Project1: Water Cycle Climatology for a Watershed

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Part A) Pick a stream gauge.

Stream Gage: USGS 04045500 Tahquamenon River Near Paradise, MI
Summary Data Here

Description - Latitude 46°34'30", Longitude 85°16'10" NAD27 - Luce County, Michigan, Hydrologic Unit 04020202 - Drainage area: 790 square miles (22,023,620,000 ft^2) - Datum of gage: 698.03 feet above NGVD29.

Remarks from the latest Water-Year-Summary Report, 2017 make no mention to regulated flows of any kind. The earliest report availabe, 2006, states that "records good for estimated daily discharges, which are fair. Several measurements of water temperature were made during the year. Gage-height telemeter at station. Remarks are included verbatim in screenshot form below.

2006 Remarks:

USGS
science for a changing world

Water-Data Report 2006

04045500 TAHQUAMENON RIVER NEAR PARADISE, MI

Southeastern Lake Superior Basin
Tahquamenon Subbasin

LOCATION.--Lat 46°34'30", long 85°16'10" referenced to North American Datum of 1927, in NE ¼ sec.11, T.48 N., R.8 W., Luce County, MI, Hydrologic Unit 04020202, on left bank 0.7 mi upstream from Tahquamenon Falls (upper), 11.5 mi west of Paradise, and 19 mi northeast of Newberry.

DRAINAGE AREA.--790 mi².

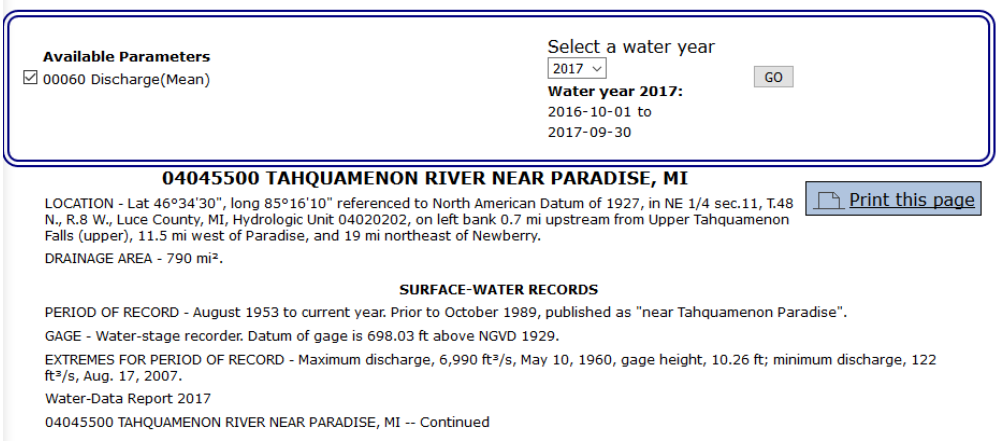
SURFACE-WATER RECORDS

PERIOD OF RECORD.--August 1953 to current year. Prior to October 1989, published as "near Tahquamenon Paradise".

GAGE.--Water-stage recorder. Datum of gage is 698.03 ft above sea level.

REMARKS.--Records good except for estimated daily discharges, which are fair. Several measurements of water temperature were made during the year. Gage-height telemeter at station.

2017 Remarks:



Available Parameters
☑ 00060 Discharge(Mean)

Select a water year
2017 GO
Water year 2017:
2016-10-01 to
2017-09-30

04045500 TAHQUAMENON RIVER NEAR PARADISE, MI

Print this page

LOCATION - Lat 46°34'30", long 85°16'10" referenced to North American Datum of 1927, in NE 1/4 sec.11, T.48 N., R.8 W., Luce County, MI, Hydrologic Unit 04020202, on left bank 0.7 mi upstream from Upper Tahquamenon Falls (upper), 11.5 mi west of Paradise, and 19 mi northeast of Newberry.

DRAINAGE AREA - 790 mi².

SURFACE-WATER RECORDS

PERIOD OF RECORD - August 1953 to current year. Prior to October 1989, published as "near Tahquamenon Paradise".

GAGE - Water-stage recorder. Datum of gage is 698.03 ft above NGVD 1929.

EXTREMES FOR PERIOD OF RECORD - Maximum discharge, 6,990 ft³/s, May 10, 1960, gage height, 10.26 ft; minimum discharge, 122 ft³/s, Aug. 17, 2007.

Water-Data Report 2017

04045500 TAHQUAMENON RIVER NEAR PARADISE, MI -- Continued

Part B) Create a table showing the average monthly discharge for 1981 to 2010. Find the 30-year average for your table.

```
In [89]: import pandas as pd
         import numpy as np
         import datetime as dt
         import matplotlib.pyplot as plt
```

```
In [112]: Area_mi2 = 790
          Area_ft2 = Area_mi2 * 27878000
          date_range = (
              dt.datetime(year=1980,month=12,day=29),
              dt.datetime(year=2010,month=12,day=29)
          )
```

```
In [76]: data = pd.read_csv(
             'TahquamenonRiver_04045500_MonthlyStatistics.txt',
             sep = '\t',
             names = ['Agency','Site Number','Parameter Code','Timeseries ID',
                      'Year','Month','Mean Value [ cfs ]'],
             skiprows = 37,
             usecols = [4,5,6]
         )

         # Set Years and Months to Type String
         data.Year = data.Year.astype(str)
         data.Month = data.Month.astype(str)

         # Join the strings with a -01- for the day.
         a = data.Month + '-01-'+ data.Year

         # Convert to a datatime format
         data['Date'] = pd.to_datetime(a)

         # Add column for days in the month... includes leap years for February
```

```
data['DaysInMonth'] = data.Date.dt.daysinmonth

# Revert Month & Year back to type int
data.Year = data.Year.astype(str)
data.Month = data.Month.astype(str)

# Select for data in Normal Range
Data_Normal = data[data['Date']>date_range[0]]
Data_Normal =  Data_Normal[Data_Normal['Date']<date_range[1]]
```

CFS to Total Volume
Have flow in $\frac{ft^3}{s}$, want $\frac{ft^3}{month}$.
To accomplish do the following:

$$\frac{ft^3}{s} * \frac{60s}{1min} * \frac{60min}{1hr} * \frac{24hr}{1day} * \frac{DaysInMonth}{1month} = [\frac{ft^3}{month}]$$

```
In [107]: # Compute Monthly Discharges in Cubic Feet
          Data_Normal['Volume_ft3'] = Data_Normal['Mean Value [ cfs ]'] \
              * Data_Normal['DaysInMonth'] * 60 * 60 * 24
```

Total Volume to Depth in Inches
To calculate this volume in inches on the watershed:

$$\frac{ft^3}{month} * \frac{1}{WatershedArea} * \frac{12in}{1ft} = [\frac{in}{month}]$$

```
In [78]: # Compute Monthly Discharge in Inches
         Data_Normal['Volume [ in ]'] = Data_Normal['Volume_ft3'] / Area_ft2 * 12
```

Prepare Table

```
In [109]: Months = Data_Normal.drop(columns=['DaysInMonth','Volume_ft3']).groupby('Month')
          Months = Months.mean()

          # Need to reorder the table by month now
          Month_str = Months.reindex(
              index=['January','October','November','December',
                     'February','March','April','May',
                     'June','July','August','September']
          )
          for i in range(0,12):
              Month_str.iloc[i] = Months.iloc[i]
          Month_str = Month_str.reindex(
              ['January','February','March','April',
               'May','June','July','August',
               'September','October','November','December']
          )
          Month_str
```

Out[109]:

Month	Mean Value [cfs]	Volume [in]
January	548.5	0.80
February	495.5	0.66
March	855.5	1.26
April	2636.5	3.72
May	1251.0	1.83
June	579.5	0.82
July	420.0	0.61
August	377.3	0.55
September	494.4	0.70
October	859.1	1.25
November	992.8	1.40
December	783.8	1.14

Part C) Create a table showing the average monthly precipitation (in inches) for the watershed.

Tahquamenon Falls State Park Weather Station (USC00208042) is located approximately 3 miles from the USGS stream gage. The 1981-2010 Precipitation normals in inches for each month are located below.

In [113]:
```
months = [
    'January','February','March','April',
    'May','June','July','August',
    'September','October','November','December'
]
precip = [
    3.12, 1.91, 2.16, 2.34,
    2.74, 2.93, 3.04, 3.41,
    3.72, 4.10, 3.27, 3.44
]

Precip_Normal = dict(zip(months,precip))
Precip_Normal = pd.DataFrame.from_dict(Precip_Normal, orient='index', )
Precip_Normal = Precip_Normal.rename(
    index=str,
    columns={0:'Precip Normals [ in ]'}
)
Precip_Normal
```

Out[113]:

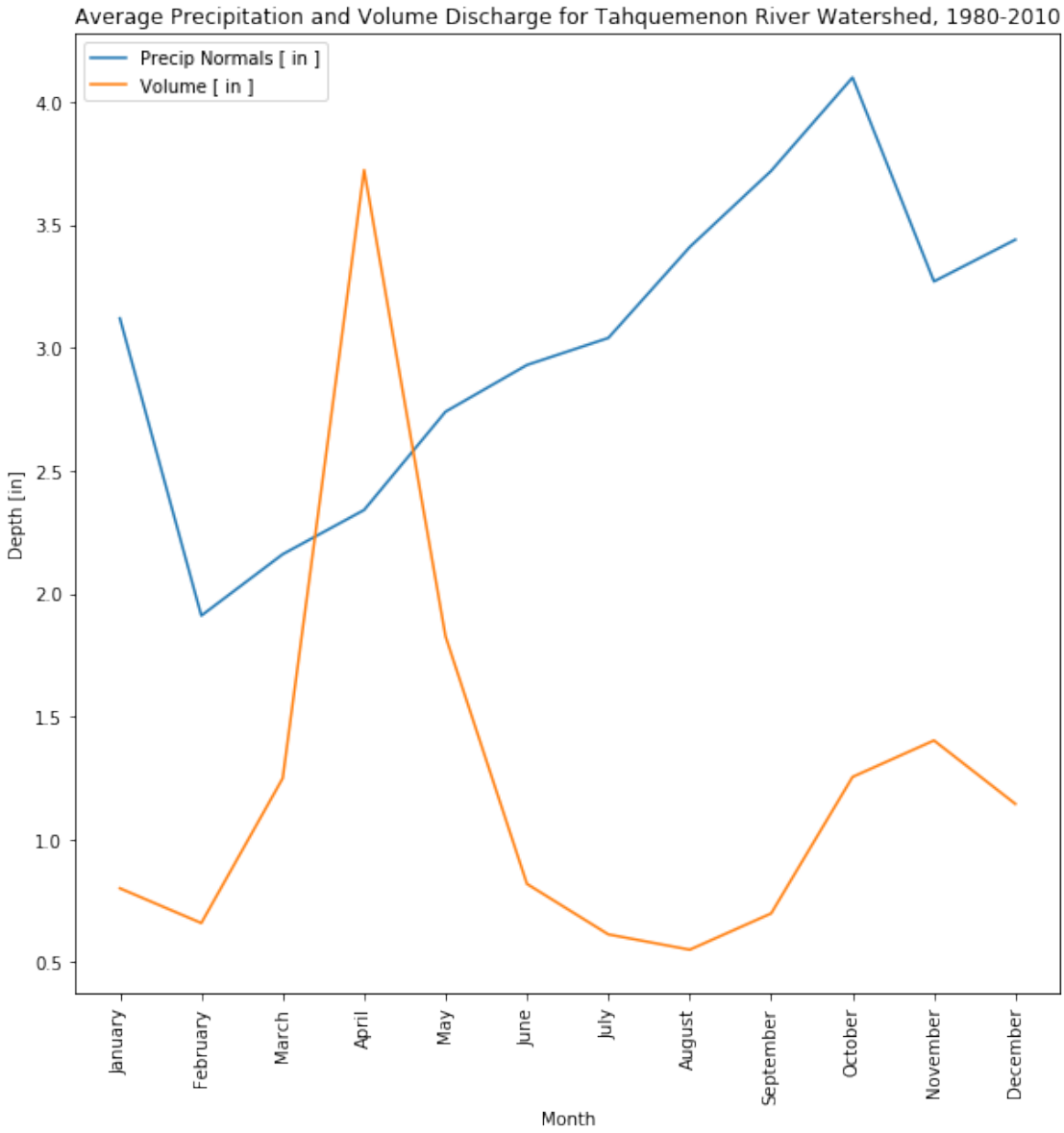
	Precip Normals [in]
January	3.12
February	1.91
March	2.16
April	2.34
May	2.74
June	2.93
July	3.04
August	3.41
September	3.72
October	4.10
November	3.27
December	3.44

Part D) Plot the average monthly precipitation (in inches) and the average monthly discharge (in inches) versus month.

In [117]:
```
fig, ax = plt.subplots(figsize=(10,10))

Precip_Normal.plot(ax=ax,xticks=np.arange(12),legend=True)
Month_str['Volume [ in ]'].plot(ax=ax,xticks=np.arange(12),legend=True)

plt.xticks(rotation='vertical')
plt.ylabel('Depth [in]')
plt.xlabel('Month')
plt.title(
    'Average Precipitation and Volume Discharge for Tahquemenon River\
 Watershed, 1980-2010'
)
plt.show()
```



Part E) Compute the average annual precipitation (in inches).

From the Tahquemon Falls State Park Station report, **annual precipitation is 36.18 inches**. This is confirmed when taking the sum of the monthly averages.

Part F) Compute the average annual discharge (in inches).

Below is a table of the total volume discharge per year. Taking the average of this table, we find that the **average annual discharge is 14.74 inches.**

```
In [99]: Year = Data_Normal.drop(columns=['DaysInMonth','Volume_ft3']).groupby('Year')
```

```
In [99]: Year.sum()

Out[99]:       Mean Value [ cfs ]  Volume [ in ]
         Year
         1981              10196.6      14.57
         1982              13152.0      18.86
         1983              10354.7      14.85
         1984              11219.5      16.05
         1985              12486.7      17.88
         1986               9667.7      13.79
         1987               8357.6      11.99
         1988              11649.8      16.65
         1989               8904.8      12.71
         1990              11330.1      16.25
         1991               9893.3      14.14
         1992              10411.8      14.94
         1993              12254.2      17.56
         1994               9527.6      13.64
         1995               9691.4      13.90
         1996              13820.0      19.87
         1997              10017.1      14.32
         1998               7512.9      10.70
         1999               8631.1      12.29
         2000               6980.8      10.04
         2001              12527.3      17.95
         2002              12118.5      17.36
         2003               9728.4      13.91
         2004              11810.8      16.92
         2005               8804.2      12.57
         2006               8881.9      12.71
         2007               8515.1      12.19
         2008              11128.1      15.94
         2009              10017.8      14.35
         2010               9222.6      13.21

In [87]: Year.sum().mean()

Out[87]: Mean Value [ cfs ]    10293.8
         Volume [ in ]            14.74
         dtype: float64
```

Part G) Compute the average annual evapotranspiration (in inches) using the long-term water budget assumption.

The long-term water budget assumption is that precipitation is equal to the sum of the basin's evapotranspiration and the surface (river) discharge, or

$$P = E + Q_0$$

Solving for our evapotranspiration term, E:

$$E = P - Q_0$$

Plugging in our numbers to this equation we find that:

$$E = 36.18 - 14.74$$

$$E = 21.44 inches$$

Part H) Compute the runoff coefficient (i.e., annual discharge as a fraction of precipitation), in percent.

$$C_{runoff} = \frac{Depth_{discharge}}{Depth_{precipitation}} * 100\%$$

$$C_{runoff} = \frac{14.74}{36.18} * 100\%$$

$$C_{runoff} = 41.74\%$$

Considering that this watershed is almost completely forested in a national forest and state park, it makes sense that the number would be lower.

Note: Streamstats isn't available in Michigan.