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 Setup
#verify working directory
getwd()
```

```
## [1] "/Users/Jack/Documents/Duke/Spring 2022/Water Data Analytics/Water_Data_Analytics_2022/Assignment
```

```
#load packages
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
```

```r
#set theme
theme_set(theme_half_open(12))

#2 Load Data
BitterrootDischarge <- readNWISdv(siteNumbers = "12344000",
                                   parameterCd = "00060", #discharge cfs
                                   startDate = "2011-10-01",
                                   endDate = "2021-09-30")
NehalemDischarge <- readNWISdv(siteNumbers = "14299800",
                                parameterCd = "00060",
                                startDate = "2011-10-01",
                                endDate = "2021-09-30")

names(BitterrootDischarge)[4:5] <- c("Discharge", "Approval Code")
names(NehalemDischarge)[4:5] <- c("Discharge", "Approval Code")

#3 Add columns
BitterrootDischarge <- BitterrootDischarge %>%
  mutate(WaterYear = water_year(Date),
         Baseflow = baseflow(Discharge),
         Stormflow = Discharge - Baseflow)
#change WaterYear to numeric
BitterrootDischarge$WaterYear <-
  as.numeric(as.character(BitterrootDischarge$WaterYear))
class(BitterrootDischarge$WaterYear)
```

```
## [1] "numeric"
```

```r
NehalemDischarge <- NehalemDischarge %>%
  mutate(WaterYear = water_year(Date),
         Baseflow = baseflow(Discharge),
         Stormflow = Discharge - Baseflow)
# change WaterYear to numeric
NehalemDischarge$WaterYear <-
  as.numeric(as.character(NehalemDischarge$WaterYear))
class(NehalemDischarge$WaterYear)
```

```
## [1] "numeric"
```

```r
#4 Calculate annual values
BitterrootSummary <- BitterrootDischarge %>%
  group_by(WaterYear) %>%
  summarise(Discharge.acft.year = sum(Discharge, na.rm = TRUE)*723.968,
            Baseflow.acft.year = sum(Baseflow, na.rm = TRUE)*723.968,
            prop.bf = Baseflow.acft.year/Discharge.acft.year) %>%
  mutate_if(is.numeric, round, 2)
# cfs*723.968 = acre-feet
NehalemSummary <- NehalemDischarge %>%
  group_by(WaterYear) %>%
```

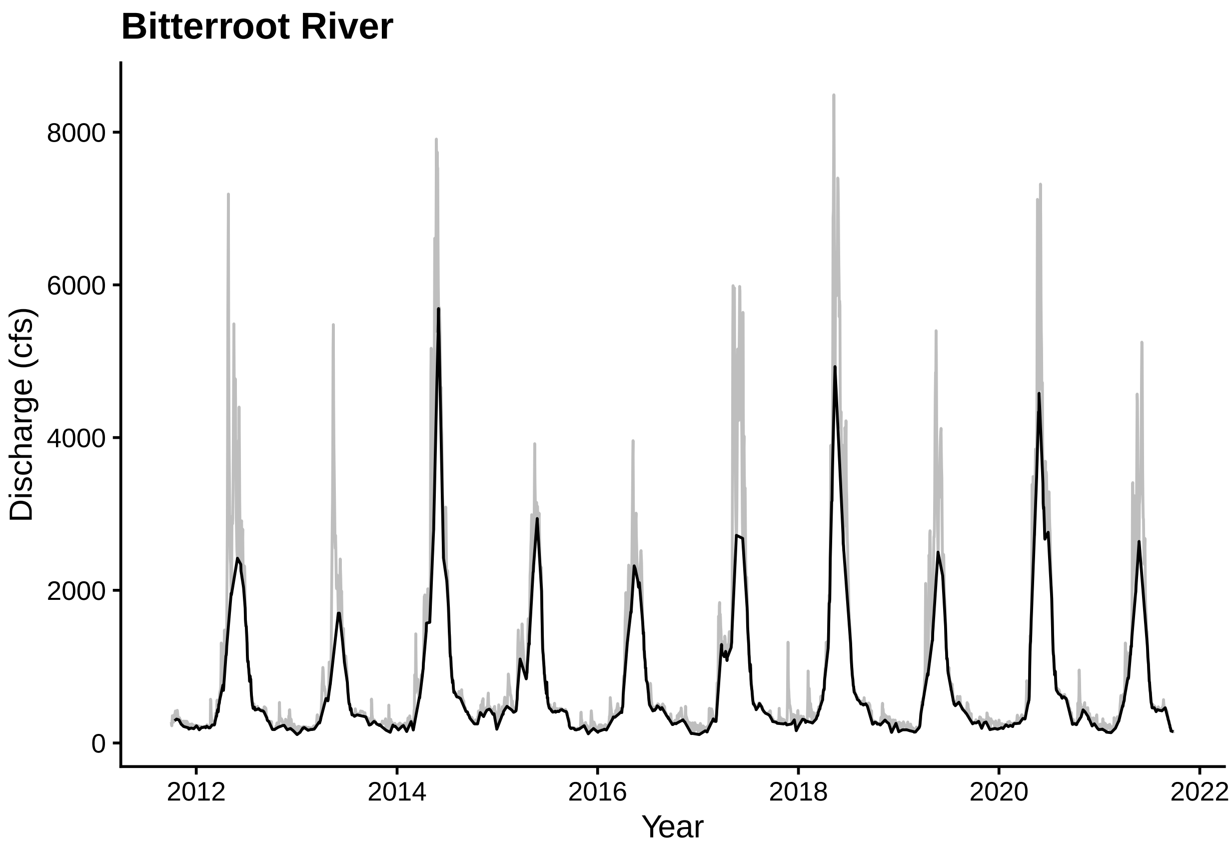
```r
  summarise(Discharge.acft.year = sum(Discharge, na.rm = TRUE)*723.968,
            Baseflow.acft.year = sum(Baseflow, na.rm = TRUE)*723.968,
            prop.bf = Baseflow.acft.year/Discharge.acft.year) %>%
  mutate_if(is.numeric, round, 2)
```

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!

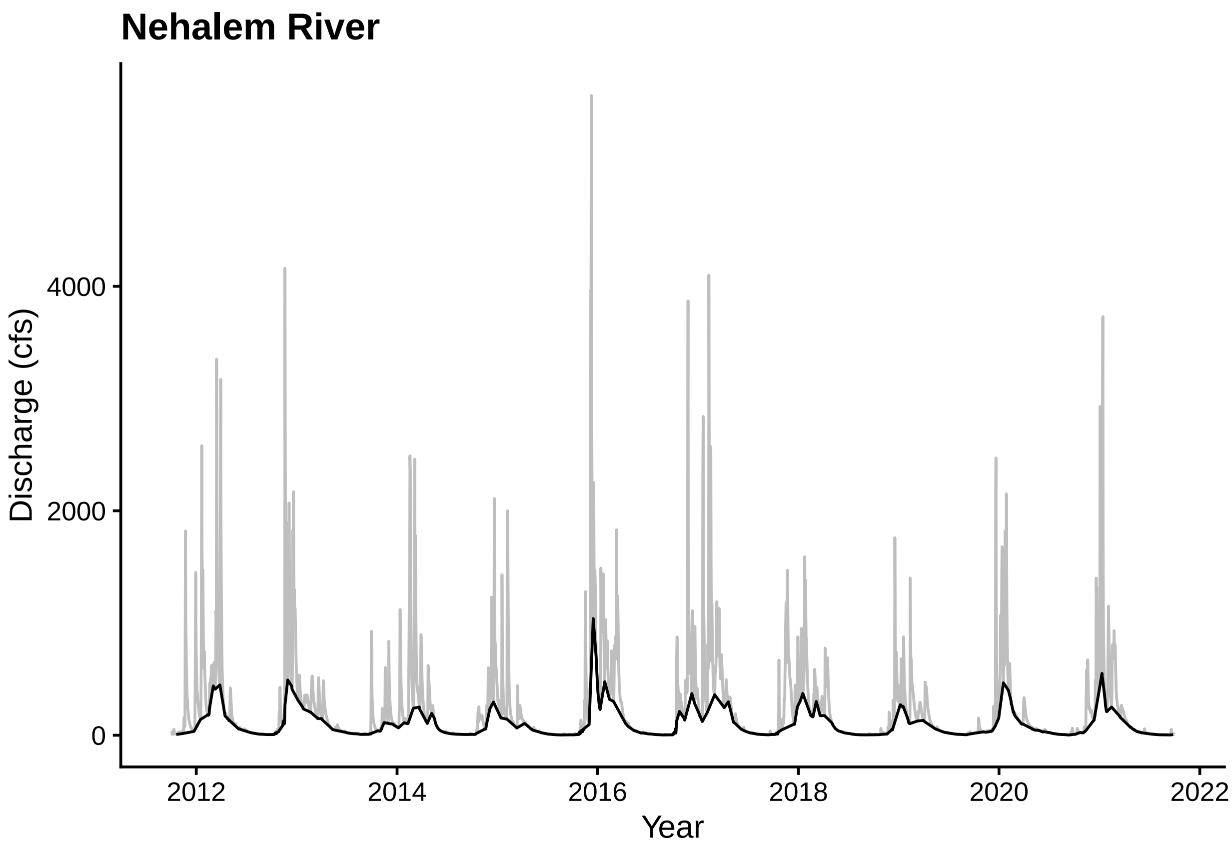
```r
#5 ggplots discharge, baseflow x date
ggplot(BitterrootDischarge, aes(x = Date, y = Discharge)) +
  geom_line(color = "grey") +
  geom_line(aes(y = Baseflow)) +
  labs(x = "Year", y = "Discharge (cfs)", title = "Bitterroot River")
```

```
## Warning: Removed 16 row(s) containing missing values (geom_path).
```

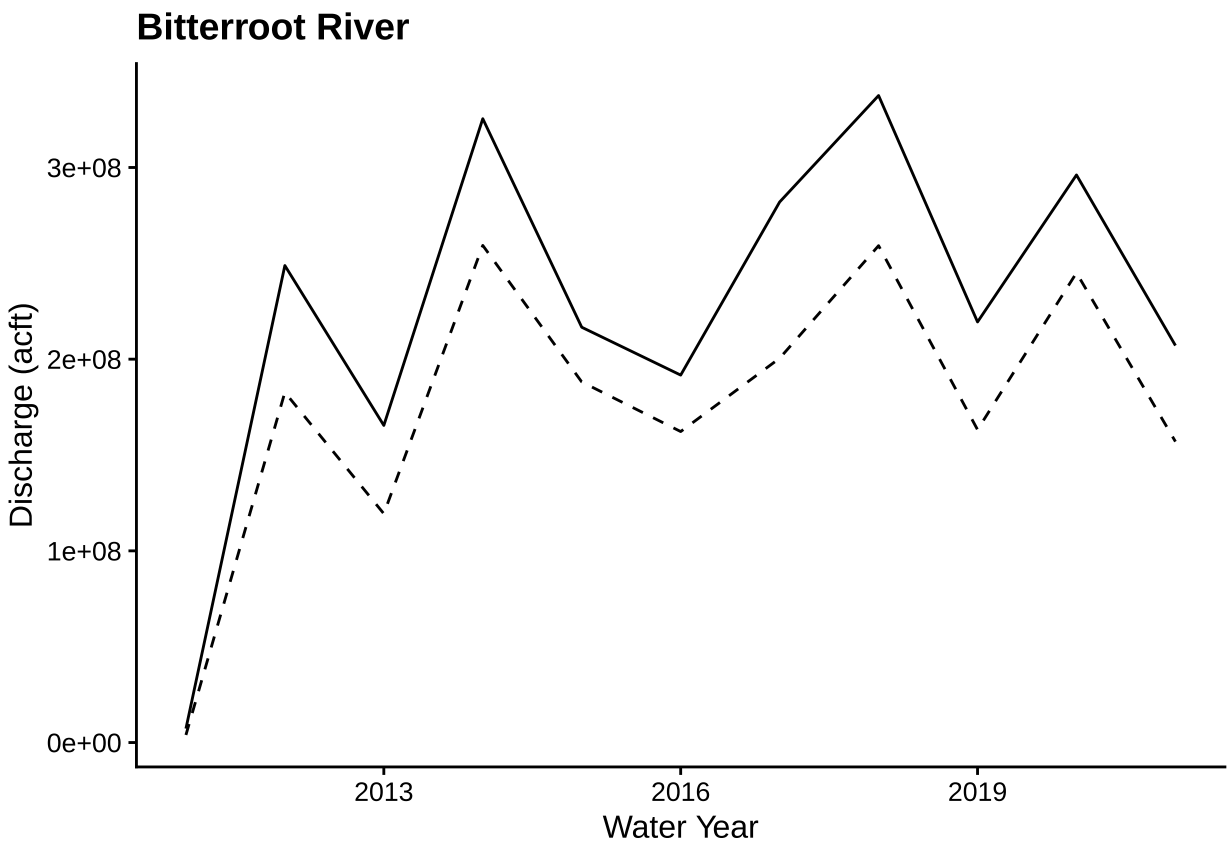



```r
ggplot(NehalemDischarge, aes(x = Date, y = Discharge)) +
  geom_line(color = "grey") +
  geom_line(aes(y = Baseflow)) +
  labs(x = "Year", y = "Discharge (cfs)", title = "Nehalem River")
```

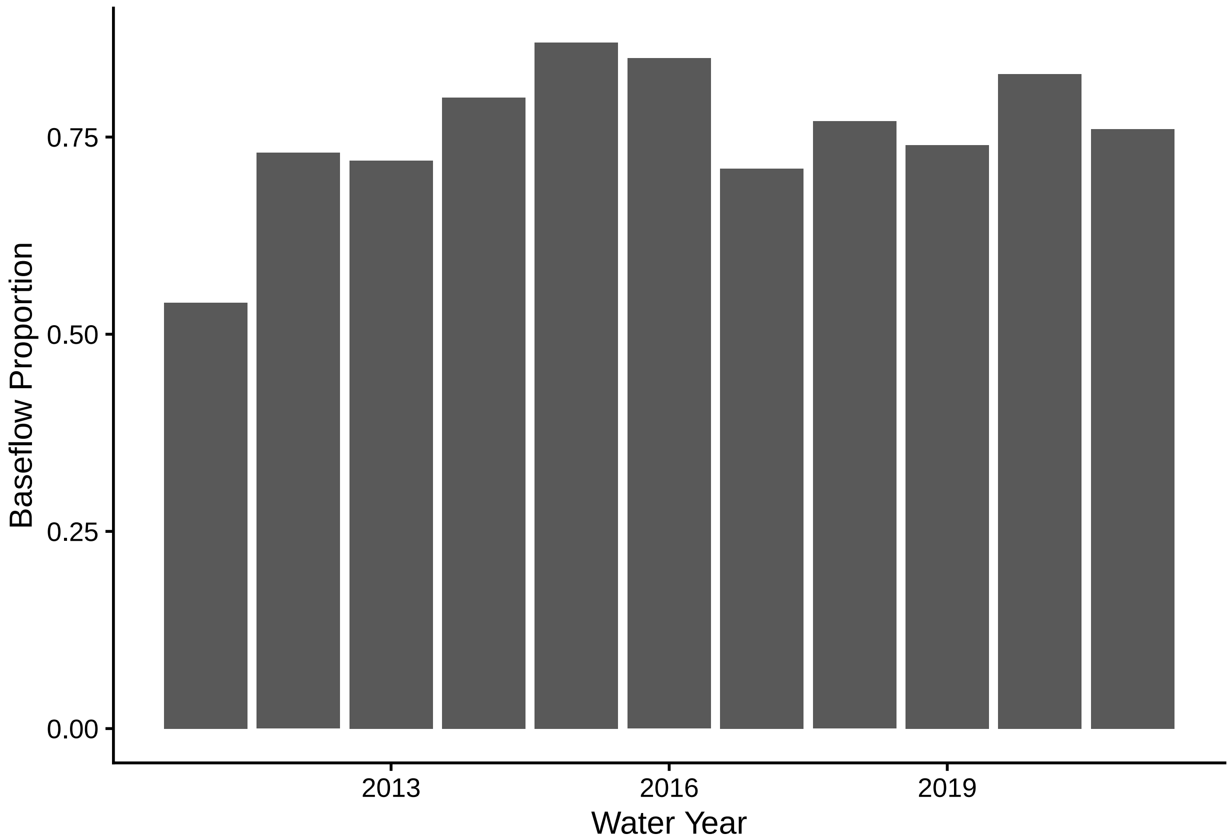
```
## Warning: Removed 23 row(s) containing missing values (geom_path).
```



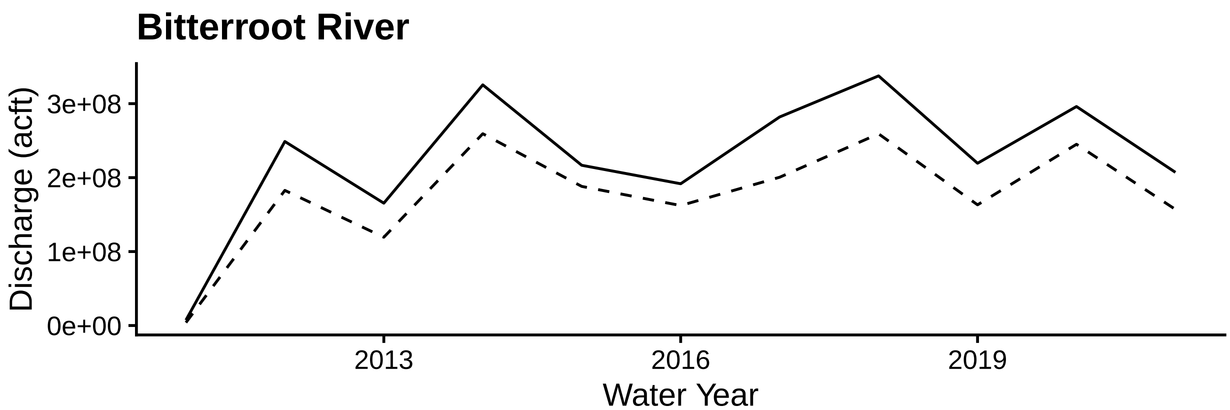

```r
#6 ggplots annual values
Bitterroot.Annualplot <- ggplot(BitterrootSummary,
                                 aes(x = WaterYear,
                                     y = Discharge.acft.year)) +
  geom_line() +
  geom_line(aes(y = Baseflow.acft.year), lty = 2) +
  labs(x = "Water Year",
       y = "Discharge (acft)",
       title = "Bitterroot River")
Bitterroot.Annualplot
```

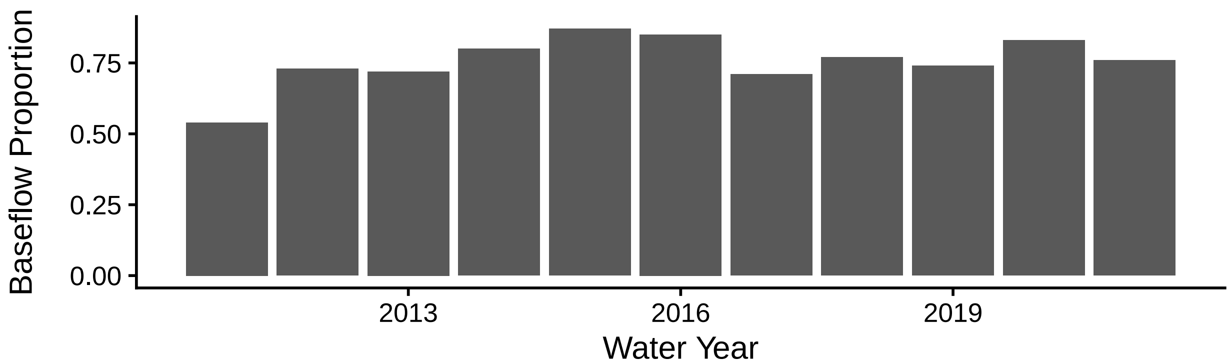



```
Bitterroot.Propplot <- ggplot(BitterrootSummary,
                              aes(x = WaterYear, y = prop.bf)) +
  geom_col() +
  labs(x = "Water Year", y = "Baseflow Proportion")
Bitterroot.Propplot
```

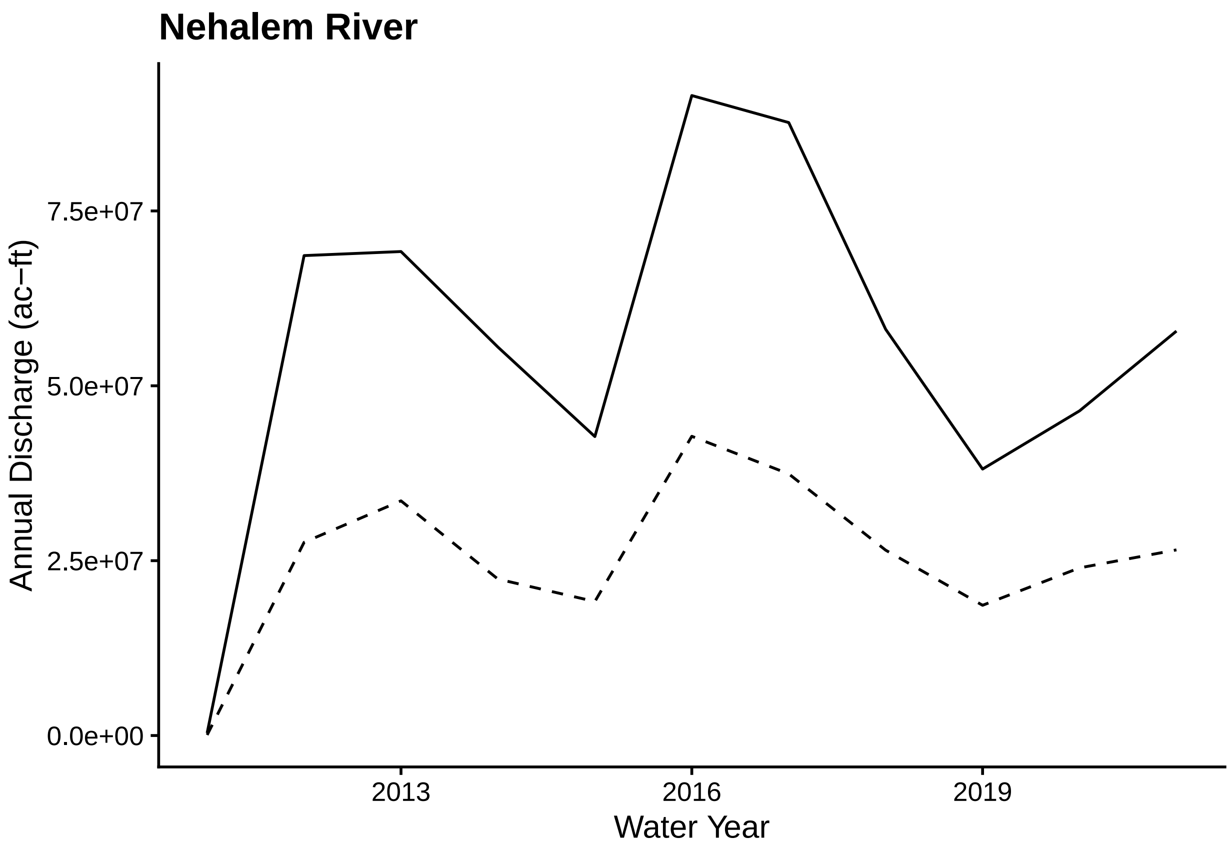



```
plot_grid(Bitterroot.Annualplot, Bitterroot.Propplot,
          align = "hv",
          ncol = 1)
```

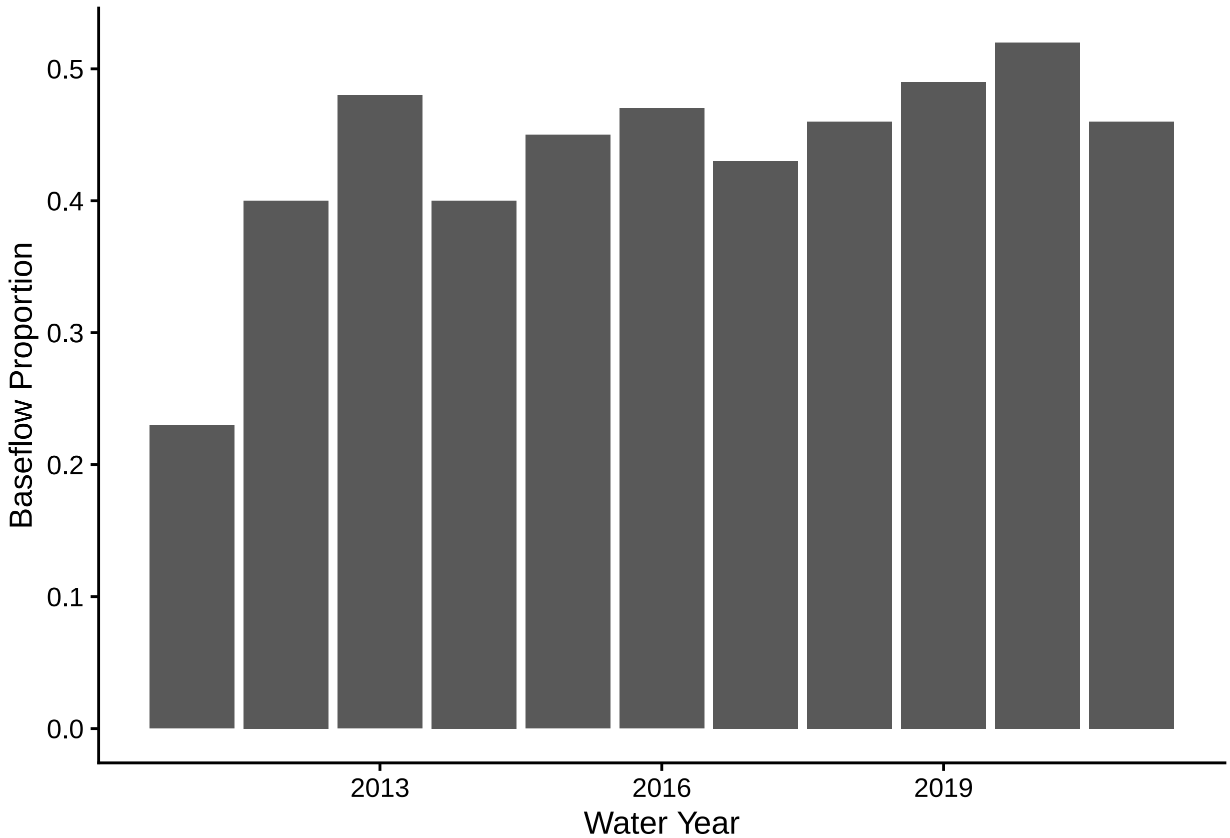




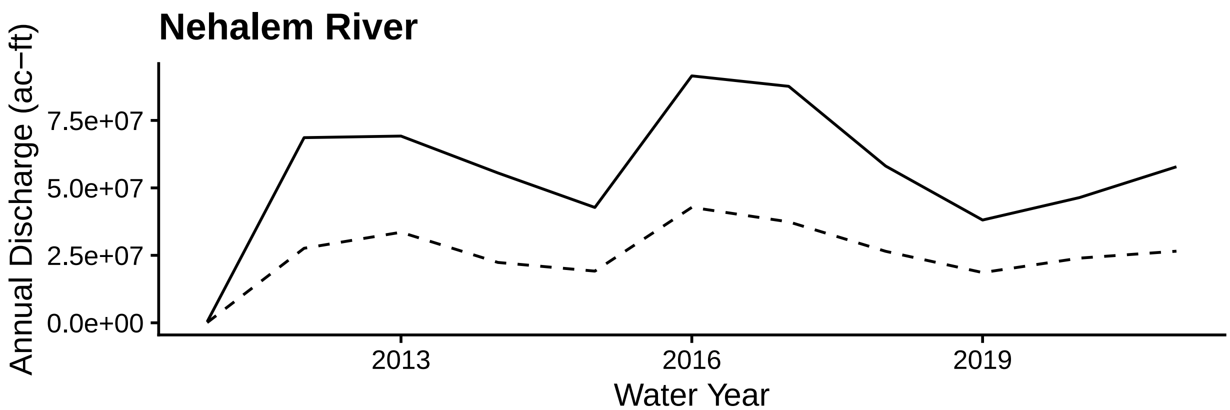

```
Nehalem.Annualplot <- ggplot(NehalemSummary,
                             aes(x = WaterYear,
                                 y = Discharge.acft.year)) +
  geom_line() +
  geom_line(aes(y = Baseflow.acft.year), lty = 2) +
  labs(x = "Water Year",
       y = "Annual Discharge (ac-ft)",
       title = "Nehalem River")
Nehalem.Annualplot
```

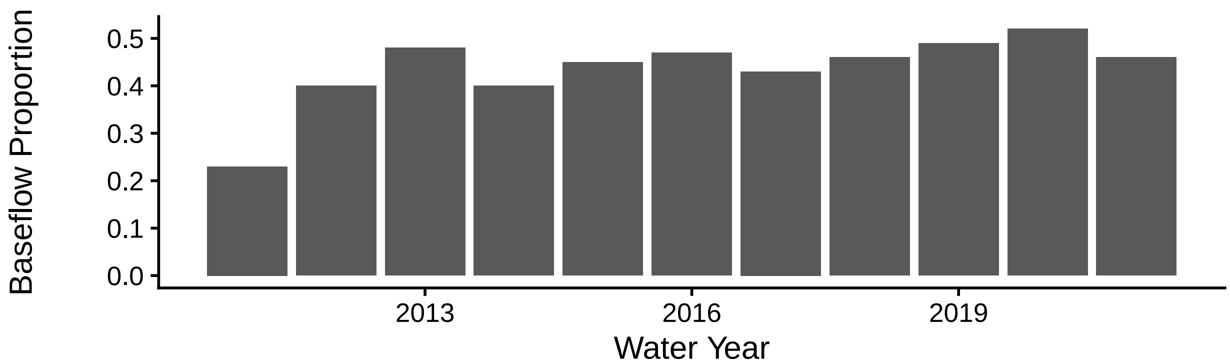



```
Nehalem.Propplot <- ggplot(NehalemSummary,
                            aes(x = WaterYear, y = prop.bf)) +
  geom_col() +
  labs(x = "Water Year", y = "Baseflow Proportion")
Nehalem.Propplot
```




```
plot_grid(Nehalem.Annualplot, Nehalem.Propplot,
  align = "vh",
  ncol = 1)
```





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 has more seasonal and annual variability than the Nehalem, and also has a higher proportion of baseflow. The baseflow is roughyl 3/4 of total and tracks closely to the total discharge, so a lower snow year (or years consecutive) can have a large impact on both baseflow and total discharge for that year. The seasonal and annual pattern for the Nehalem is generally less variable seasonally and annually, and also has a much lower proportion baseflow, indicative of the fact that the discharge river is more dependent on precipitation than highly seasonal runoff.