Wilfrid Laurier University

Department of Geography and Environmental Studies

**GG101 Introduction to Physical Geography Lab 7: Watershed Hydrology**

**Tasks and Questions**

# Climate Trends in southern Ontario and the Water Balance

In the Lab 7 background reading there are three figures that show temperature and precipitation trends. Figure 1 shows mean annual temperature trends for the Great Lakes climate region of Canada, Figure 2 shows the precipitation trend from Toronto and Figure 3 shows the precipitation trend from Wiarton.

**Question 1** (2 marks)

*Briefly describe the temperature and precipitation trends observed since 1960.*

From Ref Fig 1, (mean annual temperature deviations from 1960 to 2019), we can see several phenomenal. First is the change in variation that occurs around 1990. Prior to 1990, the variance in the data was about 0.27. After 1990. The variance was 0.68. Via an F-test in Excel, the difference is statistically significant. Second is the trend upwards. Although a linear trend through the data was drawn showing a positive relationship between time and temperature (i.e. global temperatures are increasing, we could have drawn the averages of the pre-1990 vs post 1990 values like this



Which shows a step change in temperature and in variation around 1990. That’s interesting from the standpoint of causation. Regardless, the third point is an upward “trend” “shift”, “movement, etcetera of temperatures as time ticks away.

From Ref Fig 2. We can see the deviations in annual precipitation remain centered at zero. There does not appear to be any increase in noise or variance rainfall deviation (recall this is deviation. It is the difference between that year’s total rainfall and a reference point). The slope of zero for the trend line indicates rainfall is not changing.

From Ref Fig 3., we can see that the first 8 data points (1960 to 1968) are significantly lower than the average of the next 52 data points (1969 to 2019) and significantly skew the deviations for data after 1969. It would be an interesting research effort to discover why those values are so low especially when the Toronto data did not show that trend. Regardless, from 1960 on, the trendline in the annual precipitation deviation is 0. Meaning there is no change in annual precipitation over time.

# Impact of Climate on the Water Balance of a Watershed

Climate will strongly influence the water balance as precipitation represents the major input to a watershed and temperature strongly influences evapotranspiration, a major loss from a watershed. Mean annual temperature and total annual precipitation data may not capture processes that occur over shorter intervals of time, for example, seasonal or monthly variations in inputs and outputs from a watershed may be critically important. Yet the annual data provide us with some insight.

# Water Balance Data

The water balance is given as:

Q = P - E ± ªS where Q is the Discharge or Runoff

P is Precipitation

E is Evapotranspiration

ªS is change in Storage

There are two major outputs: (i) Discharge or Runoff, and (ii) Evapotranspiration. The major input is Precipitation. At the watershed scale, we give the input (Precipitation) in units of mm. The output variable Evapotranspiration is also given in mm. The water output from the system can be given as a Discharge, which is the volume of water that is flowing from the system over a period of time in units such as m3/s or millions of m3 per year, or it can be given as a Runoff value in mm which is the amount of water that moves from the basin into the channel expressed per unit area of the watershed.

Table 1 shows data from a series of watersheds across southern Ontario. The table has columns on the following: (i) watershed **Area** in km2, (ii) **Mean Annual Flow (MAF)** in m3/s, (iii**) Mean Annual Temperature (MAT)** in oC, (iv) **Total Annual Precipitation (TAP)** in mm, (v) **Total**

**Annual Flow (TAF)** in millions of m3/yr, (vi) **Specific Discharge (SQ)** in m3/s per km2, (vii)

**Runoff (RUN)** in mm, (viii) **Evapotranspiration (ET)** in mm, and (ix) **Runoff as a % of TAP (RUN%)**. The **Area**, **MAF**, **MAT**, and **TAP** data were extracted from the Ontario Watershed and Flow Assessment Tool (OFAT) and the others are calculated.

**Total Annual Flow (TAF)** is calculated by taking the mean annual flow in m3/s and multiplying by the number of seconds in one year to express the flow as an annual volume.

**Specific Discharge (SQ)** is calculated by taking **MAF** and dividing by the watershed **Area**.

**Runoff (RUN)** is calculated by taking the **TAF** and dividing by the **Area** and then multiplying by 1000, to yield the runoff from each basin in mm per unit area.

**Evapotranspiration (ET)** is calculated from the water balance, Runoff = Precipitation - ET ±ÄS so **ET** is calculated by subtracting **Runoff (RUN)** from the **TAP** (assumes ÄS is zero).

**RUN%** is calculated by expressing **Runoff** as a percentage of **TAP**.

**ET%** is calculated by expressing **Evapotranspiration** as a percentage of **TAP**

Table 1: Southern Ontario Watersheds



**Task 1** (4 marks)

Calculate TAF, SQ, RUN and ET for the streams listed in Table 1. Enter your values into Table 1.

Complete (see table 1)

**Task 2** (6 marks)

Produce a series of graphs that show the following relations:

1. Watershed Area (x-axis) vs Mean Annual Flow (y-axis)
2. Total Annual Precipitation (x-axis) vs Specific Discharge (y-axis)
3. Total Annual Precipitation (x-axis) vs Runoff (y-axis)
4. Total Annual Precipitation (x-axis) vs Evapotranspiration (y-axis)



Figure 1:MAP vs Area



Figure 2: SQ vs TAP



Figure 3: Run vs TAP



Figure 4: ET vs TAP

Figure 1 above (MAP vs area) clearly shows a positive linear relationship between watershed area and mean annual flowrate. Meaning as watershed area increases, mean annual flowrate increases. This is expected since we assume all the precipitation within the watershed flows into the same drainage. So that for a particular region, area and MAP should be positively related

Figure 2 above (SQ vs TAP) shows a linear relationship between total annual precipitation and the mean annual flowrate per unit area but the slope of the linear relationship is near 0. This means that as the precipitation increases, the average flowrate per unit area doesn’t really depend much on the size of the watershed. This is expected size this is flowrate per unit area.

Figure 3 above (Runoff vs TAP) shows a linear relationship between total annual precipitation and the amount of runoff. Meaning the higher the precipitation, the higher the runoff. We expect this.

Figure 4 above (Evapotranspiration vs TAP) shows a linear relationship between total annual precipitation and the of water that evaporations. Meaning the higher the precipitation, the larger the amount of evaporation. Again, this is expected. The more water on the ground, the higher the evaporation (all other factors equation – such as T, humidity, pressure)

# Role of Temperature as Influence on Runoff

There is some range in the mean annual temperature and total annual precipitation of the locations in

Table 1. While the climate is similar over the region, we do see that locations in Bruce and Grey County (Stokes River, Sydenham River) are cooler and wetter than locations in the developed areas of the GTA (Don River, Etobicoke Creek, Mimico Creek). The variance in temperature and precipitation permits us to examine how these climate variables influence runoff.

**Task 3**  (2 marks)

Calculate the Runoff % variable in the spreadsheet and enter your values into Table 1. The Runoff % is calculated by taking Runoff and dividing by TAP and expressing the result as a percentage.

Calculate the Evapotranspiration % variable in the spreadsheet and enter your values into Table 1.

The Evapotranspiration % is calculated by taking Evapotranspiration and dividing by TAP and expressing the result as a percentage.

Complete (see table 1)

**Task 4** (4.5 marks)

1. Produce a graph that has Mean Annual Temperature (x-axis) plotted against Total Annual Precipitation (y-axis).
2. Produce a graph that has Mean Annual Temperature (x-axis) plotted against Runoff % (y-axis).
3. Produce a graph that has Mean Annual Temperature (x-axis) plotted against ET % (y-axis).



Figure 5: TAP vs MAT



Figure 6: Run off % vs MAT



Figure 7: ET % vs MAT

Figure 5 above (TAP vs MAT) shows a negative linear relationship between total annual precipitation and the average temperature. Meaning the higher temperature, the lower the annual precipitation. Well we know that for a given absolute humidity, as air cools, its relative humidity increases to the point where water precipitates out as rain. So it makes sense that at higher temperatures, we should see less precipitation.

Figure 6 above (Runoff% vs MAT) shows a negative linear relationship between Runoff% and the average temperature. Meaning the higher temperature, the lower the runoff %. Since Runoff % is a ratio of runoff to TAP, and since TAP and MAT are inversely proportional, this makes sense.

Figure 7 above (ET% vs MAT) shows a negative linear relationship between ET% and the average temperature. Meaning the higher temperature, the lower the ET %. Since ET% is a ratio of evaporation to TAP, and since TAP and MAT are inversely proportional, this makes sense.

# Question 2 (4 marks)

*Review all of the relations examined. Explain why areas that have higher mean annual temperatures have lower runoff %’s compared to areas that have lower mean annual temperatures?*

Precipitation occurs when the air becomes saturated with water vapor and then the temperature drops further. At higher temperatures air can hold more moisture. So for the same amount of moisture in the air the cooler the air, the more the precipitation.

# Question 3 (5 marks)

*Given the temperature and precipitation trends shown in Figures 1, 2, and 3 describe what the impact will be on runoff to, and the flow volumes of, streams in southern Ontario should those trends continue in the future. In your response refer to the relations that you have uncovered in examining the water balance for streams in southern Ontario.*

If the temperature trends continue, then there will be less precipitation, less runoff, less accumulation and the area will become drier. At the same time, areas that experience precipitation due to cold weather / warm weather fronts, will experience higher precipitation as the warm air with the higher humidity mixes with the cooler air lowering the maximum amount of moisture the air can hold. .