54 |
| DearyPS (load) | 2016-2020 | -2.8% | 0.68 |
| DearyUP (load) | 2018-2020 | 19.8% | 0.82 |

Note: Calibration using load when both observed flow and concentration data were available. Calibration using concentration when only concentration data were available.

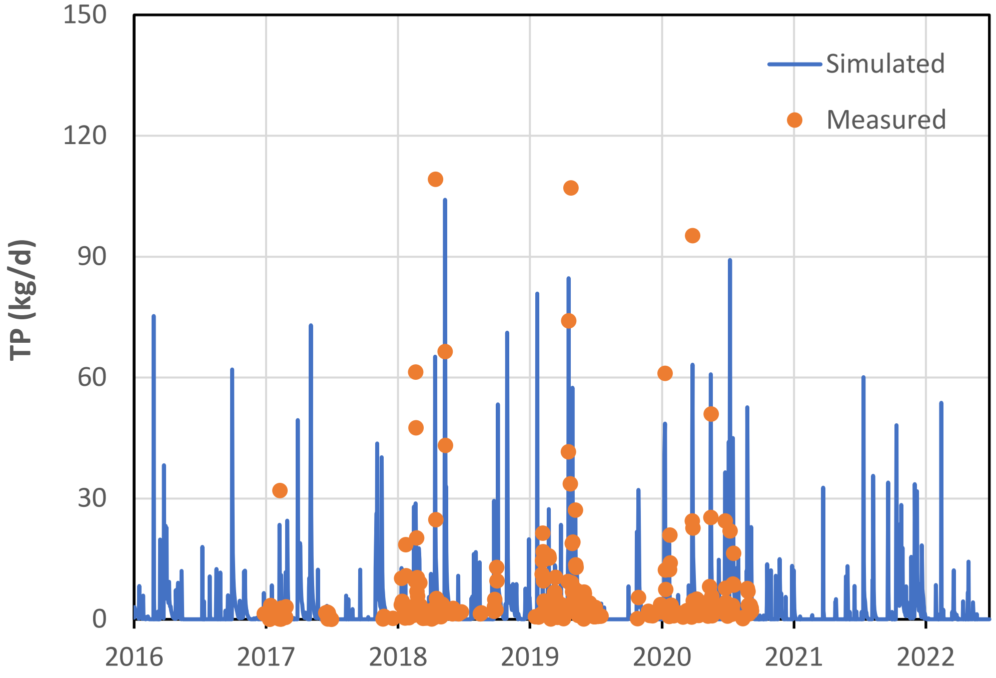

Figure 5-11. Measured vs. simulated total phosphorus load at the DauphinPS site

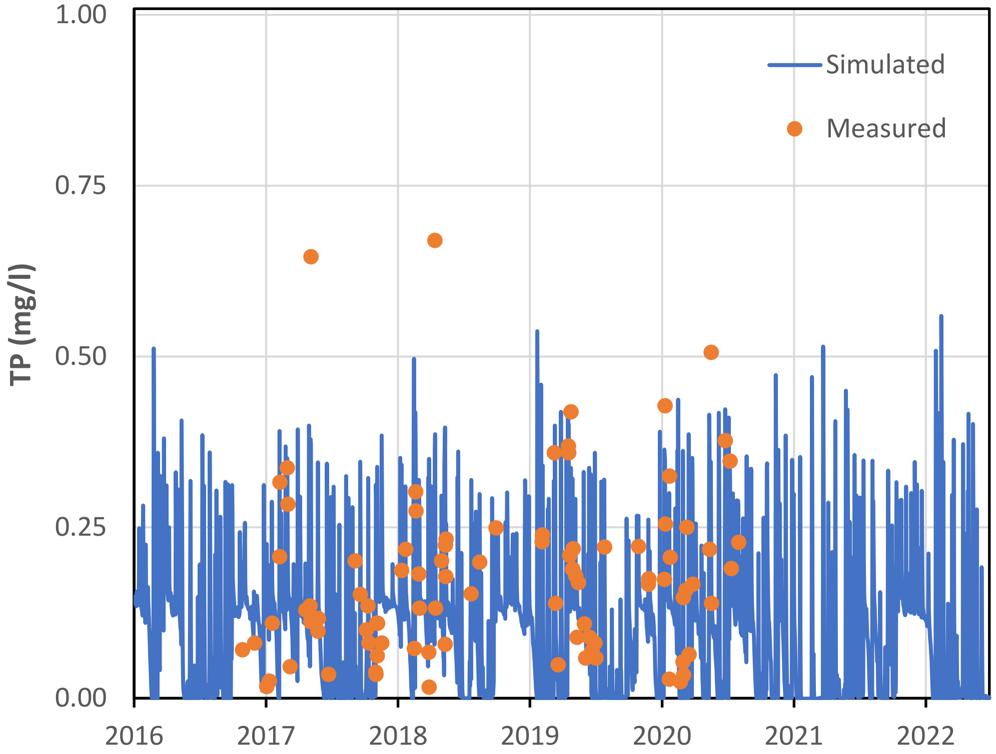

Figure 5-12. Measured vs. simulated total phosphorus concentration at the DauphinUP site

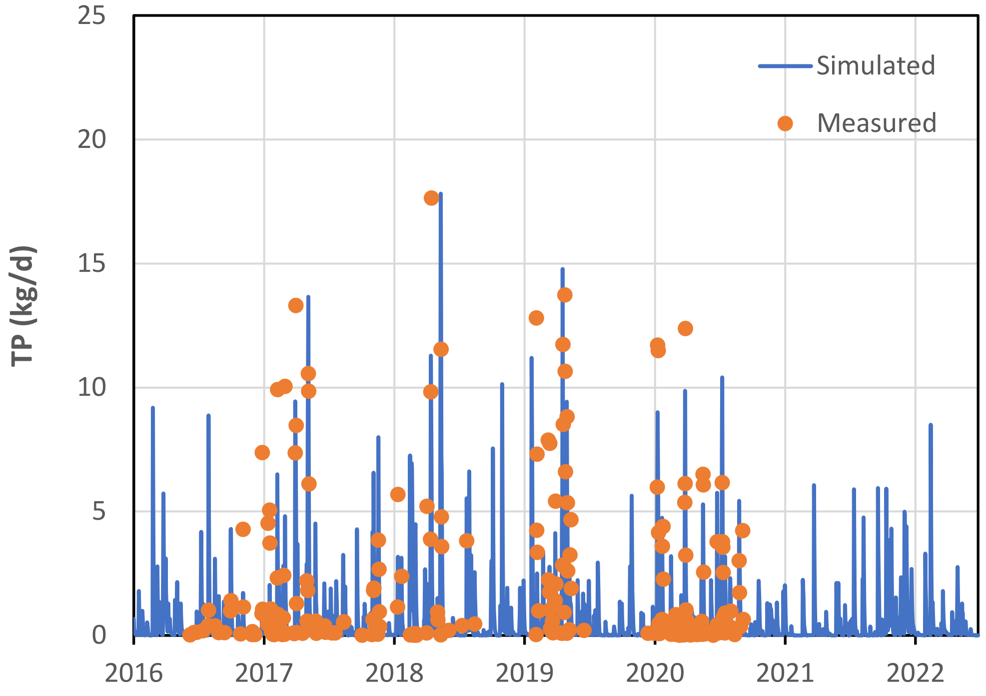

Figure 5-13. Measured vs. simulated total phosphorus load at the BoudreauPS site

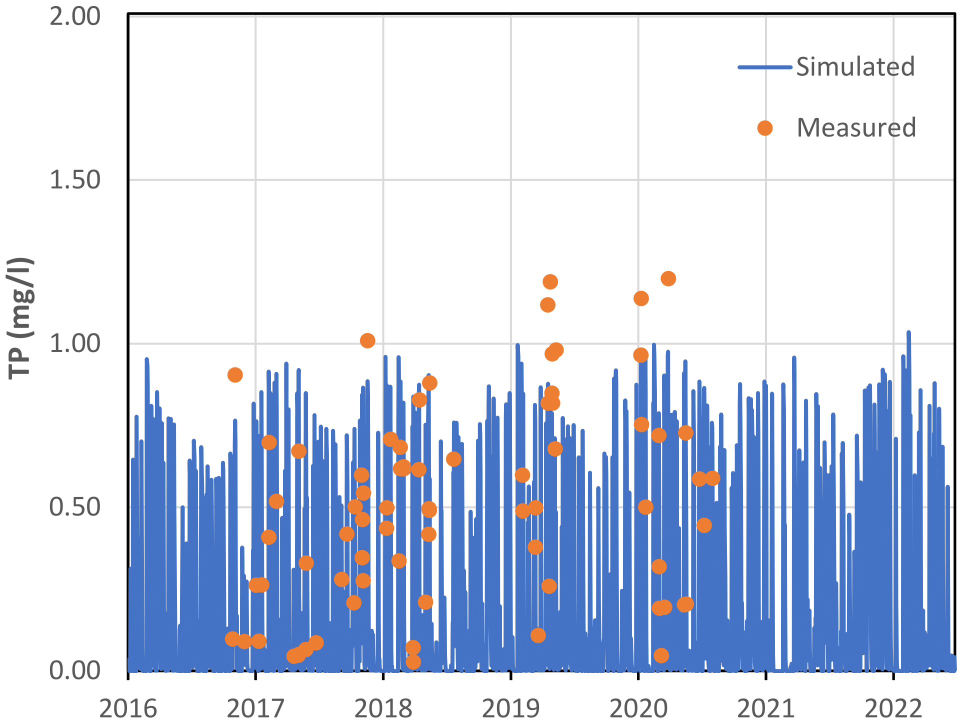

Figure 5-14. Measured vs. simulated total phosphorus concentration at the BoudreauUP site

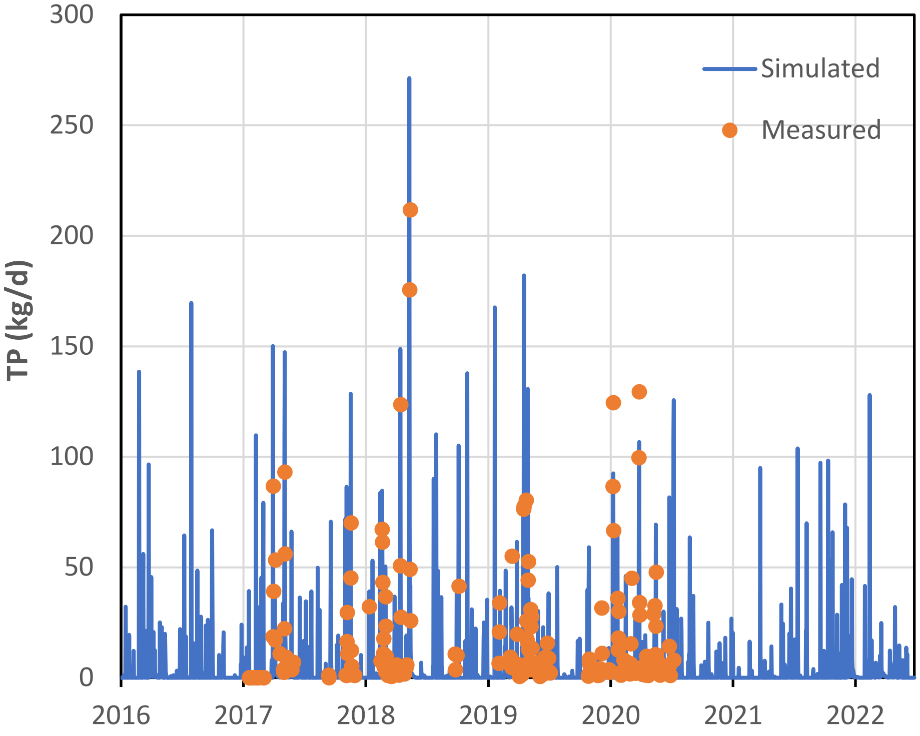

Figure 5-15. Measured vs. simulated total phosphorus load at the DearyPS site

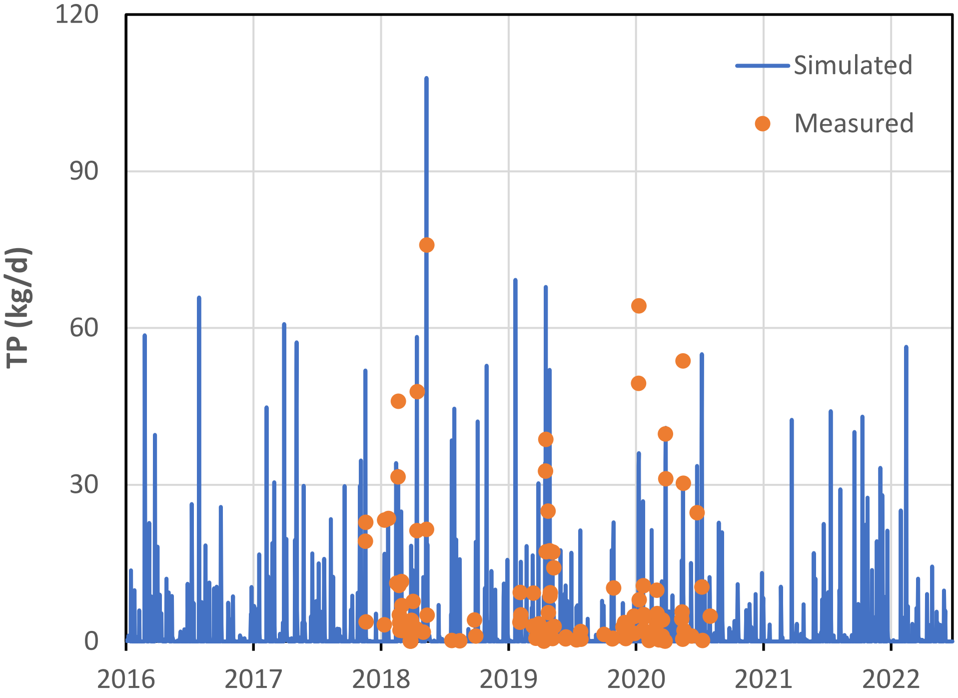

Figure 5-16. Measured vs. simulated total phosphorus load at the DearyUP site

Particulate, dissolved, and total nitrogen load/concentration calibration was conducted for six major monitoring sites – DauphinPS (load), DauphinUP (concentration), BoudreauPS (load), BoudreauUP (concentration), DearyPS (load) and DearyUP (load) and the observed data from other water quality monitoring sites were used as references. Load calibration was conducted when both observed flow and concentration data were available and concentration calibration was conducted when only observed concentration data were available. Table 5-7 presents the parameters adjusted for dissolved and particulate nitrogen load/concentration calibration and Table 5-8 lists the performance statistics for total nitrogen load/concentration calibration at the six major monitoring sites. Figures 5-17, 5-18, 5-19, 5-20, 5-21 and 5-22 show the graphs of measured vs. simulated total nitrogen load/concentration at the six major monitoring sites. A satisfactory total nitrogen load/concentration calibration was achieved at the six major monitoring sites resulting in a model bias of -22.9% to -6.0%, and a CORR of 0.48 to 0.76 based on the criteria outlined in Moriasi et. al (2007).

Table 5-7. Calibrated nitrogen parameters for the Jeannette's Creek Subwatershed IMWEBs model

| **Parameter** | **Definition** | **Value** |
|---|---|---|
| **initialSoilOrganicN** | Initial organic N concentration in soil, SOL_ORGN | -20.0 |
| **initialSoilNO3** | Initial NO3 concentration in soil, SOL_NO3 | 50.0 |
| **organicN_coefficient** | Organic nitrogen adjustment coefficient | 2.0 |
| **nitratePercoCo** | Nitrate percolation coefficient | 0.45 |
| **gwNO3** | NO$_3$ concentration in groundwater loading to reach | 0.3 |
| **gwOrganicN** | Organic N concentration in groundwater loading to reach | 0.03 |
| **organicN_enrich** | Organic nitrogen enrichment ratio | -2.0 |

Table 5-8. Model performance for total nitrogen load/concentration simulation at six major monitoring sites in the Jeannette's Creek subwatershed

| **Station** | **Period** | **PBIAS** | **CORR** |
|---|---|---|---|
| DauphinPS(load) | 2016-2020 | -12.3% | 0.64 |
| DauphinUP (concentration) | 2016-2020 | -17.2% | 0.48 |
| BoudreauPS (load) | 2016-2020 | -16.9% | 0.60 |
| BoudreauUP (concentration) | 2016-2020 | -16.7% | 0.55 |
| DearyPS (load) | 2016-2020 | -22.9% | 0.76 |
| DearyUP (load) | 2018-2020 | -6.0% | 0.52 |

Note: Calibration using load when both observed flow and concentration data were available. Calibration using concentration when only concentration data were available.

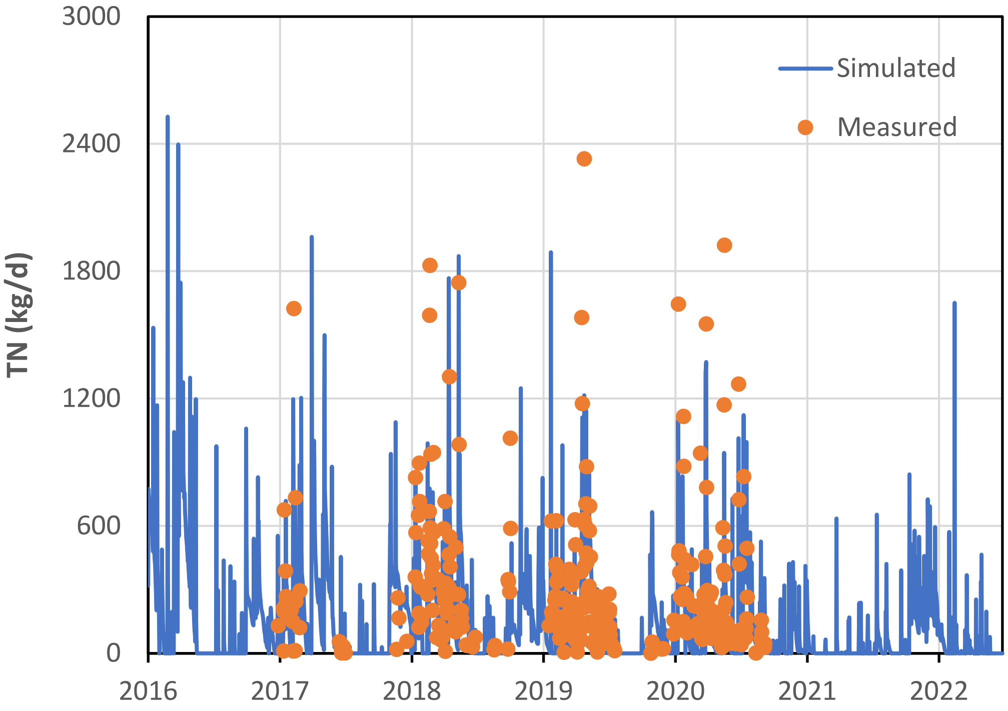

Figure 5-17. Measured vs. simulated total nitrogen load at the DauphinPS site

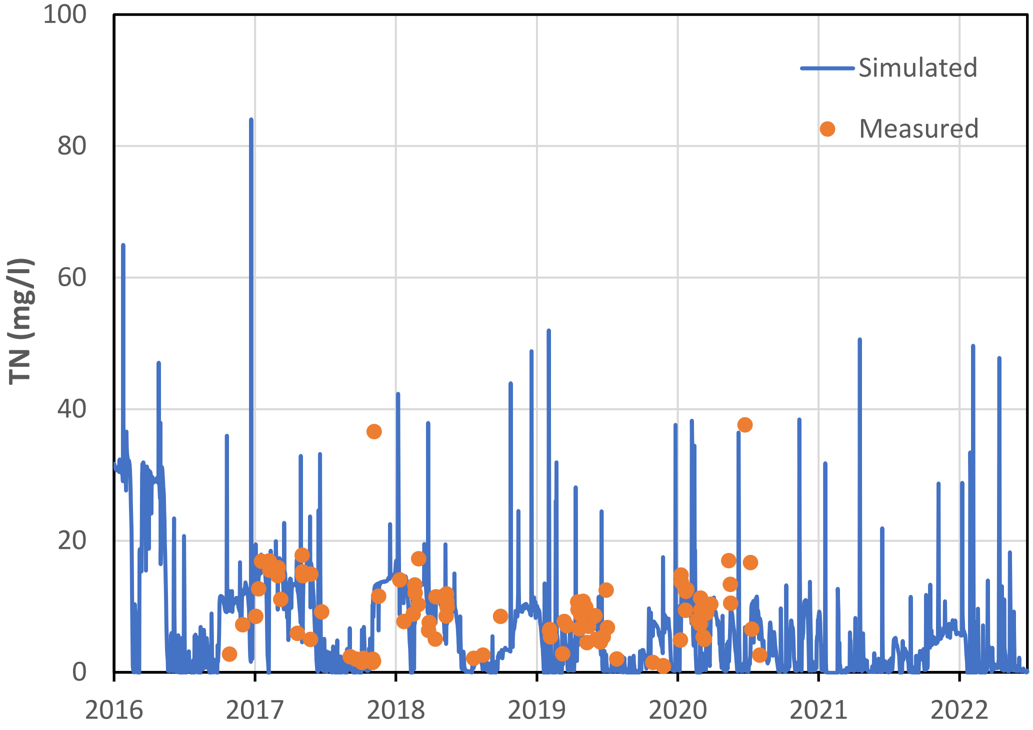

Figure 5-18. Measured vs. simulated total nitrogen concentration at the DauphinUP site

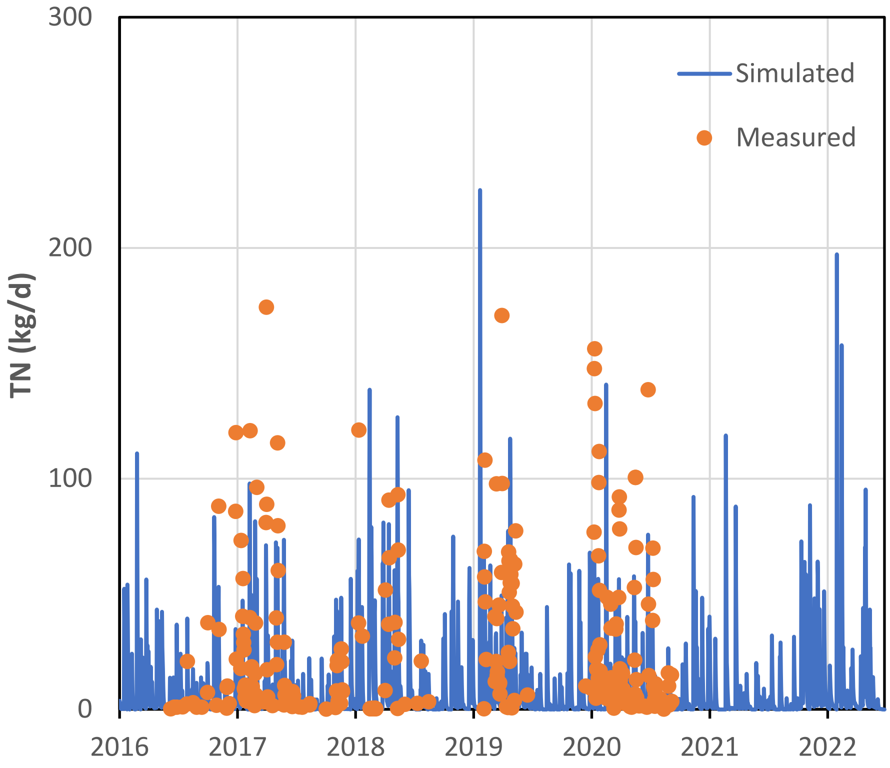

Figure 5-19. Measured vs. simulated total nitrogen load at the BoudreauPS site

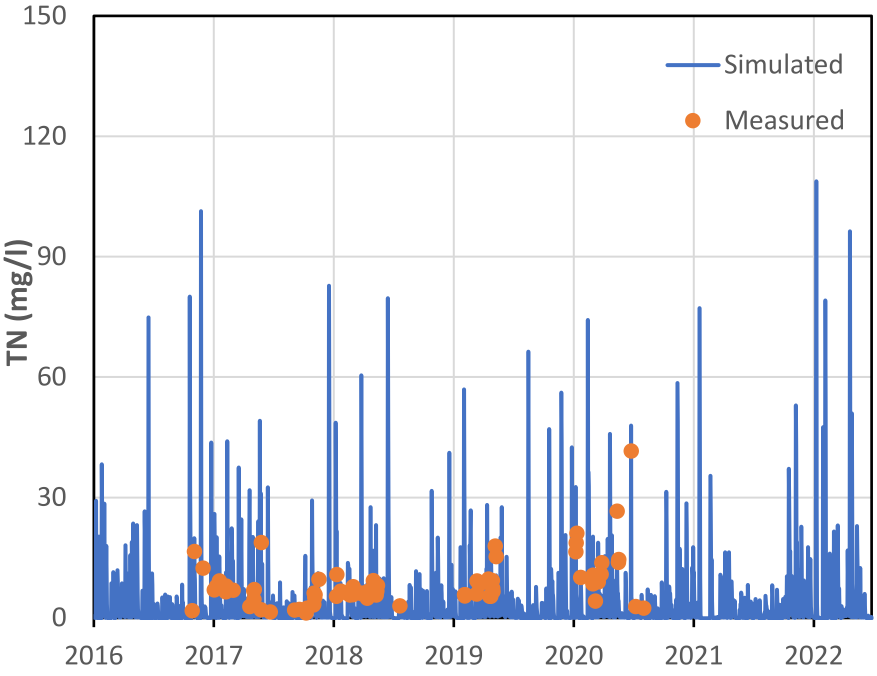

Figure 5-20. Measured vs. simulated total nitrogen concentration at the BoudreauUP site

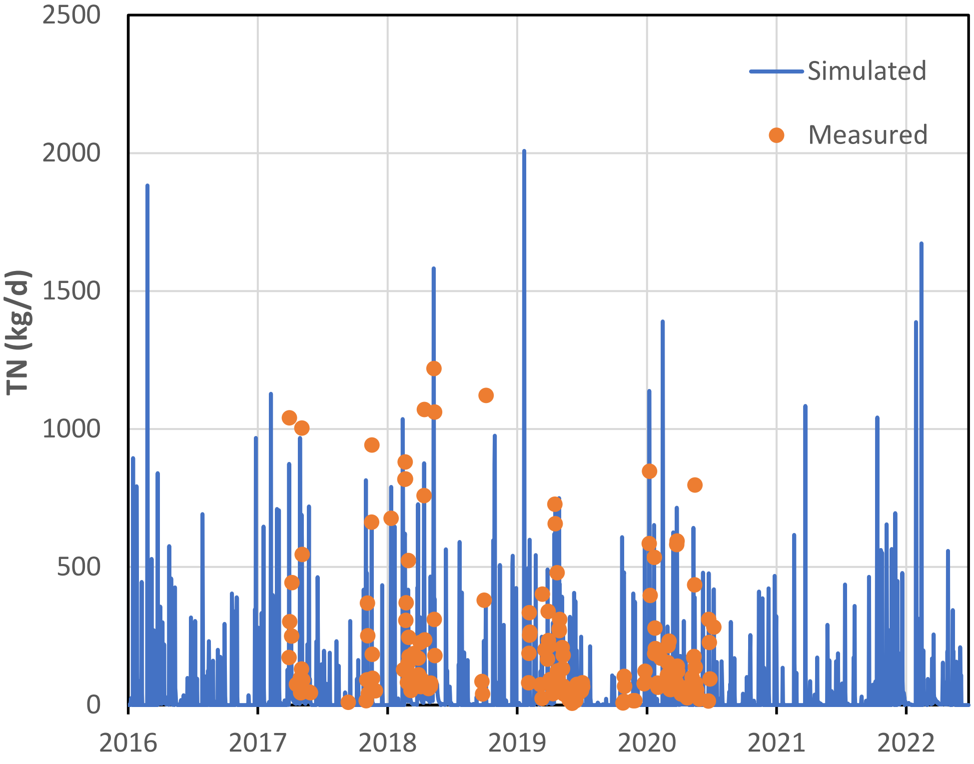

Figure 5-21. Measured vs. simulated total nitrogen load at the DearyPS site

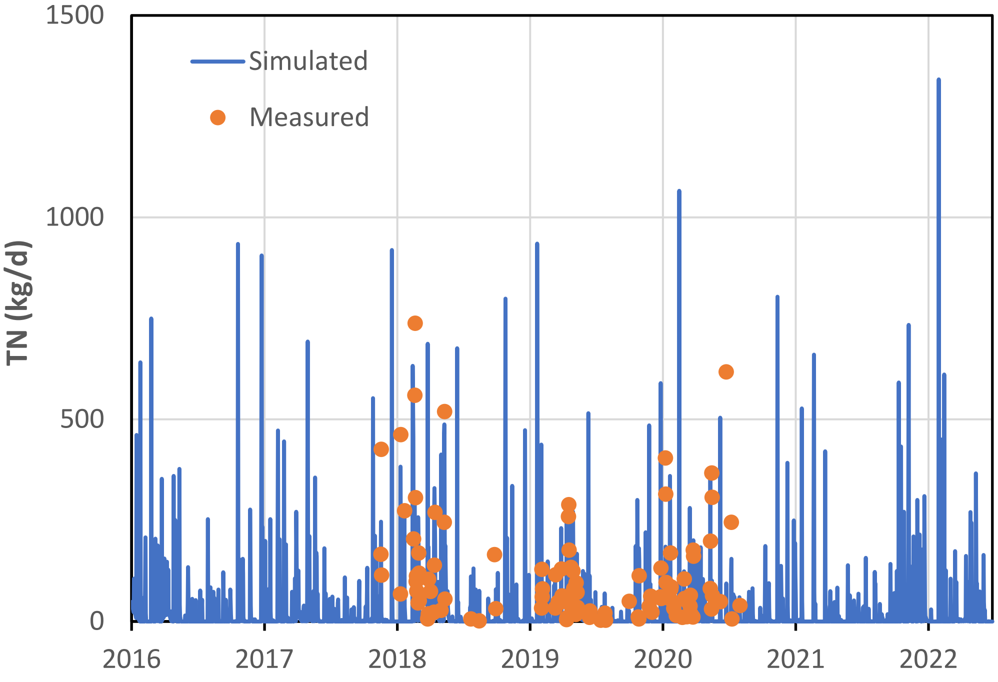

Figure 5-22. Measured vs. simulated total nitrogen load at the DearyUP site

## 6.0 DEFINITION OF BMP SCENARIOS AND BMP ASSESSMENT APPROACHES

In IMWEBs modelling, the crop management, tillage management, and fertilizer/manure management input tables for the IMWEBs model, prepared using the information collected through the landowner interviews and roadside observations represented the actual land management conditions present in the watershed landscape including established BMPs. This input represented the actual field conditions that produced the streamflow and water quality observations made at the various watershed monitoring stations. The model run that utilized this input dataset was defined as the "existing actual BMP" scenario.

In addition to this "existing actual BMP" condition, model input files were constructed to represent two additional theoretical field conditions, namely the "no existing BMP" condition and the "potential future BMP" condition. Within each of these main field conditions, there were three sub-scenarios prepared that focused on the three soil health-related BMPs (cover cropping, conservation tillage including no-till, and fertilizer/manure incorporation following application). Model output was then compared between these various model runs, in order to arrive at an estimate of the potential efficacy of these key BMPs with respect to water quality improvement under varying levels of adoption of these practices across the watershed. A comparison of model outputs between the "existing actual BMP" scenario and the "no existing BMP" scenario provided an estimate of the efficacy of historical/existing BMP adoption. A comparison of model outputs between the "existing actual BMP" scenario and the "potential future BMP" scenario provided an estimate of the efficacy of additional potential BMP adoption. Furthermore, a comparison of model outputs between the "no existing BMP" scenario and the "potential future BMP" scenario provided an estimate of the efficacy of full adoption of these practices across the watershed. The specific scenario runs compared to achieve this were as follows: no existing cover cropping scenario vs. potential future cover cropping scenario, no existing conservation tillage scenario vs. potential future conservation tillage scenario, and no existing fertilizer/manure incorporation scenario vs. potential future fertilizer/manure incorporation scenario. Unfortunately, we were not able to proceed with the BMP assessment due to time constraints. BMP assessment results however are expected to be in the similar order of magnitude on this study watershed as was calculated for other ONFARM watersheds for which the BMP assessment work was completed.

### 6.1 Existing actual BMP scenario

The "existing actual BMP" scenario characterizes all of the historical/existing BMPs or established BMPs in the Jeannette's Creek subwatershed. This includes the key soil health-related BMPS of interest in this study as well as a few other soil conservation structural and agronomic best practices. These all needed to be represented in the model as they are present and influence the water flow and quality observations that were made. The crop management, tillage management, and fertilizer/manure management data for the existing actual BMP scenario includes all land management BMPs collected through the ONFARM, GLASI and windshield surveys, such as conservation tillage, no-till, cover crops, and fertilizer/manure incorporation.

### 6.2 No existing BMPs scenarios

The no existing BMP scenarios were built by removing all of the key BMPs of interest from the Jeannette's Creek model input files. Three "no existing BMP" scenarios were developed including: no existing cover cropping scenario (i.e. removal of existing cover crops), no existing conservation tillage scenario (i.e. converting existing conservation tillage and no-till operations to conventional tillage), and no existing fertilizer/manure incorporation scenario (i.e. converting existing fertilizer and manure incorporation into no incorporation or surface application), respectively.

## 6.3 Potential future BMPs scenarios

The potential future BMP scenarios were built by adding the key soil health-related BMPs of interest to the model's input file. If a field is already utilizing the BMP, as observed from the land management operations or windshield surveys, then they were left in the model input file. If there were fields, however, that had opportunity to implement the BMPs, but they had not been adopted yet, then the model input file was adjusted to assume its adoption. In this way the full adoption potential of the BMPs of interest was represented in the "potential future BMP" model runs. The potential future BMP scenarios in the Jeannette's Creek subwatershed include potential future cover cropping scenario (i.e. implementing cover crop in all potential fields beyond existing cover crop fields), potential future conservation tillage scenario (i.e. implementing conservation tillage and no-till in all potential fields beyond existing conservation tillage and no-till fields), and potential future fertilizer/manure incorporation scenario (i.e. implementing fertilizer/manure incorporation in all potential fields beyond existing fertilizer/manure incorporation fields), respectively.

### 6.3.1 Assumptions used in developing potential future BMP scenarios

This section describes the methods that were used in developing the input that was used to represent a potential theoretical situation where the three key BMPs are adopted to their fullest potential across the watershed landscape. The potential future cover cropping scenario was defined by adding either oats or rye as a cover crop to all crop fields and all years that did not already have an existing cover crop in the "existing actual BMP" scenario. In the potential future cover cropping scenario, an oats cover crop was planted after winter wheat and terminated by year end in the future cover crop scenario. A rye cover crop was simulated as being planted after either corn or soybean (when the next crop was not winter wheat or a cover crop) and terminated when the following crop was seeded, simulating cover crops growing over winter. Nitrogen fertilizer application rates were reduced for the crops following future cover crops in consultation with experts from the OMAFRA and the University of Guelph, as shown in Table 6-1.

Table 6-1. Nitrogen credit amounts to reduce N fertilizer rates by for the crop that follows a future cover crop

| Cover Crop | Nitrogen credit (kg/ha/yr) |
|---|---|
| Red Clover | 66 |
| Oats | 45 |
| Rye | 45 |

The potential conservation tillage scenario was defined by changing all historical/existing conventional tillage in the existing actual BMP scenario into conservation tillage.

The potential future fertilizer/manure incorporation scenario was defined by changing all historical/existing manure and fertilizer applications with no or partial incorporation in the existing BMP scenario into full incorporation.

### 6.4 BMP assessment approaches

Assessing the water quality benefits of implementing the three key soil health-related BMPs, identified by the ONFARM study's technical working group (TWG), was not carried out for the Jeannette's Creek watershed because of a lack of available time at the end of the study. The model datasets, however, could be prepared and model runs could be generated at a future date if feasible. The BMP assessment approach planned to be used is identical to the approach described in corresponding reports for other ONFARM watersheds for which the analysis was fully completed, namely the Garvey Glenn and Upper Medway Creek subwatersheds. Readers are suggested to refer to these reports for a full description of the BMP assessment approach details.

It is expected that the results of the BMP assessment analysis for the Jeannette's Creek watershed, if completed, would be in the similar order of magnitude as was obtained from these other ONFARM watersheds given the similar approaches used, similar crops and level of adoption observed in this watershed compared to these other watersheds.

## 7.0 IMWEBs MODELLING RESULTS UNDER BOTH HISTORICAL/EXISTING AND THEORETICAL CONDITIONS/SCENARIOS

With the IMWEBs model input variables calibrated against available streamflow and water quality measurement data, the IMWEBs model was run for the period of 2016-2021 for the Jeannette's Creek subwatershed. The simulated average yearly stream flow along with sediment and nutrient yields/loads at the watershed outlet during the IMWEBs modelling simulation period were documented and presented in a tabular format.

For the Jeannette's Creek subwatershed, the average annual precipitation for the period of 2016 to 2021 was 826 mm and the simulated annual total runoff/flow was 303 mm, with a runoff/flow coefficient of 0.37. The simulated average annual total sediment load at the watershed outlet was 764 tonnes (0.41 t/ha), of which 576 tonnes (0.31 t/ha) were from overland sediment yield and 188 tonnes (0.10 t/ha) were from channel sediment load. The average overland sediment delivery rate was calculated using the estimated sediment yield associated with the surface runoff and tile flow before it entered into the defined streams/channels divided by the watershed area. The average channel sediment delivery rate was calculated by dividing the total channel/stream sediment load by the watershed area. The estimated average annual TN load at the watershed outlet was 43,410 kg (23.25 kg/ha), of which 11,185 kg was in particulate form (25.8%) and 32,225 kg was in dissolved form (74.2%). The estimated average annual TP load at the watershed outlet was 3,091 kg (1.66 kg/ha), of which 1,593 kg was in particulate form (51.5%) and 1,498 kg was in dissolved form (48.5%) (Table 7-1).

Table 7-1. Simulated average yearly sediment and nutrient yield/load at watershed outlet over the period 2001-2021 under historical/existing land management conditions for the Jeannette's Creek subwatershed

| | | | | | | |
|---|---|---|---|---|---|---|
| Overland sediment yield | 576 | t | 0.31 | t/ha | 75.4 | % |
| Channel sediment load | 188 | t | 0.10 | t/ha | 24.6 | % |
| Total sediment | 764 | t | 0.41 | t/ha | 100 | % |
| Particulate P | 1,593 | kg | 0.85 | kg/ha | 51.5 | % |
| Dissolved P | 1,498 | kg | 0.81 | kg/ha | 48.5 | % |
| TP | 3,091 | kg | 1.66 | kg/ha | 100 | % |
| Particulate N | 11,185 | kg | 5.99 | kg/ha | 25.8 | % |
| Dissolved N | 32,225 | kg | 17.26 | kg/ha | 74.2 | % |
| TN | 43,410 | kg | 23.25 | kg/ha | 100 | % |

## 8.0 IMWEBS MODELLING RESULTS FOR ASSESSING THE EFFECTIVENESS OF EXISTING ACTUAL BMPS

The calibrated Jeannette's Creek IMWEBs model can be applied to estimate the water quality benefits of the three key soil health-related BMPs including cover cropping, conservation tillage/no-till and fertilizer/manure incorporation under the current level of adoption of these practices by landowners across the watershed in relation to no adoption of these measures. Due to project time constraints, however, these model runs were not completed, their output not compared, and the results not tabulated. It is expected that the results would be very similar to those arrived at for the other ONFARM watersheds for which such work was completed. Completing this work in the future for the Jeannette's Creek watershed, however, would confirm this.

## 9.0 IMWEBS MODELLING RESULTS FOR ASSESSING THE EFFECTVENESS OF ADDITIONAL POTENTIAL BMP ADOPTION

The calibrated Jeannette's Creek IMWEBs model can be applied to estimate the water quality benefits of additional adoption of the three key soil health-related BMPs including cover cropping, conservation tillage/no-till, and fertilizer/manure incorporation in relation to the current level of adoption of these same BMPs in the watershed. Due to project time constraints, however, these model runs were not completed, their output not compared, and the results not tabulated. It is expected that the results would be very similar to those arrived at for the other ONFARM watersheds for which such work was completed. Completing this work in the future for the Jeannette's Creek watershed, however, would confirm this.

## 10.0 IMWEBS MODELLING RESULTS FOR ASESSING THE EFFECTIVENESS OF FULL ADOPTION OF SELECTED BMPS

The calibrated Jeannette's Creek IMWEBs model can be applied to estimate the water quality benefits of full adoption of the three key soil health-related BMPs of interest including cover cropping, conservation tillage/no-till, and fertilizer/manure incorporation in relation to the entire absence of implementation of these BMPs in the watershed. Due to project time constraints, however, these model runs were not completed, their output not compared, and the results not tabulated. It is expected that the results would be very similar to those arrived at for the other ONFARM watersheds for which such work was completed. Completing this work in the future for the Jeannette's Creek watershed, however, would confirm this.

## 11.0 BMP COST-EFFECTIVENESS ANALYSIS

No cost of production data were collected from farmers in the Jeannette's Creek subwatershed during the duration of the project. No BMP cost-benefit analysis (CBA) was done for the Jeannette's Creek watershed. No BMP assessment was done for the Jeannette's Creek watershed. Without BMP assessment data to combine with cost of production data, it was not possible to complete a BMP cost-effectiveness analysis for activities in the Jeannette's Creek subwatershed.

## 12.0 GENERAL SUMMARY AND FUTURE RECOMMENDATIONS

In the ONFARM project we developed IMWEBs modelling for evaluating the water quality benefits of three key soil health beneficial practices, namely cover cropping, conservation tillage/no-till, and fertilizer/manure incorporation BMPs in the six priority subwatersheds. The IMWEBs modelling was setup based on watershed boundary, stream network, climate, topography/DEM, soil, landuse, and historical/existing land management and BMPs. It was then calibrated based on observed flow and water quality monitoring data. Effort was made to calibrate IMWEBs modelling for all six priority subwatersheds with various levels of success. In the end, only the calibrated IMWEBs modelling for the Garvey Glenn and Upper Medway Creek subwatersheds was applied for BMP assessment. For these two subwatersheds, the calibrated IMWEBs modelling was re-setup and subsequently run to simulate an absence of each of the three evaluated BMPs in the study watersheds. This was achieved by removing from the model's input datasets each of the three existing key BMPs in those fields and years where they were present. Other model set-ups went to the other extreme and assumed full adoption of the three key BMPS in the study watersheds. This was achieved by adding each of the three BMPs to potential fields and years where they were not currently being applied but where they could be used within the study watersheds. The differences between the IMWEBs results under various combinations for these model set-ups were used as the basis for arriving at estimates of the benefits of the three key BMPs studied as currently adopted across the watershed as well as what might potentially be achieved in terms of water quality improvements if they were fully adopted and, finally, what could be the water quality consequences if no adoption of these practices occurred in the watersheds. The differences between the IMWEBs results under the conventional "no existing BMP" scenarios and the "existing actual BMP" scenario (characterized by the calibrated IMWEBs model) represented the water quality benefits of the current level of adoption of the BMPs of interest. This result could then be used to estimate what has been achieved by the current level of BMP implementation in the subwatershed. The differences between the IMWEBs results under the existing actual BMP scenario and the potential future BMP scenarios represent the water quality benefits of what additional adoption of the three key BMPs in the watershed could potentially achieve. Finally, by taking the difference between the "no existing BMP" model runs and the "potential future" model runs, an estimate could be made of what full adoption of these BMPs in the entire subwatershed would mean in terms of water quality improvements, relative to an absolute absence of these BMPS in the watershed landscape.

In addition, we worked with Conservation Authority colleagues to conduct BMP cost-benefit analyses (for Garvey Glenn, Gully Creek, Upper Medway Creek, and North Kettle Creek subwatersheds) and cost effectiveness analyses (for Garvey Glenn and Upper Medway Creek subwatersheds). The cost effectiveness analysis put a dollar cost on removing 1 kg of TP using the three key best practices studied under ONFARM.

The ONFARM modelling, by necessity, is a collaborative initiative. Conservation Authority colleagues, in collaboration with the landowners and operators, worked very hard to provide land management survey data, climate data, flow and water quality monitoring data, soil data and other data to us. We also asked for inputs from CA, OSCIA and OMAFRA colleagues on various modelling parameterization questions. Moving forward, we would like to make the following suggestions:

1). Support the development of a long-term watershed-based monitoring and data collection program

In Ontario, the WBBE, GLASI and ONFARM programs have invested on establishing the monitoring and data collection program for BMP assessment in several representative subwatersheds since 2014. These data are highly valuable for understanding watershed hydrology and other watershed characteristics and for setting up and calibrating watershed BMP modelling. We hope that the investment on the monitoring and data collection program can be sustained to support future BMP assessment initiatives.

We would like to provide several suggestions on improving quality control for climate and water monitoring data:

a). Ensure that the climate monitoring equipment setup is in good working order (such as free from obstruction), comparing climate data with nearby stations quickly after its initial collection to help identify inconsistencies, and make data corrections, if necessary;

b). Check climate, flow, TSS and nutrient data regularly to detect abnormal outliners or errors and make data corrections, if necessary;

c). Conduct consistency analysis between precipitation and flow observations, identify possible reasons for mismatches between precipitation and flow during a time window (such as periods where no precipitation was observed but flow occurred and conversely periods with precipitation but no flow), making data corrections promptly, if necessary.

2). Develop paired experimental sites for BMP assessment

In BMP assessment, it would be important to develop paired experimental sites, one with BMPs and one without BMPs, for monitoring flow and water quality differences. These monitoring data would be very helpful for setting up and calibrating watershed BMP modelling to evaluate on-site or edge-of-field and off-site or watershed outlet BMP effectiveness. We understand the challenges in setting up the paired experimental sites and conducting water monitoring (no two watersheds are exactly the same) but hope resources can be provided for this important component of the BMP assessment initiatives.

3). Transfer or scale up IMWEBs modelling to other representative subwatersheds or larger watersheds

The IMWEBs modelling was able to utilize valuable data collected by the WBBE, GLASI, and ONFARM programs to evaluate BMP effectiveness. While IMWEBs modelling can be further developed as more data from ONFARM subwatersheds are available, we would like to propose transferring or scaling up IMWEBs modelling to other representative subwatersheds or larger watersheds in future BMP assessment initiatives. Transferring IMWEBs modelling will extend BMP modelling to other representative subwatersheds with different landscape characteristics. Scaling up IMWEBs modelling from the existing subwatersheds can support the BMP assessment in larger areas. Both transferring and scaling up can broaden the scope of BMP assessment in the future.

## 13.0 REFERENCES

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