Assignment 4: Physical Properties of Rivers

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OVERVIEW

This exercise accompanies the lessons in Water Data Analytics on the physical properties of rivers.

Directions

1. Change "Student Name" on line 3 (above) with your name.
2. Work through the steps, **creating code and output** that fulfill each instruction.
3. Be sure to **answer the questions** in this assignment document.
4. When you have completed the assignment, **Knit** the text and code into a single PDF file.
5. After Knitting, check your PDF against the key and then submit your assignment completion survey at https://forms.gle/futQwtCsyYsZG9nCA

Having trouble? See the assignment's answer key if you need a hint. Please try to complete the assignment without the key as much as possible - this is where the learning happens!

Target due date: 2022-02-15

Setup and Data Processing

1. Verify your working directory is set to the R project file. Load the tidyverse, cowplot, dataRetrieval, lubridate, lfstat, and EcoHydRology packages. Set your ggplot theme (can be theme_classic or something else).
2. Acquire daily mean discharge data for the Bitterroot River in Montana (USGS gage 12344000) and the Nehalem River in Oregon (USGS gage 14299800). Collect the 10 most recent complete water years.
3. Add columns in the dataset for water year, baseflow, and stormflow. Feel free to use either baseflow separation function we used in class.
4. Calculate annual total discharge, annual baseflow, and annual proportion baseflow for the two sites.

```
#1
getwd()
```

```
## [1] "/Users/ataliefischer/Desktop/WDA/Water_Data_Analytics_2022/Assignments"
```

```
library(EcoHydRology)
```

```
## Loading required package: operators
```

```
##
## Attaching package: 'operators'
```

```
## The following objects are masked from 'package:base':
##
##     options, strrep
```

```
## Loading required package: topmodel
```

```
## Loading required package: DEoptim
```

```
## Loading required package: parallel
```

```
##
## DEoptim package
## Differential Evolution algorithm in R
## Authors: D. Ardia, K. Mullen, B. Peterson and J. Ulrich

## Loading required package: XML
```

```
library(tidyverse)
```

```
## -- Attaching packages --------------------------------------- tidyverse 1.3.1 --

## v ggplot2 3.3.5     v purrr   0.3.4
## v tibble  3.1.4     v dplyr   1.0.7
## v tidyr   1.1.3     v stringr 1.4.0
## v readr   2.0.1     v forcats 0.5.1

## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x forcats::%>%()  masks stringr::%>%(), dplyr::%>%(), purrr::%>%(), tidyr::%>%(), tibble::%>%(), ope
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
```

```
library(cowplot)
library(dataRetrieval)
library(lubridate)
```

```
##
## Attaching package: 'lubridate'

## The following object is masked from 'package:cowplot':
##
##     stamp

## The following objects are masked from 'package:base':
##
##     date, intersect, setdiff, union
```

```
library(lfstat)
```

```
## Loading required package: xts

## Loading required package: zoo

##
## Attaching package: 'zoo'

## The following objects are masked from 'package:base':
##
##     as.Date, as.Date.numeric

##
## Attaching package: 'xts'

## The following objects are masked from 'package:dplyr':
##
##     first, last

## Loading required package: lmom

## Loading required package: lattice

##
## Attaching package: 'lfstat'
```

```
## The following object is masked from 'package:EcoHydRology':
##
##     hydrograph
```

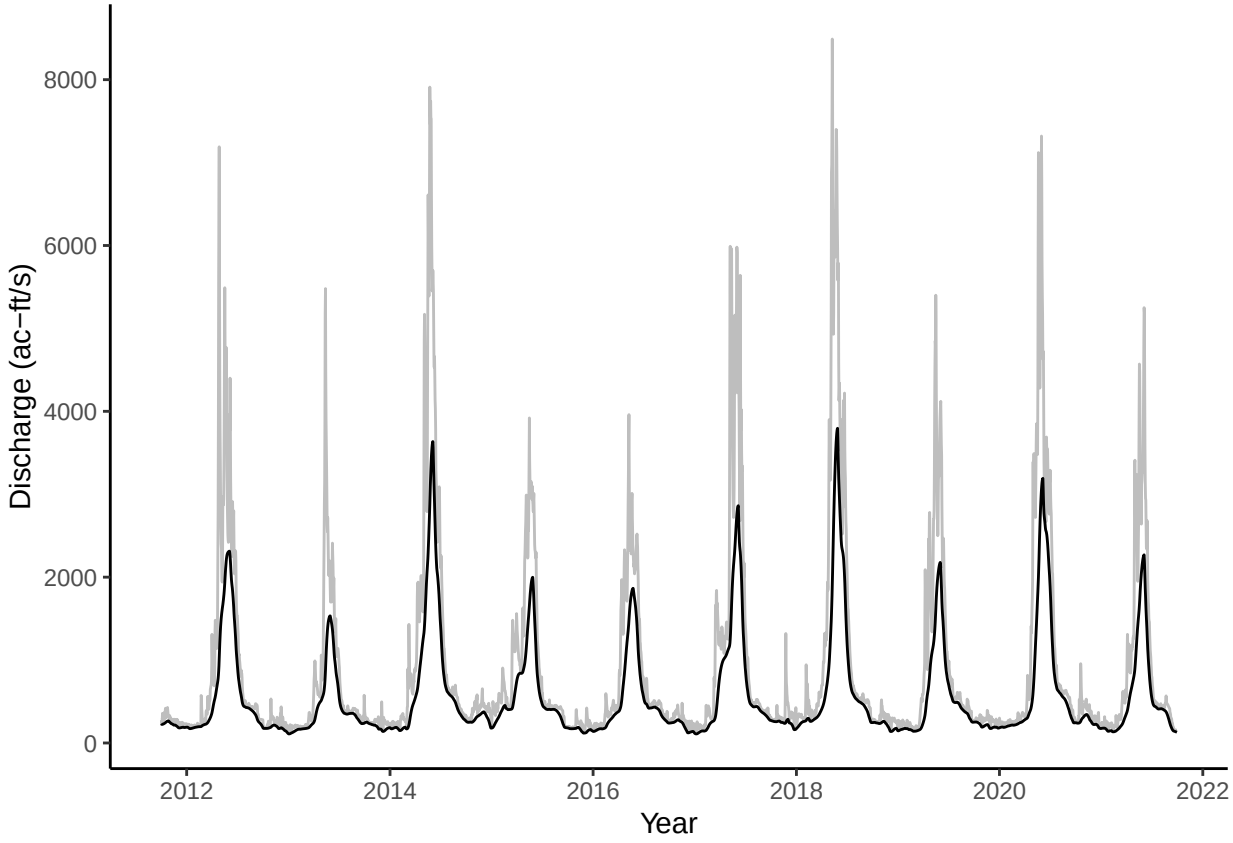
```
theme_set(theme_classic())

#2
BitterrootDischarge <- readNWISdv(siteNumbers = "12344000",
                     parameterCd = "00060", # discharge (ft3/s)
                     startDate = "2011-10-01",
                     endDate = "2021-09-30")
names(BitterrootDischarge)[4:5] <- c("Discharge", "Approval.Code")

NehalemDischarge <- readNWISdv(siteNumbers = "14299800",
                     parameterCd = "00060", # discharge (ft3/s)
                     startDate = "2011-10-01",
                     endDate = "2021-09-30")
names(NehalemDischarge)[4:5] <- c("Discharge", "Approval.Code")

#3) Finding baseflow using EcoHydro Package...
BitterrootDischarge <- mutate(BitterrootDischarge, WaterYear = water_year(Date))
BitterrootDischarge$WaterYear <- as.numeric(as.character(BitterrootDischarge$WaterYear))

BitterrootDischarge <- drop_na(BitterrootDischarge)
BitterrootDischarge_basesep_EcoHydro <- BaseflowSeparation(BitterrootDischarge$Discharge)
BitterrootDischarge <- cbind(BitterrootDischarge, BitterrootDischarge_basesep_EcoHydro)

NehalemDischarge <- mutate(NehalemDischarge, WaterYear = water_year(Date))
NehalemDischarge$WaterYear <- as.numeric(as.character(NehalemDischarge$WaterYear))

NehalemDischarge_basesep_EcoHydro <- BaseflowSeparation(NehalemDischarge$Discharge)
NehalemDischarge <- cbind(NehalemDischarge, NehalemDischarge_basesep_EcoHydro)

#4) using baseflow from EcoHydro Package...ERROR: in UseMethod("tbl_vars") :
#  no applicable method for 'tbl_vars' applied to an object of class "function"
## NEED TO LOAD ECOHYDROLOGY PACKAGE BEFORE THE TIDYVERSE PACKAGE!!!

BitterrootDischarge_summary <- BitterrootDischarge %>%
  group_by(WaterYear) %>%
  summarise(AnnualDischarge = sum(Discharge, na.rm = TRUE)*723.968,
            AnnualBaseflow = sum(bt, na.rm = TRUE)*723.968,
            BaseflowProportion = AnnualBaseflow/AnnualDischarge) %>%
  mutate_if(is.numeric, round, 2)

NehalemDischarge_summary <- NehalemDischarge %>%
  group_by(WaterYear) %>%
  summarise(AnnualDischarge = sum(Discharge, na.rm = TRUE)*723.968,
            AnnualBaseflow = sum(bt, na.rm = TRUE)*723.968,
            BaseflowProportion = AnnualBaseflow/AnnualDischarge) %>%
  mutate_if(is.numeric, round, 2)
```

Analyze seasonal patterns in discharge

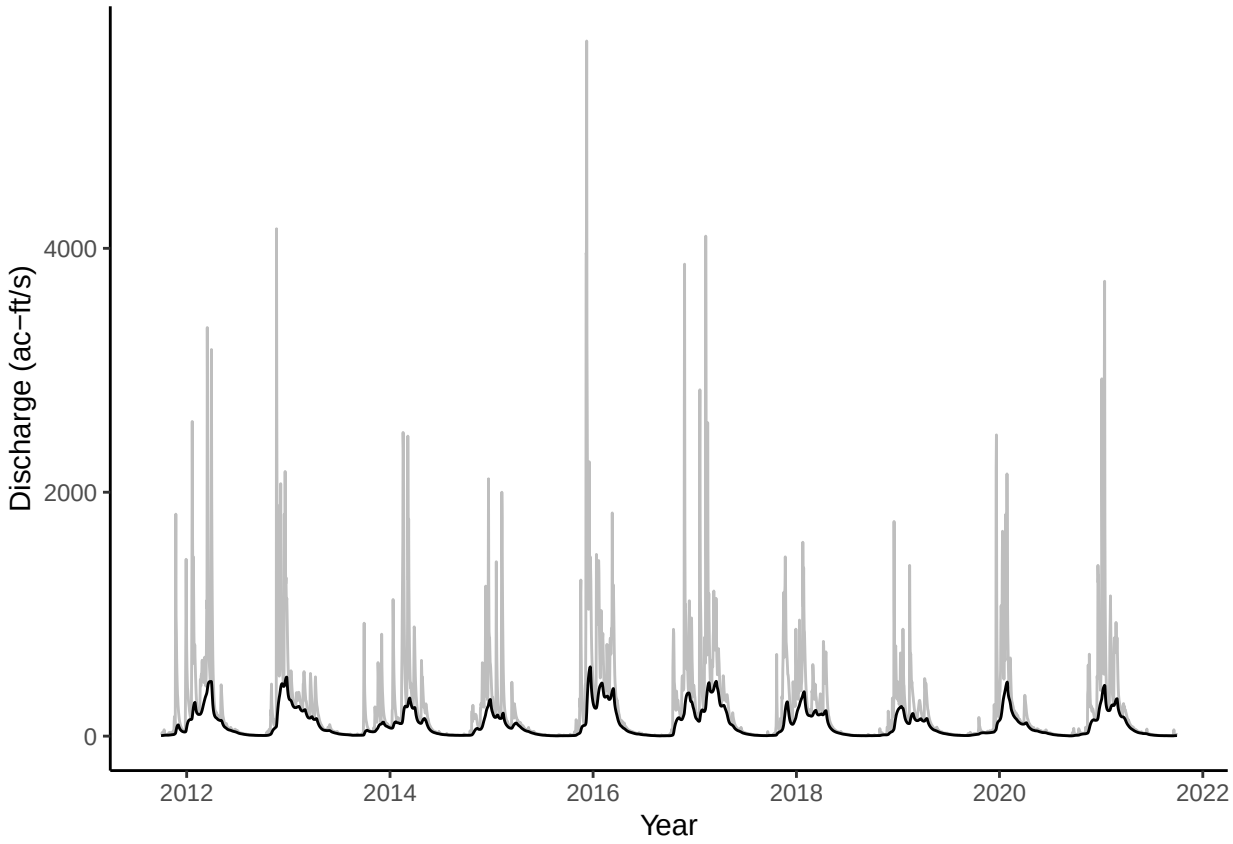
5. For both sites, create a graph displaying discharge and baseflow by date. Adjust axis labels accordingly.

6. For both sites, create a graph displaying annual total discharge and annual baseflow across years, and a second graph displaying the proportion baseflow across years (adjust axis labels accordingly). Plot these graphs on top of one another using `plot_grid`. Remember to align the axes!

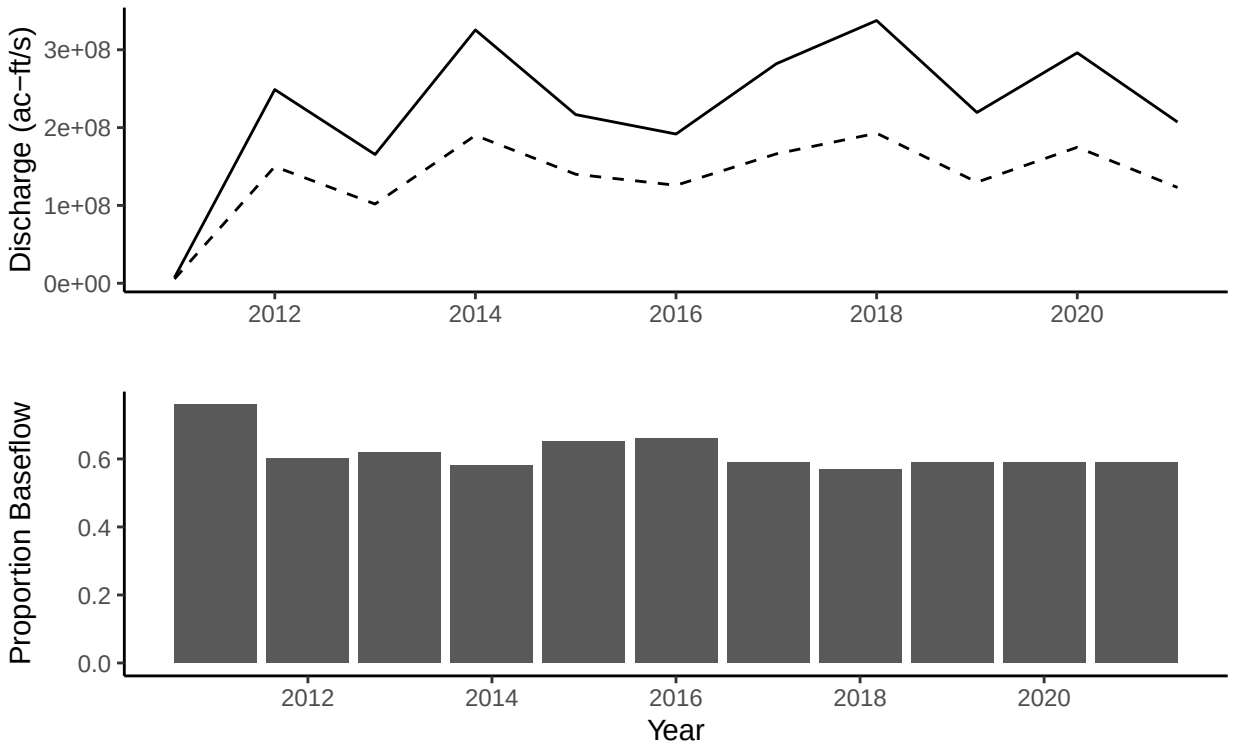
```
#5
Bitterroot_daily.discharge.plot <- ggplot(BitterrootDischarge, aes(x = Date)) +
  geom_line(aes(y = Discharge), color = "grey") +
  geom_line(aes(y = bt), color = "black") +
  labs(x = "Year", y = "Discharge (ac-ft/s)")
print(Bitterroot_daily.discharge.plot)
```



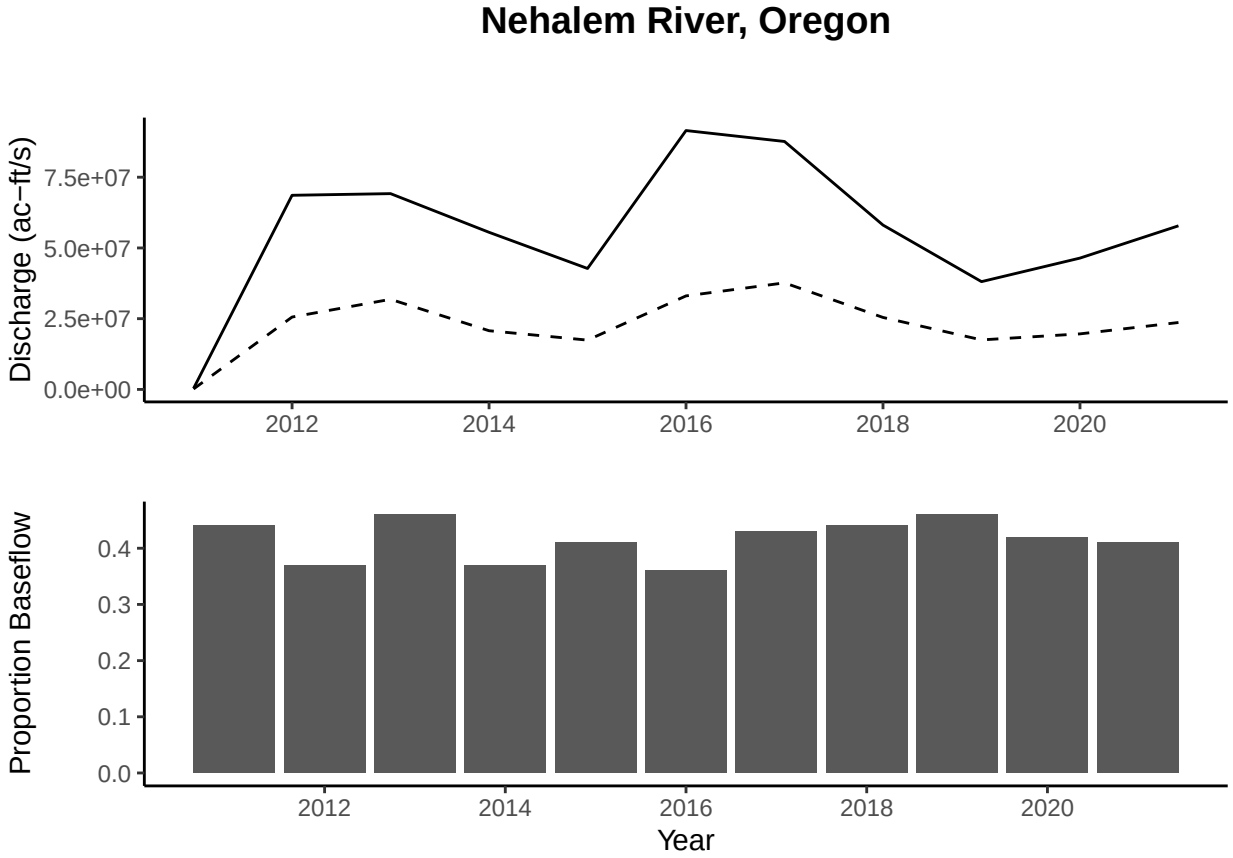

```
Nehalem_daily.discharge.plot <- ggplot(NehalemDischarge, aes(x = Date)) +
  geom_line(aes(y = Discharge), color = "grey") +
  geom_line(aes(y = bt), color = "black") +
  labs(x = "Year", y = "Discharge (ac-ft/s)")
print(Nehalem_daily.discharge.plot)
```




```
#6
Bitterroot_discharge.plot <- ggplot(BitterrootDischarge_summary, aes(x = WaterYear)) +
  geom_line(aes(y = AnnualDischarge)) +
  geom_line(aes(y = AnnualBaseflow), lty = 2) +
  labs(x = " ", y = "Discharge (ac-ft/s)") +
  scale_x_continuous(breaks = c(2012, 2014, 2016, 2018, 2020, 2022))

Bitterroot_prop.baseflow.plot <- ggplot(BitterrootDischarge_summary, aes(x = WaterYear)) +
  geom_col(aes(y = BaseflowProportion)) +
  labs(x = "Year", y = "Proportion Baseflow") +
  scale_x_continuous(breaks = c(2012, 2014, 2016, 2018, 2020, 2022))

Bitterroot_title <- ggdraw() +
  draw_label("Bitterroot River, Montana", fontface='bold')

Bitterroot_combinedplot <- plot_grid(Bitterroot_title, Bitterroot_discharge.plot, Bitterroot_prop.basefl
                                     ncol = 1, nrow = 3, rel_heights = c(0.25, 1, 1),
                                     align = 'hv')
print(Bitterroot_combinedplot)
```




```
Nehalem_discharge.plot <- ggplot(NehalemDischarge_summary, aes(x = WaterYear)) +
  geom_line(aes(y = AnnualDischarge)) +
  geom_line(aes(y = AnnualBaseflow), lty = 2) +
  labs(x = " ", y = "Discharge (ac-ft/s)") +
  scale_x_continuous(breaks = c(2012, 2014, 2016, 2018, 2020, 2022))

Nehalem_prop.baseflow.plot <- ggplot(NehalemDischarge_summary, aes(x = WaterYear)) +
  geom_col(aes(y = BaseflowProportion)) +
  labs(x = "Year", y = "Proportion Baseflow") +
  scale_x_continuous(breaks = c(2012, 2014, 2016, 2018, 2020, 2022))

Nehalem_title <- ggdraw() +
  draw_label("Nehalem River, Oregon", fontface='bold')

Nehalem_combined.plot <- plot_grid(Nehalem_title, Nehalem_discharge.plot, Nehalem_prop.baseflow.plot,
                                   ncol = 1, nrow = 3, rel_heights = c(0.25, 1, 1),
                                   align = 'hv')
print(Nehalem_combined.plot)
```



7. How do these rivers differ in their discharge and baseflow, both within and across years? How would you attribute these patterns to the climatic conditions in these locations?

   The Bitterroot River has a discharge magnitude on the order of 200 - 300 million acre-feet per second and a baseflow between 100 to 200 million acre-feet per second. The Nehalem River has a lower discharge, ranging between 50 and 80 million acre-feet per second, and a baseflow around 25 million acre-feet per second. The Bitterroot River has greater variability, with many more peaks and troughs within the 10-year span of the dataset compared to the Nehalem River. The greater variability in discharge of the Bitterroot River is likely due to the domination of snowmelt in the system. The Nehalem River, on the other hand, is more dominated by broader climatic variations of drought approximately every 5 years. The Bitterroot River has a higher proportion of baseflow at approximately 0.6 compared to the Nehalem River at approximately 0.4. This suggests that the Nehalem River is directly influenced by precipitation events more than the Bitterroot River, which is likely more influenced by groundwater recharge than the Nehalem River.