Assignment 8: Mapping

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OVERVIEW

This exercise accompanies the lessons in Hydrologic Data Analysis on mapping

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, submit the completed exercise (pdf file) to the dropbox in Sakai. Add your last name into the file name (e.g., "A08_Salk.html") prior to submission.

The completed exercise is due on 23 October 2019 at 9:00 am.

Setup

1. Verify your working directory is set to the R project file,
2. Load the tidyverse, lubridate, cowplot, LAGOSNE, sf, maps, and viridis packages.
3. Set your ggplot theme (can be theme_classic or something else)
4. Load the lagos database, the USA rivers water features shape file, and the HUC6 watershed shape file.

```
getwd()
```

```
## [1] "/Users/lindsayroth/Documents/MEM 2nd Year/HydroData/Hydrologic_Data_Analysis"
```

```
library(tidyverse)
```

```
## -- Attaching packages ------------------------------------------------------------------------ tidyve

## v ggplot2 3.2.1     v purrr   0.3.2
## v tibble  2.1.3     v dplyr   0.8.3
## v tidyr   1.0.0     v stringr 1.4.0
## v readr   1.3.1     v forcats 0.4.0

## -- Conflicts --------------------------------------------------------------------------- tidyverse_c
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
```

```
library(lubridate)
```

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

## The following object is masked from 'package:base':
##
##     date
```

```
library(cowplot)
```

```
##
## ********************************************************
```

```
## Note: As of version 1.0.0, cowplot does not change the
##   default ggplot2 theme anymore. To recover the previous
##   behavior, execute:
##   theme_set(theme_cowplot())
## ********************************************************
##
## Attaching package: 'cowplot'
## The following object is masked from 'package:lubridate':
##
##     stamp
```

```
library(LAGOSNE)
library(sf)
```

```
## Linking to GEOS 3.7.2, GDAL 2.4.2, PROJ 5.2.0
```

```
library(maps)
```

```
##
## Attaching package: 'maps'
## The following object is masked from 'package:purrr':
##
##     map
```

```
library(viridis)
```

```
## Loading required package: viridisLite
```

```
library(RColorBrewer)

theme_set(theme_classic())

LAGOSdata <- lagosne_load()
```

```
## Warning in `_f`(version = version, fpath = fpath): LAGOSNE version
## unspecified, loading version: 1.087.3
```

```
waterfeatures <- st_read("./Data/Raw/hydrogl020.dbf")
```

```
## Reading layer `hydrogl020' from data source `/Users/lindsayroth/Documents/MEM 2nd Year/HydroData/Hyd
## Simple feature collection with 76975 features and 12 fields
## geometry type:  LINESTRING
## dimension:      XY
## bbox:           xmin: -179.9982 ymin: 17.67469 xmax: 179.9831 ymax: 71.39819
## epsg (SRID):    NA
## proj4string:    NA
```

```
HUC6 <- st_read("./Data/Raw/Watersheds_Spatial/WBDHU6.dbf")
```

```
## Reading layer `WBDHU6' from data source `/Users/lindsayroth/Documents/MEM 2nd Year/HydroData/Hydrolo
## Simple feature collection with 33 features and 15 fields
## geometry type:  MULTIPOLYGON
## dimension:      XY
## bbox:           xmin: -90.6235 ymin: 24.39533 xmax: -75.3981 ymax: 37.52103
## epsg (SRID):    4269
```

```
## proj4string:    +proj=longlat +ellps=GRS80 +towgs84=0,0,0,0,0,0,0 +no_defs
```

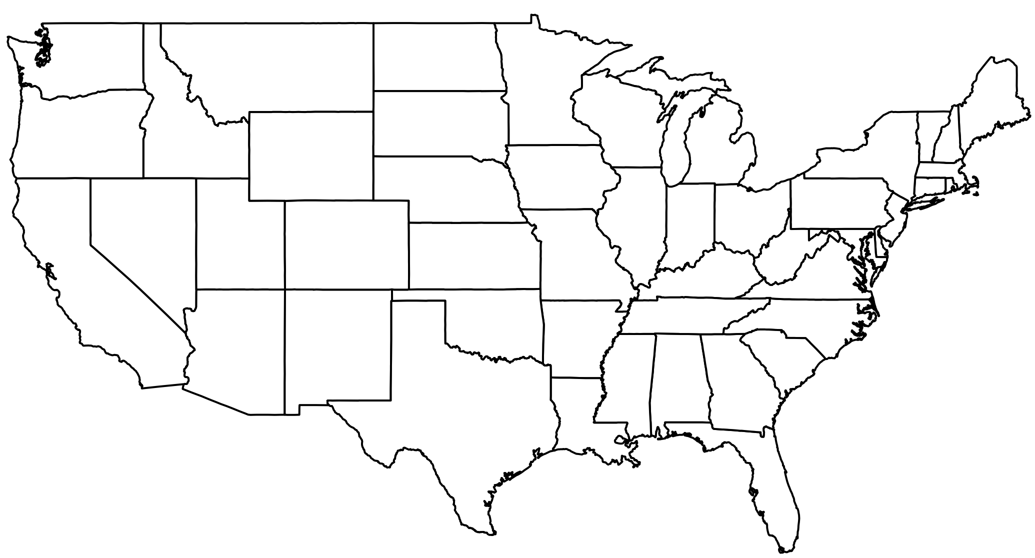
Mapping water quality in lakes

Complete the in-class exercise from lesson 15, to map average secchi depth measurements across states in Maine, considering lake area and lake depth as predictors for water clarity. Steps here are identical to the lesson, with the following edits:

- Make sure all your wrangling is done in this document (this includes basic wrangling of the LAGOS database)
- In your cowplot, do not adjust the legend items (even though they look ugly). Rather, reflect on how you would improve them with additional coding.
- For item 9, **do** run a regression on secchi depth by lake area and a separate regression on secchi depth by lake depth. Make scatterplots of these relationships. Note that log-transforming one of these items may be necessary.

5. Filter the states and secchi depth datasets so that they contain Maine only. For the secchi depth dataset, create a summary dataset with just the mean secchi depth.

```
states <- st_as_sf(map(database = "state", plot = TRUE, fill = TRUE, col = "white"))
```



```
LAGOSlocus <- LAGOSdata$locus
LAGOSstate <- LAGOSdata$state
LAGOSnutrient <- LAGOSdata$epi_nutr
LAGOSlimno <- LAGOSdata$lakes_limno
```

```r
LAGOScombined <-
  left_join(LAGOSnutrient, LAGOSlocus) %>%
  left_join(., LAGOSlimno) %>%
  left_join(., LAGOSstate) %>%
  filter(!is.na(state)) %>%
  select(lagoslakeid, sampledate, secchi, lake_area_ha, maxdepth, nhd_lat, nhd_long, state)
```

```
## Joining, by = "lagoslakeid"

## Joining, by = c("lagoslakeid", "nhdid", "nhd_lat", "nhd_long")

## Joining, by = "state_zoneid"
```

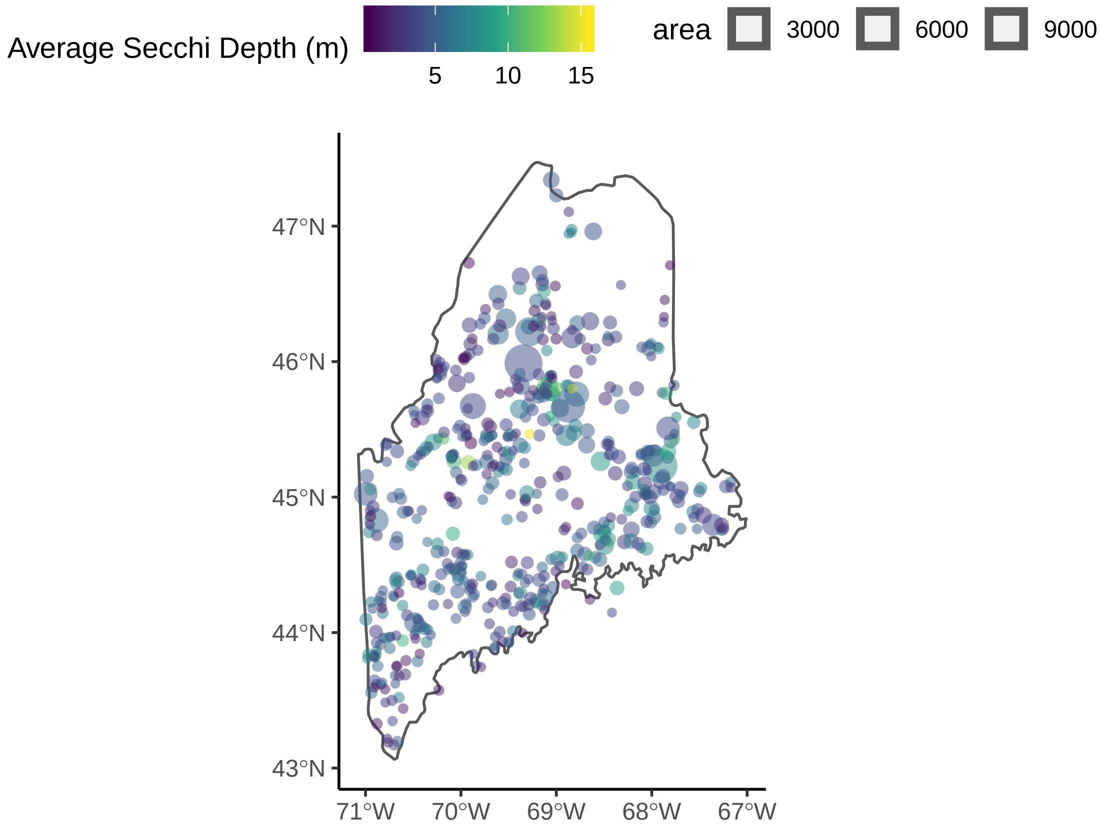
```r
secchi.maine <- LAGOScombined %>%
  filter(state == "ME") %>%
  group_by(lagoslakeid) %>%
  summarise(secchi.mean = mean(secchi),
            area = mean(lake_area_ha),
            depth = mean(maxdepth),
            lat = mean(nhd_lat),
            long = mean(nhd_long)) %>%
  drop_na()


maine.subset <- filter(states, ID %in%
                          c("maine"))


maine.spatial <- st_as_sf(secchi.maine, coords = c("long", "lat"), crs = 4326)
```

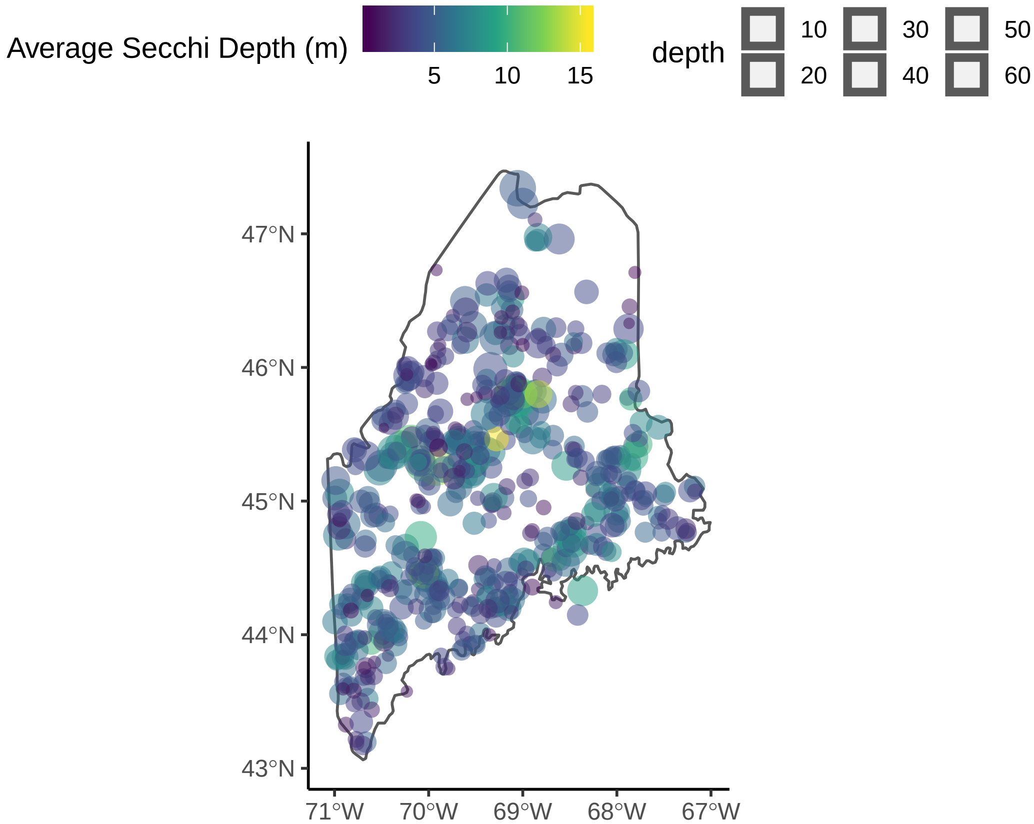
6. Create a plot of mean secchi depth for lakes in Maine, with mean secchi depth designated as color and the lake area as the size of the dot. Remember that you are using size in the aesthetics and should remove the size = 1 from the other part of the code. Adjust the transparency of points as needed.

```r
Maineplot.area <- ggplot() +
  geom_sf(data = maine.subset, fill = "white") +
  geom_sf(data = maine.spatial, aes(color = secchi.mean, size = area),
          alpha = 0.5) +
  scale_color_viridis_c() +
  labs(color = "Average Secchi Depth (m)") +
  theme(legend.position = "top")
print(Maineplot.area)
```



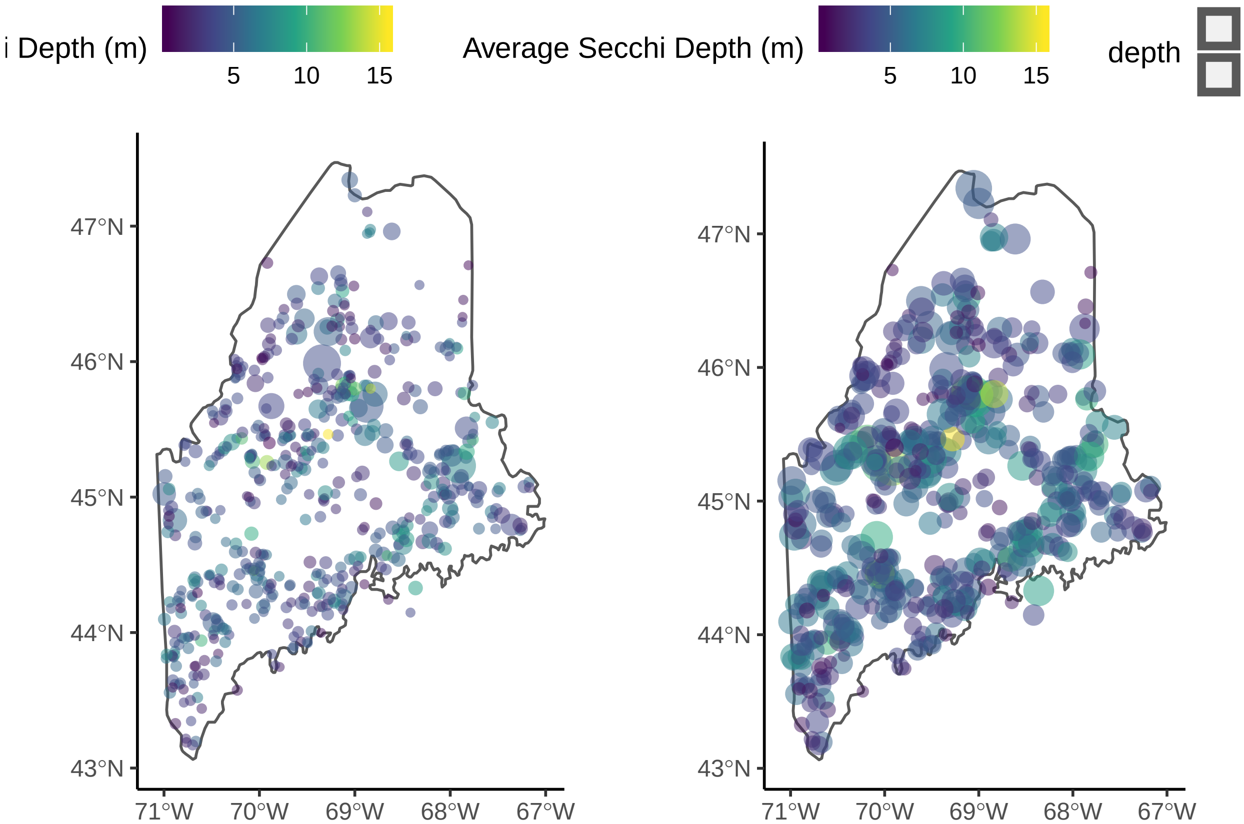
7. Create a second plot, but this time use maximum depth of the lake as the size of the dot.

```
Maineplot.depth <- ggplot() +
  geom_sf(data = maine.subset, fill = "white") +
  geom_sf(data = maine.spatial, aes(color = secchi.mean, size = depth),
          alpha = 0.5) +
  scale_color_viridis_c() +
  labs(color = "Average Secchi Depth (m)") +
  theme(legend.position = "top")
print(Maineplot.depth)
```



8. Plot these maps in the same plot with the `plot_grid` function. Don't worry about adjusting the legends (if you have extra time this would be a good bonus task).

```
plot_grid(Maineplot.area, Maineplot.depth)
```



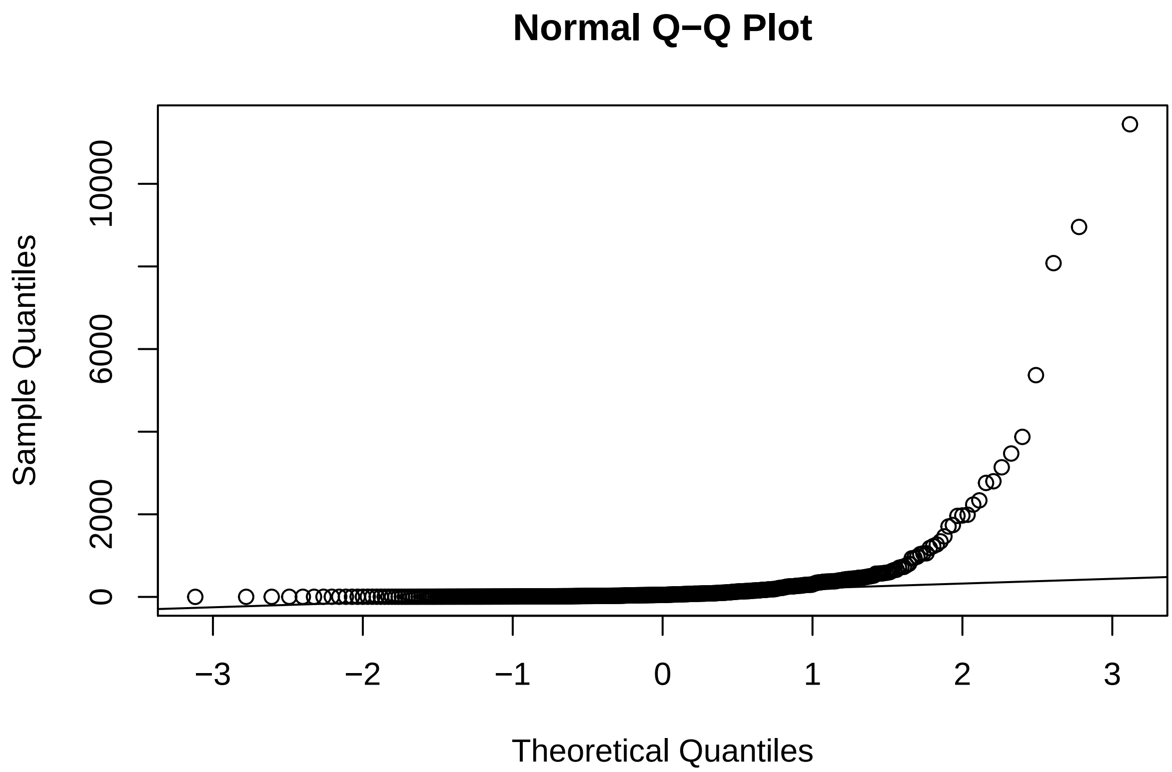
What would you change about the legend to make it a more effective visualization?

> I would make the same colors correspond with the same secchi depths, and I would have the shapes of the circles represented in the legend as a guide for what areas/lake depths correspond with which size circle on the graph.

9. What relationships do you see between secchi depth, lake area, and lake depth? Which of the two lake variables seems to be a stronger determinant of secchi depth? (make a scatterplot and run a regression to test this)

Note: consider log-transforming a predictor variable if appropriate

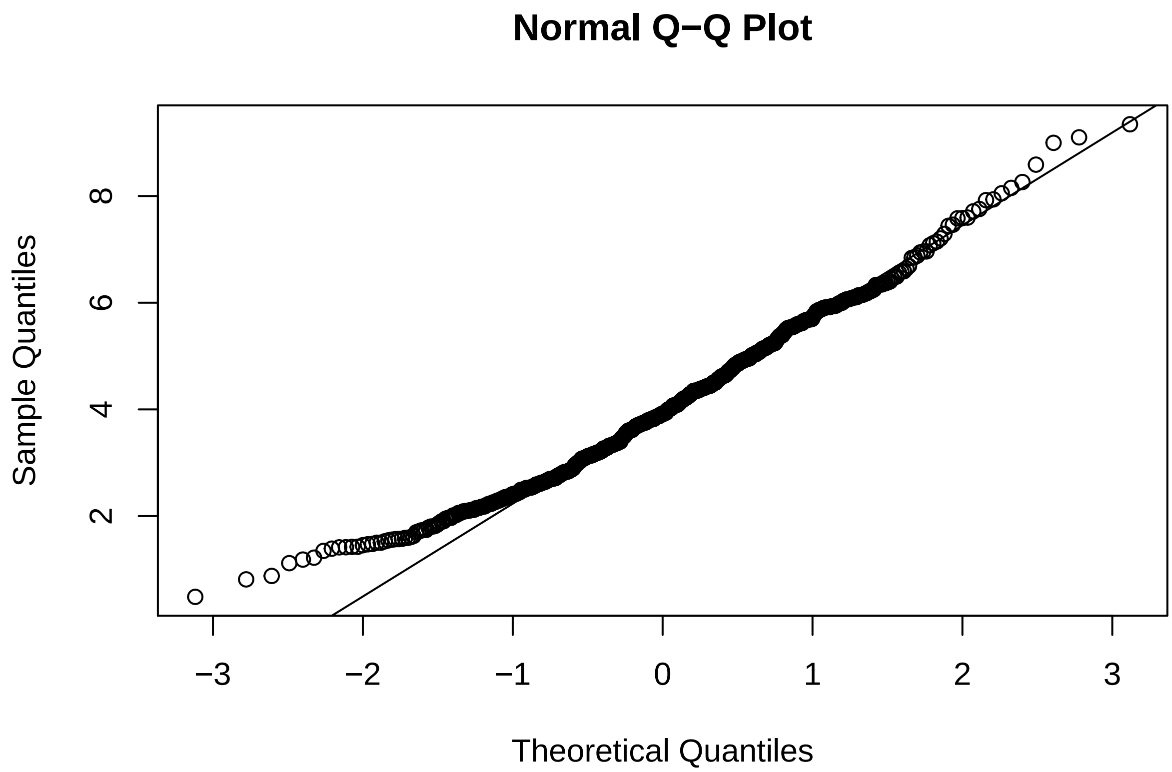
```
qqnorm(secchi.maine$area)
qqline(secchi.maine$area)
```




```r
shapiro.test(secchi.maine$area)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  secchi.maine$area
## W = 0.2577, p-value < 2.2e-16
```

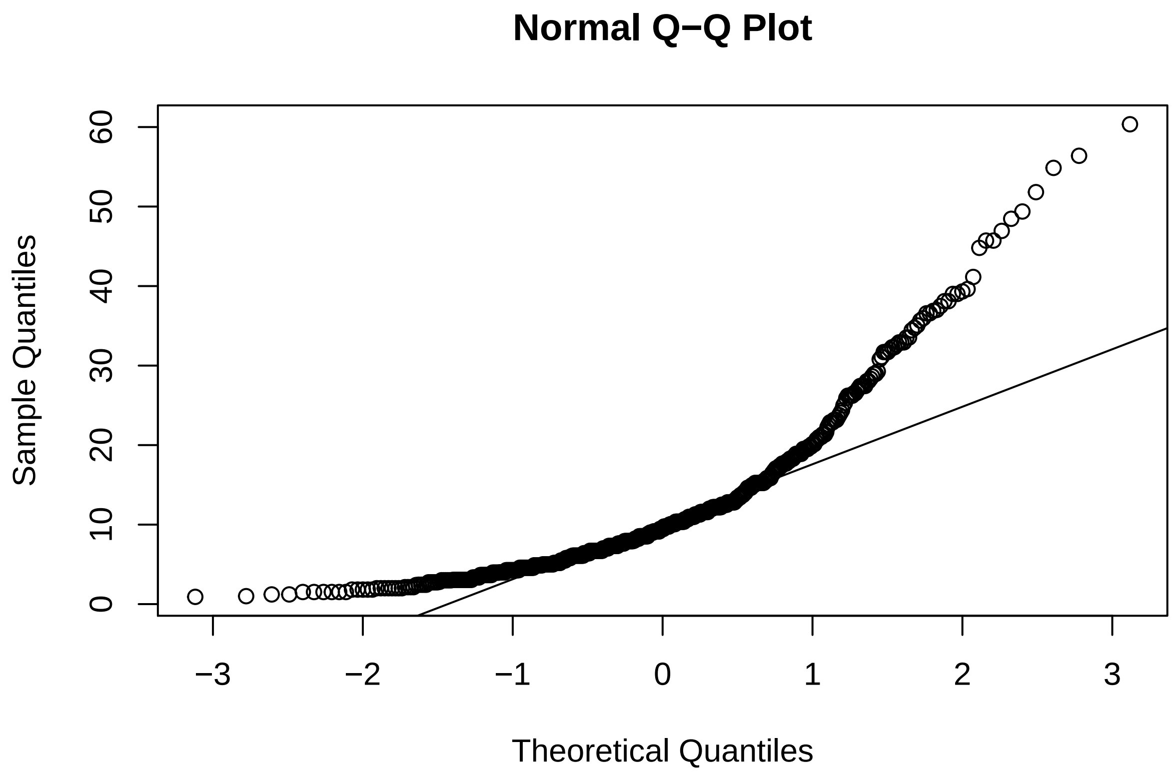
```r
qqnorm(log(secchi.maine$area))
qqline(log(secchi.maine$area))
```




```r
shapiro.test(log(secchi.maine$area))
```

```
##
##  Shapiro-Wilk normality test
##
## data:  log(secchi.maine$area)
## W = 0.9831, p-value = 5.447e-06
```

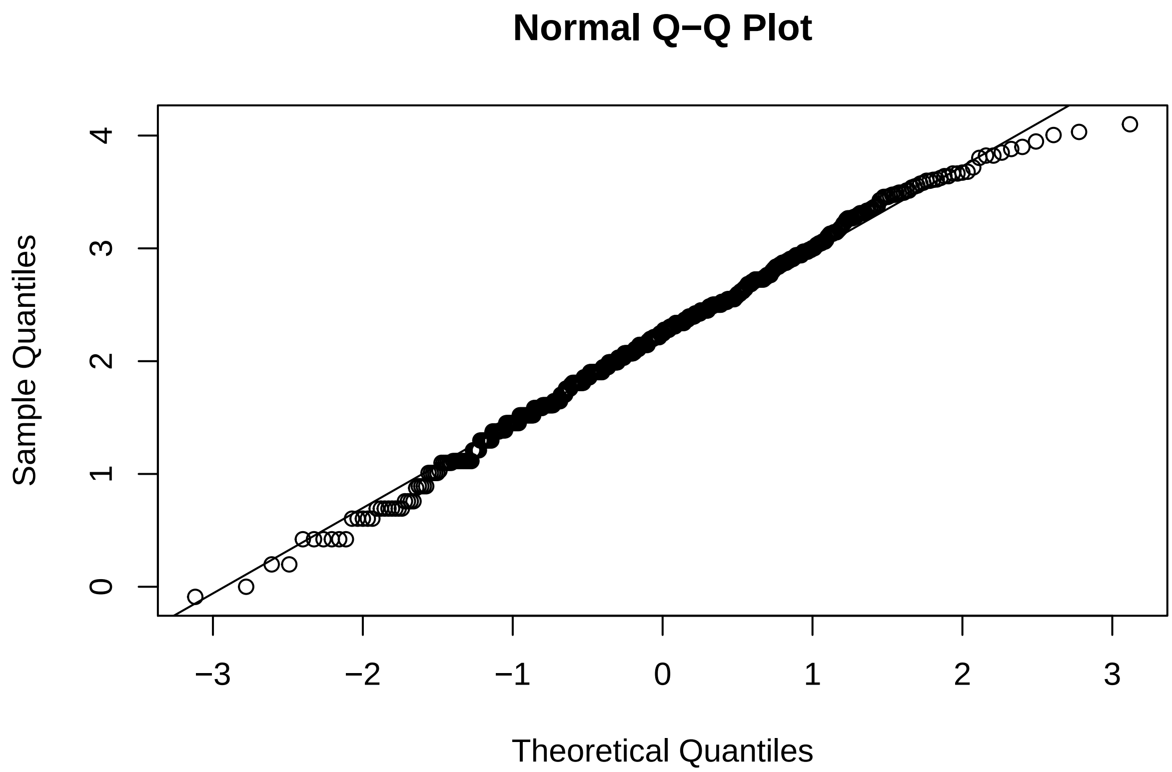
```r
qqnorm(secchi.maine$depth)
qqline(secchi.maine$depth)
```




```
shapiro.test(secchi.maine$depth)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  secchi.maine$depth
## W = 0.83016, p-value < 2.2e-16
```

```
qqnorm(log(secchi.maine$depth))
qqline(log(secchi.maine$depth))
```




```r
shapiro.test(log(secchi.maine$depth))
```

```
##
##  Shapiro-Wilk normality test
##
## data:  log(secchi.maine$depth)
## W = 0.99505, p-value = 0.07565
```

```r
maine.test <- lm(secchi.mean ~ log(area) + log(depth), secchi.maine)
summary(maine.test)
```

```
##
## Call:
## lm(formula = secchi.mean ~ log(area) + log(depth), data = secchi.maine)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -3.8424 -0.9754 -0.0069  0.8011  9.4708
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  0.53440    0.22100   2.418  0.01593 *
## log(area)   -0.14439    0.04864  -2.968  0.00312 **
## log(depth)   2.06428    0.09851  20.954  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
```

```
## Residual standard error: 1.572 on 546 degrees of freedom
## Multiple R-squared:  0.4831, Adjusted R-squared:  0.4812
## F-statistic: 255.1 on 2 and 546 DF,  p-value: < 2.2e-16
```

Lake area and lake depth both significantly determine secchi depth in Maine. Secchi depth decreases with lake area and increases with lake depth. Lake depth has a stronger influence on secchi depth ($p < 2e-16$) than lake area ($p = 0.00312$).

Mapping water features and watershed boundaries

10. Wrangle the USA rivers and HUC6 watershed boundaries dataset so that they include only the features present in Florida (FL). Adjust the coordinate reference systems if necessary to ensure they use the same projection.

```r
summary(HUC6$States)
```

```
##       AL    AL,FL AL,FL,GA AL,GA,TN AL,LA,MS    AL,MS       FL    FL,GA
##        1        3        1        1        1        2        6        4
##       GA GA,NC,SC    LA,MS       NC    NC,SC NC,SC,VA    NC,VA       SC
##        2        1        1        4        2        1        2        1
```

```r
HUC6.FL <- HUC6 %>%
  filter(States %in% c("AL,FL", "AL,FL,GA", "FL", "FL,GA"))


waterfeatures <- filter(waterfeatures, STATE == "FL")


waterfeatures <- filter(waterfeatures, FEATURE != "Apparent Limit" & FEATURE != "Closure Line")
```

11. Create a map of watershed boundaries in Florida, with the layer of water features on top. Color the watersheds gray (make sure the lines separating watersheds are still visible) and color the water features by type.

```r
st_crs(waterfeatures)
```

```
## Coordinate Reference System: NA
```

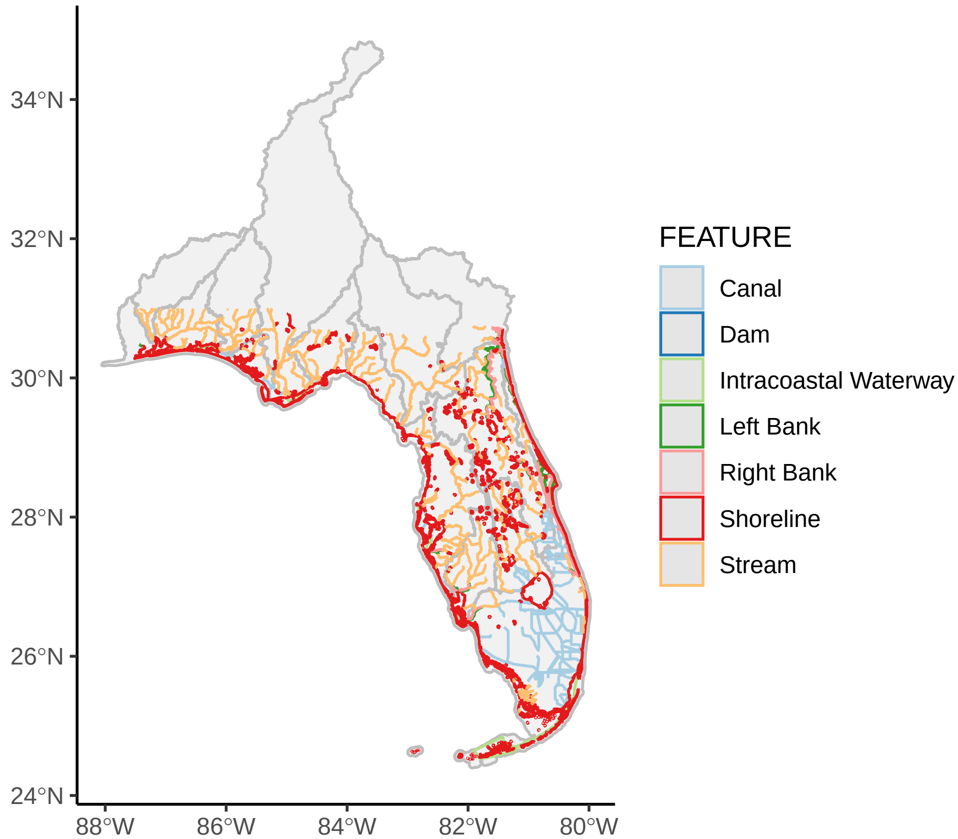
```r
st_crs(HUC6.FL)
```

```
## Coordinate Reference System:
##   EPSG: 4269
##   proj4string: "+proj=longlat +ellps=GRS80 +towgs84=0,0,0,0,0,0,0 +no_defs"
```

```r
waterfeatures <- st_set_crs(waterfeatures, 4269)
st_crs(waterfeatures)
```

```
## Coordinate Reference System:
##   EPSG: 4269
##   proj4string: "+proj=longlat +ellps=GRS80 +towgs84=0,0,0,0,0,0,0 +no_defs"
```

```r
FLlayers <- ggplot() +
  geom_sf(data = HUC6.FL, color = "gray", alpha = 0.5) +
  geom_sf(data = waterfeatures, aes(color = FEATURE)) +
  scale_color_brewer(palette = "Paired")
print(FLlayers)
```



12. What are the dominant water features in Florida? How does this distribution differ (or not) compared to North Carolina?

    The dominant water features in Florida are streams, shorelines, and canals. North Carolina also has a large number of streams and rivers, but has a smaller amount of shoreline and fewer canals.

Reflection

13. What are 2-3 conclusions or summary points about mapping you learned through your analysis?

    I learned that secchi depth is more dependent on lake depth than lake area in Maine and the state of Florida's waterways are primarily streams, shoreline, and canals.

14. What data, visualizations, and/or models supported your conclusions from 13?

    The linear model helped me determine the first conclusion, and the spatial visualization helped me reach the second conclusion.

15. Did hands-on data analysis impact your learning about mapping relative to a theory-based lesson? If so, how?

    Hands on analysis always helps be learn better than a theory-based lesson because I am a visual learner.

16. How did the real-world data compare with your expectations from theory?

    I was not expecting as many canals in Florida as there are.