Precipitation_Analysis

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Load in relevant packages and complete Cleaned Alaska Dataset

```
library(tidyverse)
library(ggplot2)
library(scales)
setwd("/Users/gabrielagarcia/Desktop/Hydrologic Data Analysis/Hydrologic_Data_Analysis/Course_Project/Al
AlaskaTempPrecipDischarge<-read.csv("AlaskaTempPrecipDischarge.csv")
```

Create Precipitation only Dataframe with Bins included

```
AlaskaPrecipOnly<-select(AlaskaTempPrecipDischarge, .data$DATE, .data$PRCP, .data$Bin)
```

Check number of Precipitation NA's and remove them

```
newdata<-na.omit(AlaskaPrecipOnly)
```

Ensure Date is a date object and not a factor

```
newdata$DATE<-as.Date(newdata$DATE)
```

Ensure Bin is a factor and not an integer

```
newdata$Bin <- as.factor(newdata$Bin)
```

Subset the Data by Bin

```
Bin1Precip<-filter(newdata, Bin== 1)
Bin2Precip<-filter(newdata, Bin== 2)
Bin3Precip<-filter(newdata, Bin == 3)
Bin4Precip<-filter(newdata, Bin == 4)
Bin5Precip<-filter(newdata, Bin == 5)
Bin6Precip<-filter(newdata, Bin == 6)
Bin7Precip<-filter(newdata, Bin == 7)
Bin8Precip<-filter(newdata, Bin == 8)
Bin9Precip<-filter(newdata, Bin == 9)
```

Set Personal Theme

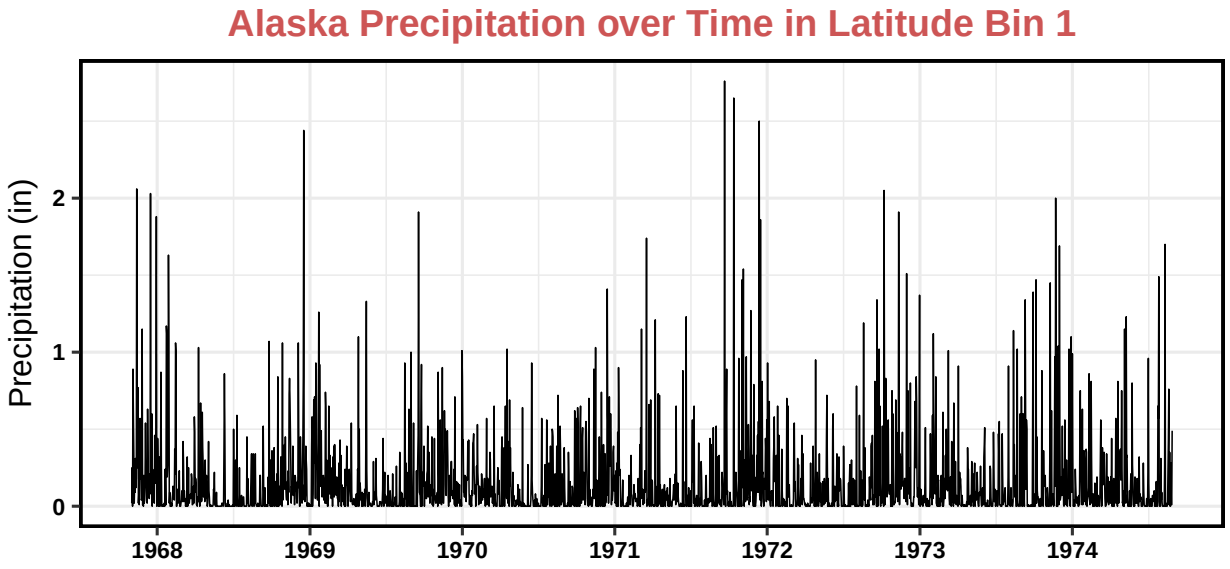
```
gabytheme <- theme_bw(base_size = 22) +
  theme(plot.title=element_text(face="bold", size="26", color="IndianRed3", hjust=0.5),
        axis.title=element_text(size=22, color="black"),
axis.text = element_text(face="bold", size=16, color = "black"),
panel.background=element_rect(fill="white", color="darkblue"),
```

```
panel.border = element_rect(color = "black", size = 2),
legend.position = "top", legend.background = element_rect(fill="white", color="black"),
            legend.key = element_rect(fill="transparent", color="NA"))

theme_set(gabytheme)
```

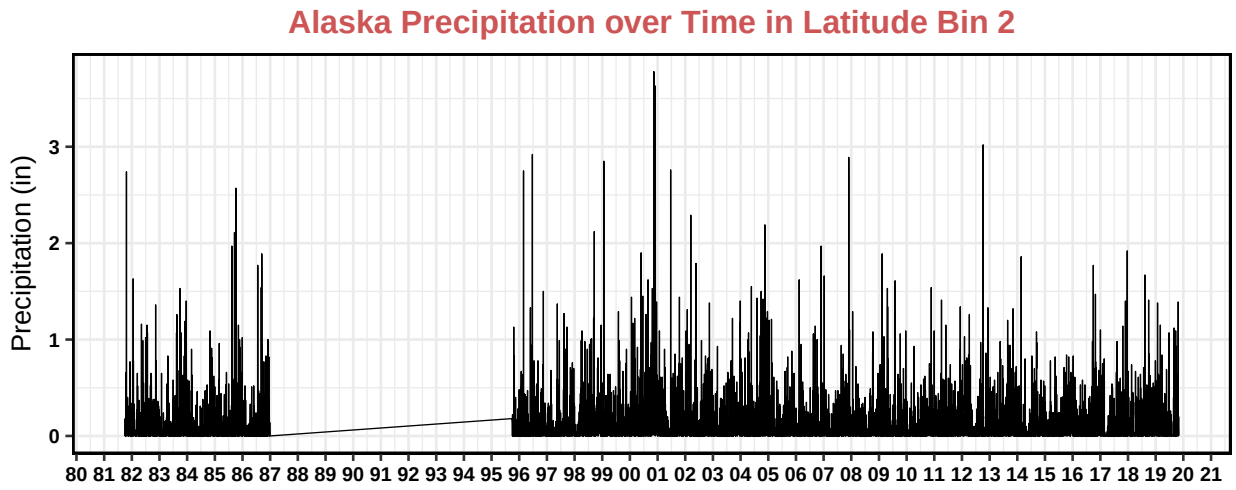
Plot Bin 1 Precip

```
Bin1PrecipPlot<-
  ggplot(Bin1Precip, aes(x = DATE, y = PRCP)) +
  geom_line() +
  ggtitle("Alaska Precipitation over Time in Latitude Bin 1") +
  labs(x = "", y = expression("Precipitation (in)"))+
  scale_x_date(labels=date_format("%Y"),
               breaks=date_breaks("1 year"))+
  gabytheme
print(Bin1PrecipPlot)
```



Plot Bin 2 Precip over Time

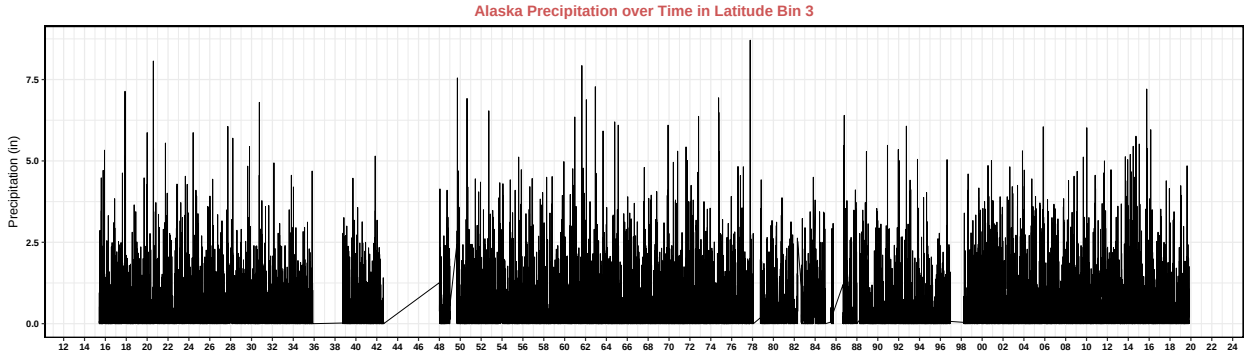
```
Bin2PrecipPlot<-
  ggplot(Bin2Precip, aes(x = DATE, y = PRCP)) +
  geom_line() +
  ggtitle("Alaska Precipitation over Time in Latitude Bin 2") +
  labs(x = "", y = expression("Precipitation (in)"))+
  scale_x_date(labels=date_format("%y"),
               breaks=date_breaks("1 year"))+
  gabytheme
print(Bin2PrecipPlot)
```



>There is a gap in precipitation data collection for Bin 2 from 1986-12-31 to 1995-10-01

Plot Bin 3 Precip over Time

```
Bin3PrecipPlot<-
  ggplot(Bin3Precip, aes(x = DATE, y = PRCP)) +
  geom_line() +
  ggtitle("Alaska Precipitation over Time in Latitude Bin 3") +
  labs(x = "", y = expression("Precipitation (in)"))+
  scale_x_date(labels=date_format("%y"),
               breaks=date_breaks("2 years"))+
  gabytheme
print(Bin3PrecipPlot)
```

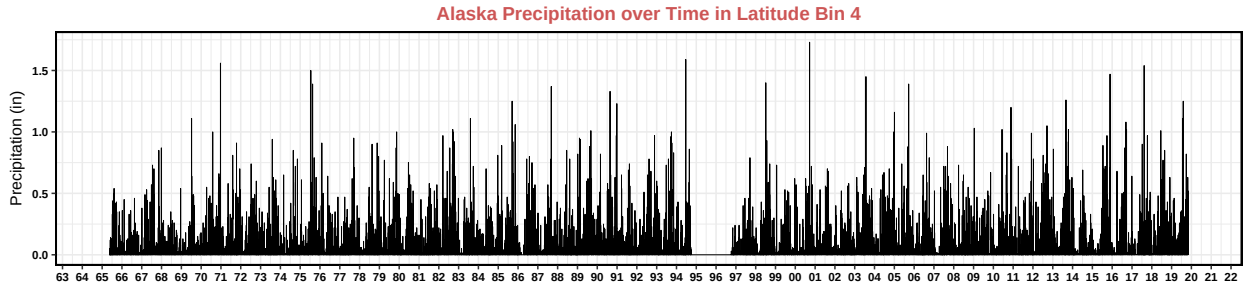


>Much higher range in precip values–>more rain and snowfall?

Plot Bin 4 Precip over Time

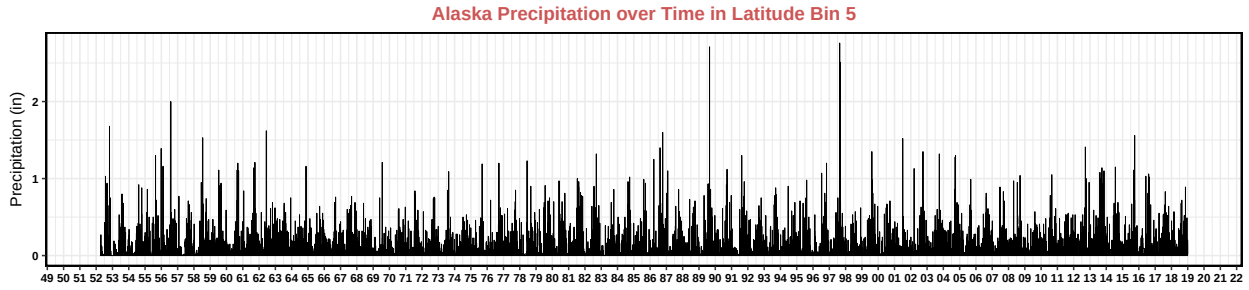
```
Bin4PrecipPlot<-
  ggplot(Bin4Precip, aes(x = DATE, y = PRCP)) +
  geom_line() +
  ggtitle("Alaska Precipitation over Time in Latitude Bin 4") +
  labs(x = "", y = expression("Precipitation (in)"))+
```

```
  scale_x_date(labels=date_format("%y"),
               breaks=date_breaks("1 year"))+
  gabytheme
print(Bin4PrecipPlot)
```



Plot Bin 5 Precip over Time

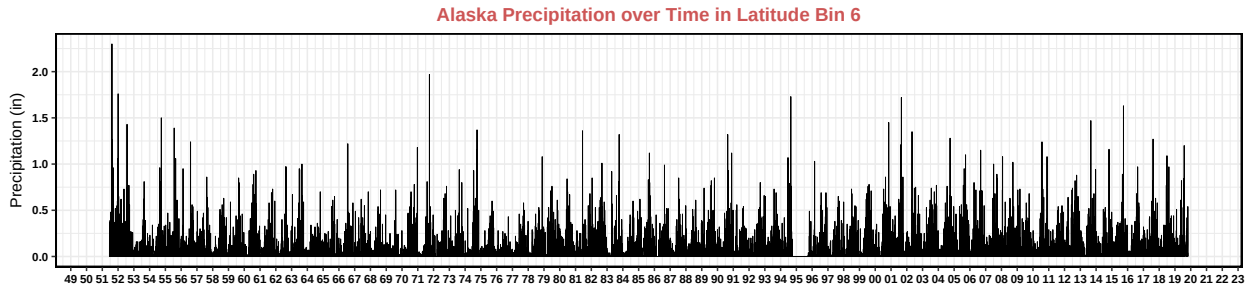
```
library(scales)
library(ggplot2)
Bin5PrecipPlot<-
  ggplot(Bin5Precip, aes(x = DATE, y = PRCP)) +
  geom_line() +
  ggtitle("Alaska Precipitation over Time in Latitude Bin 5") +
  labs(x = "", y = expression("Precipitation (in)"))+
  scale_x_date(labels=date_format("%y"),
               breaks=date_breaks("1 year"))+
  gabytheme
print(Bin5PrecipPlot)
```



Plot Bin 6 Precip over Time

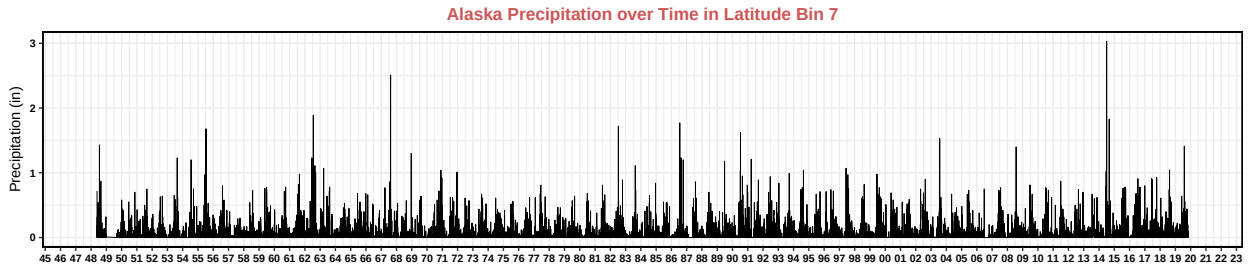
```
library(scales)
library(ggplot2)
Bin6PrecipPlot<-
  ggplot(Bin6Precip, aes(x = DATE, y = PRCP)) +
  geom_line() +
  ggtitle("Alaska Precipitation over Time in Latitude Bin 6") +
  labs(x = "", y = expression("Precipitation (in)"))+
  scale_x_date(labels=date_format("%y"),
               breaks=date_breaks("1 year"))+
```

```
  gabytheme
print(Bin6PrecipPlot)
```



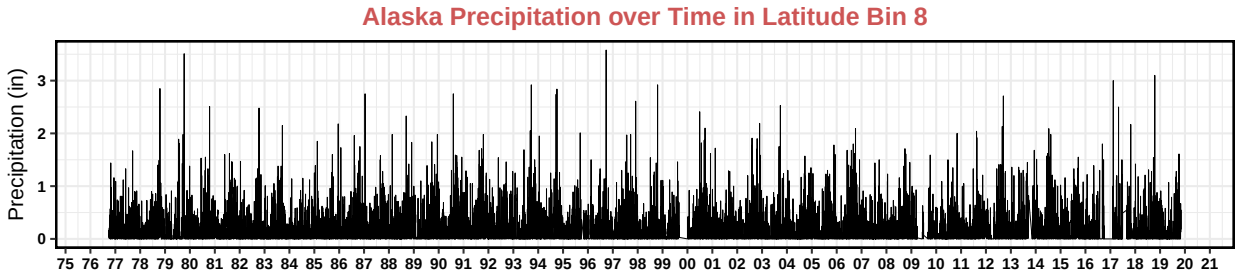
Plot Bin 7 Precip over time

```
library(scales)
library(ggplot2)
Bin7PrecipPlot<-
  ggplot(Bin7Precip, aes(x = DATE, y = PRCP)) +
  geom_line() +
  ggtitle("Alaska Precipitation over Time in Latitude Bin 7") +
  labs(x = "", y = expression("Precipitation (in)"))+
  scale_x_date(labels=date_format("%y"),
               breaks=date_breaks("1 year"))+
  gabytheme
print(Bin7PrecipPlot)
```



Plot Bin 8 Precip over time

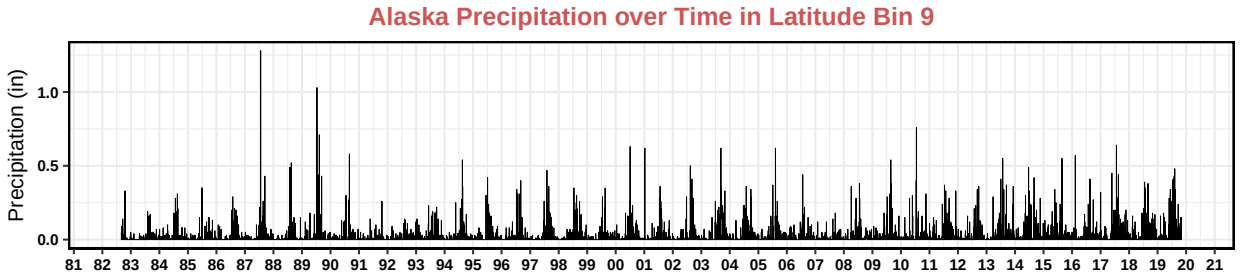
```
library(scales)
library(ggplot2)
Bin8PrecipPlot<-
  ggplot(Bin8Precip, aes(x = DATE, y = PRCP)) +
  geom_line() +
  ggtitle("Alaska Precipitation over Time in Latitude Bin 8") +
  labs(x = "", y = expression("Precipitation (in)"))+
  scale_x_date(labels=date_format("%y"),
               breaks=date_breaks("1 year"))+
  gabytheme
print(Bin8PrecipPlot)
```



Plot Bin 9 Precip over time

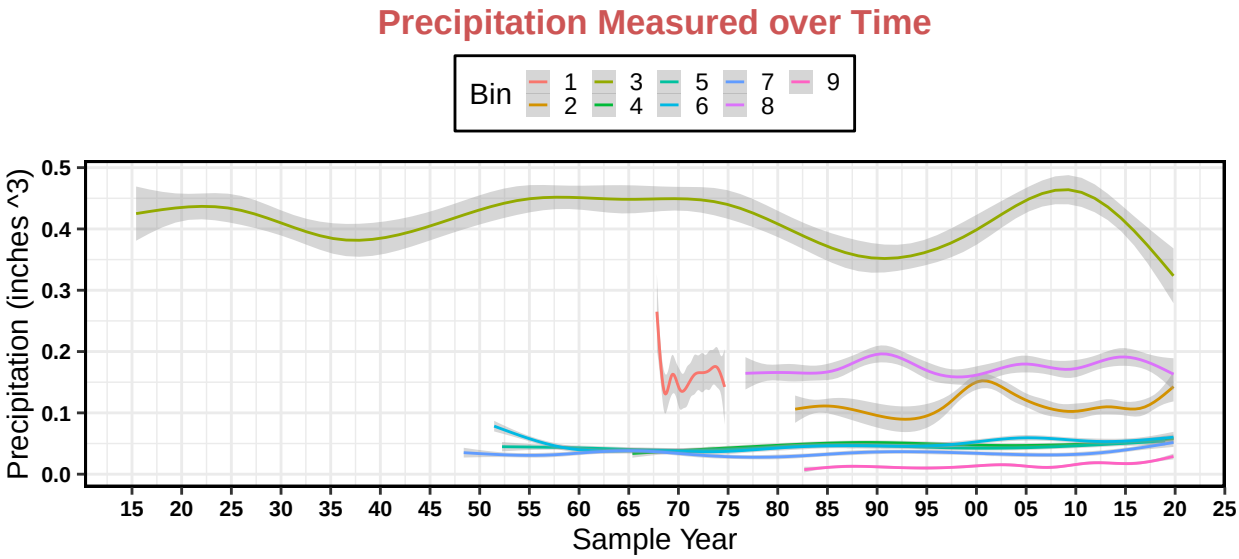
```
library(scales)
library(ggplot2)
Bin9PrecipPlot<-
  ggplot(Bin9Precip, aes(x = DATE, y = PRCP)) +
  geom_line() +
  ggtitle("Alaska Precipitation over Time in Latitude Bin 9") +
  labs(x = "", y = expression("Precipitation (in)"))+
  scale_x_date(labels=date_format("%y"),
               breaks=date_breaks("1 year"))+
  gabytheme

print(Bin9PrecipPlot)
```



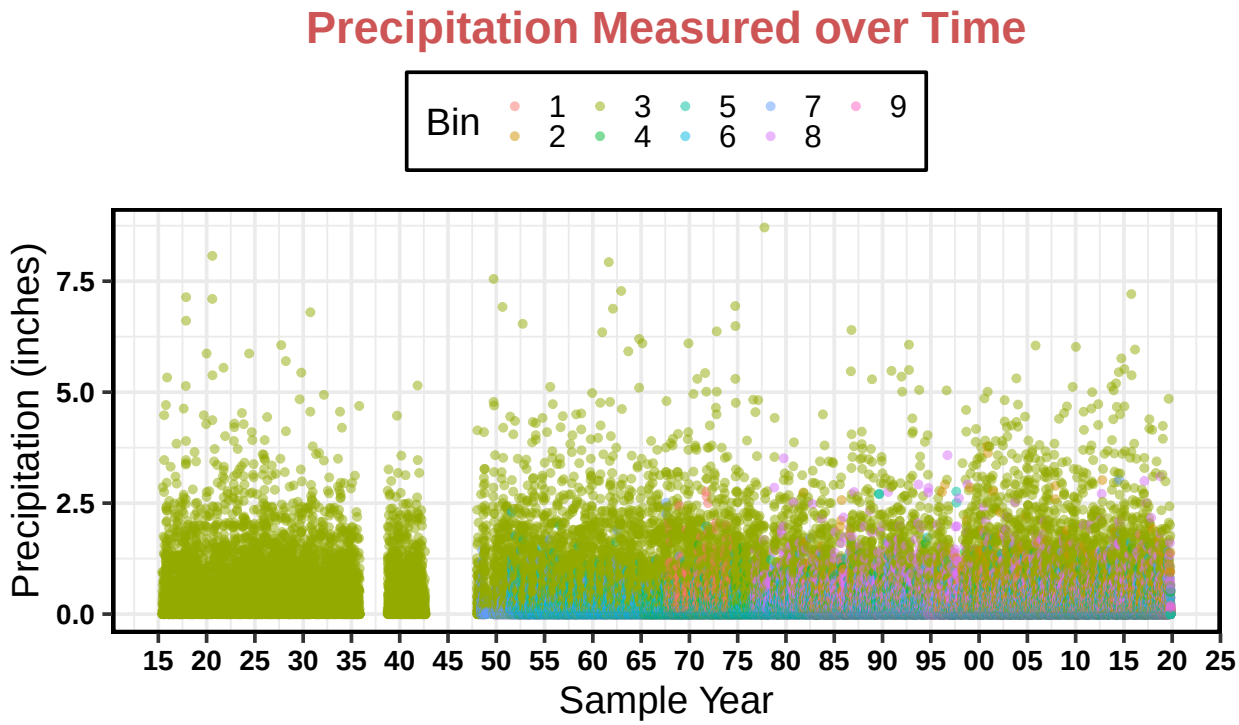
Precip Line Graph but with geom_smooth

```
PrecipLinePlot<-ggplot(newdata, aes(x = DATE, y = PRCP, color = Bin))  +
  geom_smooth() +
labs(title="Precipitation Measured over Time", x="Sample Year",
       y="Precipitation (inches ^3)")+
  scale_x_date(labels=date_format("%y"),
               breaks=date_breaks("5 years"))+
  gabytheme
print(PrecipLinePlot)
```



Scatterplot of Full Precipitation Period of Record Colored by Bin

```
PrecipBoxplot<-ggplot(newdata, aes(x = DATE, y = PRCP, color = Bin))  +
  geom_point(alpha=0.5, size=2) +
labs(title="Precipitation Measured over Time", x="Sample Year",
       y="Precipitation (inches)")+
  scale_x_date(labels=date_format("%y"),
               breaks=date_breaks("5 years"))+
  theme(legend.position="top",
        legend.key.width=unit(1.5, "cm"))+
  gabytheme
print(PrecipBoxplot)
```



Add Day of Year Column to complete dataframe

```
library(dplyr)
library(lubridate)
newdata <-mutate(newdata, DOY = yday(DATE), Year=year(DATE), Month=month(DATE))
```

Run a Mann-Kendall test for each Bin

A Mann-Kendall test will analyze whether there is a monotonic trend in the response variable over time.

Mann Kendall for Bin 1

```
library(trend)
Bin1Precip$PRCP<-as.numeric(Bin1Precip$PRCP)
mk.test(Bin1Precip$PRCP)
```

```
##
##  Mann-Kendall trend test
##
## data:  Bin1Precip$PRCP
## z = -1.2729, n = 2492, p-value = 0.203
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##             S          varS           tau
## -5.218700e+04  1.680746e+09 -1.769376e-02
```

We see a negative trend in precipitation over time. z is the direction and magnitude of the trend. p=0.203 so we reject the null hypothesis

Pettitt's Test

Pettitt's test is also included in the `trend` package. This nonparametric test will determine whether there is a shift in the central tendency of the time series and will tell us at what point the changepoint occurs (if it detects one). Note: Pettitt's Test will only test for one changepoint, and further tests must be run if multiple change points are suspected.

```
# Test for change point
pettitt.test(Bin1Precip$PRCP)
```

```
##
##  Pettitt's test for single change-point detection
##
## data:  Bin1Precip$PRCP
## U* = 104422, p-value = 0.02923
## alternative hypothesis: two.sided
## sample estimates:
## probable change point at time K
##                             910
```

> Is our p-value <0.05? IF SO THEN OUR CHANGE POINT IS SIGNIFICANT. It is 0.029, so we'll have to go into our data set and look at where change point happened change point is 910, so scroll down to place 910 in data set. It happened in 1970-04-28.

Run separate Mann-Kendall for each change point

```
mk.test(Bin1Precip$PRCP[1:909])
```

```
##
##  Mann-Kendall trend test
##
## data:  Bin1Precip$PRCP[1:909]
## z = 1.3001, n = 909, p-value = 0.1936
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##            S         varS          tau
## 1.179400e+04 8.228130e+07 2.976876e-02
```

```
mk.test(Bin1Precip$PRCP[910:2492])
```

```
##
##  Mann-Kendall trend test
##
## data:  Bin1Precip$PRCP[910:2492]
## z = 1.9439, n = 1583, p-value = 0.05191
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##            S         varS          tau
## 4.024500e+04 4.285946e+08 3.405116e-02
```

Is there a second change point?

```
pettitt.test(Bin1Precip$PRCP[910:2492])
```

```
##
##  Pettitt's test for single change-point detection
```

```
##
## data:  Bin1Precip$PRCP[910:2492]
## U* = 63075, p-value = 0.00489
## alternative hypothesis: two.sided
## sample estimates:
## probable change point at time K
##                              858
```

910+858=1768, so look at 1768 row in datatable to see second change point. 1972-09-02

Check to see if Second Change Point is significant

```
mk.test(Bin1Precip$PRCP[910:1767])
```

```
##
##  Mann-Kendall trend test
##
## data:  Bin1Precip$PRCP[910:1767]
## z = 0.10862, n = 858, p-value = 0.9135
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##            S         varS          tau
## 8.930000e+02 6.743620e+07 2.608407e-03
```

```
mk.test(Bin1Precip$PRCP[1768:2492])
```

```
##
##  Mann-Kendall trend test
##
## data:  Bin1Precip$PRCP[1768:2492]
## z = -3.6748, n = 725, p-value = 0.0002381
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##             S          varS           tau
## -2.372300e+04  4.167182e+07 -9.447352e-02
```

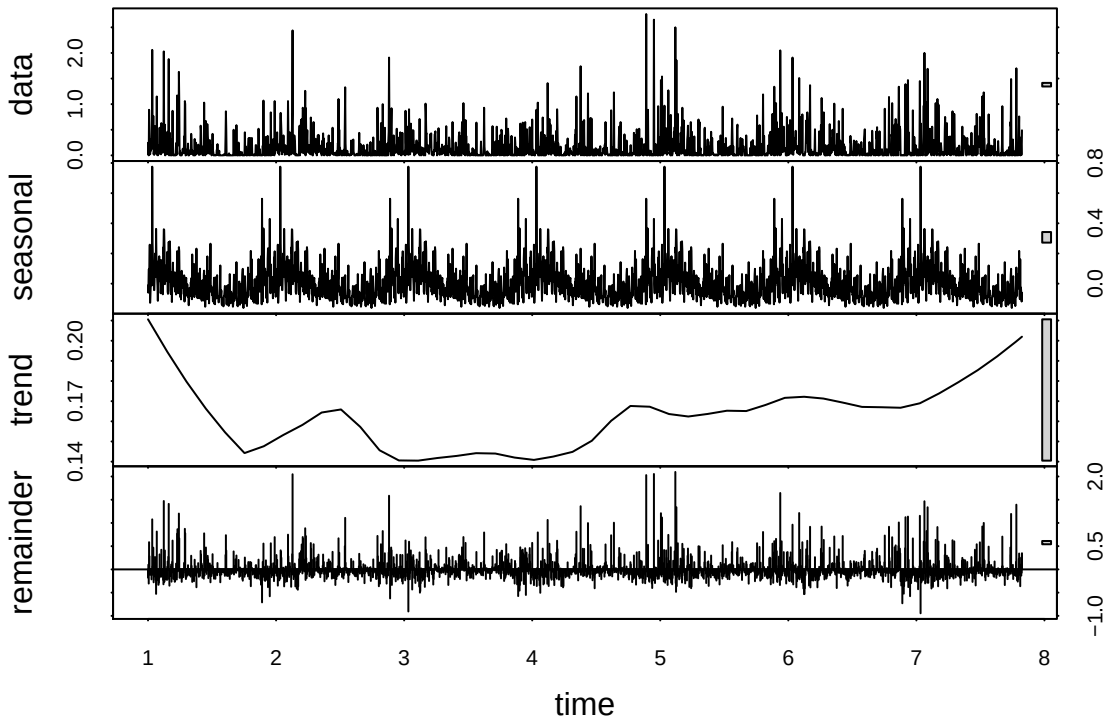
Seasonal Mann Kendall for Bin 1 Precip

Create a time series object

```
Bin1TimeSeries<- ts(Bin1Precip$PRCP,
                                frequency = 365)
```

Decomposition

```
Bin1Decomposed <- stl(Bin1TimeSeries, s.window = "periodic")
plot(Bin1Decomposed)
```



Perform Seasonal Mann Kendall Test

```
Bin1SeasonalTrend <- smk.test(Bin1TimeSeries)

summary(Bin1SeasonalTrend)
```

```
##
##  Seasonal Mann-Kendall trend test (Hirsch-Slack test)
##
## data: Bin1TimeSeries
## alternative hypothesis: two.sided
##
## Statistics for individual seasons
##
## H0
##                        S varS    tau      z  Pr(>|z|)
## Season 1:   S = 0    -8 43.3 -0.390 -1.063 0.2876113
## Season 2:   S = 0   -15 42.3 -0.751 -2.152 0.0314190  *
## Season 3:   S = 0    -1 42.3 -0.050  0.000 1.0000000
## Season 4:   S = 0    -5 44.3 -0.238 -0.601 0.5480056
## Season 5:   S = 0   -11 44.3 -0.524 -1.502 0.1331285
## Season 6:   S = 0    -2 43.3 -0.098 -0.152 0.8792572
## Season 7:   S = 0    -1 42.3 -0.050  0.000 1.0000000
## Season 8:   S = 0    -8 40.7 -0.411 -1.098 0.2723409
## Season 9:   S = 0    -2 43.3 -0.098 -0.152 0.8792572
## Season 10:   S = 0    5 44.3  0.238  0.601 0.5480056
```

```
## Season 11:   S = 0   -4 43.3 -0.195 -0.456 0.6485822
## Season 12:   S = 0   -4 43.3 -0.195 -0.456 0.6485822
## Season 13:   S = 0   -3 44.3 -0.143 -0.300 0.7638906
## Season 14:   S = 0    1 44.3  0.048  0.000 1.0000000
## Season 15:   S = 0   -9 44.3 -0.429 -1.202 0.2295562
## Season 16:   S = 0  -12 43.3 -0.586 -1.671 0.0947177  .
## Season 17:   S = 0    2 43.3  0.098  0.152 0.8792572
## Season 18:   S = 0    3 42.3  0.150  0.307 0.7585471
## Season 19:   S = 0    2 43.3  0.098  0.152 0.8792572
## Season 20:   S = 0   -8 43.3 -0.390 -1.063 0.2876113
## Season 21:   S = 0   -1 44.3 -0.048  0.000 1.0000000
## Season 22:   S = 0    7 44.3  0.333  0.901 0.3675207
## Season 23:   S = 0    0 43.3  0.000  0.000 1.0000000
## Season 24:   S = 0   10 43.3  0.488  1.367 0.1715632
## Season 25:   S = 0    9 44.3  0.429  1.202 0.2295562
## Season 26:   S = 0  -11 44.3 -0.524 -1.502 0.1331285
## Season 27:   S = 0   -4 43.3 -0.195 -0.456 0.6485822
## Season 28:   S = 0   -2 43.3 -0.098 -0.152 0.8792572
## Season 29:   S = 0    0 40.7  0.000  0.000 1.0000000
## Season 30:   S = 0    0 43.3  0.000  0.000 1.0000000
## Season 31:   S = 0   13 44.3  0.619  1.802 0.0715054  .
## Season 32:   S = 0    1 44.3  0.048  0.000 1.0000000
## Season 33:   S = 0    1 44.3  0.048  0.000 1.0000000
## Season 34:   S = 0   -5 42.3 -0.250 -0.615 0.5387009
## Season 35:   S = 0   -6 43.3 -0.293 -0.760 0.4475209
## Season 36:   S = 0   -9 44.3 -0.429 -1.202 0.2295562
## Season 37:   S = 0    2 43.3  0.098  0.152 0.8792572
## Season 38:   S = 0   11 44.3  0.524  1.502 0.1331285
## Season 39:   S = 0    0 43.3  0.000  0.000 1.0000000
## Season 40:   S = 0    4 43.3  0.195  0.456 0.6485822
## Season 41:   S = 0    0 43.3  0.000  0.000 1.0000000
## Season 42:   S = 0    0 43.3  0.000  0.000 1.0000000
## Season 43:   S = 0   -7 44.3 -0.333 -0.901 0.3675207
## Season 44:   S = 0   -8 43.3 -0.390 -1.063 0.2876113
## Season 45:   S = 0   -8 43.3 -0.390 -1.063 0.2876113
## Season 46:   S = 0   -6 43.3 -0.293 -0.760 0.4475209
## Season 47:   S = 0   -3 44.3 -0.143 -0.300 0.7638906
## Season 48:   S = 0  -13 44.3 -0.619 -1.802 0.0715054  .
## Season 49:   S = 0   -9 44.3 -0.429 -1.202 0.2295562
## Season 50:   S = 0    8 43.3  0.390  1.063 0.2876113
## Season 51:   S = 0    3 44.3  0.143  0.300 0.7638906
## Season 52:   S = 0    6 43.3  0.293  0.760 0.4475209
## Season 53:   S = 0    1 44.3  0.048  0.000 1.0000000
## Season 54:   S = 0   -6 43.3 -0.293 -0.760 0.4475209
## Season 55:   S = 0    3 44.3  0.143  0.300 0.7638906
## Season 56:   S = 0   11 44.3  0.524  1.502 0.1331285
## Season 57:   S = 0    7 44.3  0.333  0.901 0.3675207
## Season 58:   S = 0    6 43.3  0.293  0.760 0.4475209
## Season 59:   S = 0   -4 43.3 -0.195 -0.456 0.6485822
## Season 60:   S = 0   -1 44.3 -0.048  0.000 1.0000000
## Season 61:   S = 0   12 40.7  0.617  1.725 0.0845387  .
## Season 62:   S = 0    6 43.3  0.293  0.760 0.4475209
## Season 63:   S = 0   -1 44.3 -0.048  0.000 1.0000000
## Season 64:   S = 0    5 44.3  0.238  0.601 0.5480056
```

```
## Season 65:   S = 0    6 40.7  0.309  0.784 0.4330034
## Season 66:   S = 0   -4 43.3 -0.195 -0.456 0.6485822
## Season 67:   S = 0   -8 43.3 -0.390 -1.063 0.2876113
## Season 68:   S = 0    1 44.3  0.048  0.000 1.0000000
## Season 69:   S = 0    1 35.7  0.056  0.000 1.0000000
## Season 70:   S = 0  -13 44.3 -0.619 -1.802 0.0715054  .
## Season 71:   S = 0  -10 40.7 -0.514 -1.411 0.1581525
## Season 72:   S = 0   -3 44.3 -0.143 -0.300 0.7638906
## Season 73:   S = 0   -3 44.3 -0.143 -0.300 0.7638906
## Season 74:   S = 0   -7 44.3 -0.333 -0.901 0.3675207
## Season 75:   S = 0   -7 44.3 -0.333 -0.901 0.3675207
## Season 76:   S = 0    3 44.3  0.143  0.300 0.7638906
## Season 77:   S = 0    0 40.7  0.000  0.000 1.0000000
## Season 78:   S = 0   -6 40.7 -0.309 -0.784 0.4330034
## Season 79:   S = 0   -6 40.7 -0.309 -0.784 0.4330034
## Season 80:   S = 0    2 40.7  0.103  0.157 0.8753926
## Season 81:   S = 0   -9 44.3 -0.429 -1.202 0.2295562
## Season 82:   S = 0    8 43.3  0.390  1.063 0.2876113
## Season 83:   S = 0    4 43.3  0.195  0.456 0.6485822
## Season 84:   S = 0   -8 40.7 -0.411 -1.098 0.2723409
## Season 85:   S = 0   -1 35.7 -0.056  0.000 1.0000000
## Season 86:   S = 0  -11 44.3 -0.524 -1.502 0.1331285
## Season 87:   S = 0  -11 42.3 -0.551 -1.537 0.1243064
## Season 88:   S = 0    3 44.3  0.143  0.300 0.7638906
## Season 89:   S = 0   -6 43.3 -0.293 -0.760 0.4475209
## Season 90:   S = 0   -9 44.3 -0.429 -1.202 0.2295562
## Season 91:   S = 0    8 43.3  0.390  1.063 0.2876113
## Season 92:   S = 0   -2 43.3 -0.098 -0.152 0.8792572
## Season 93:   S = 0    4 43.3  0.195  0.456 0.6485822
## Season 94:   S = 0    1 42.3  0.050  0.000 1.0000000
## Season 95:   S = 0    5 35.7  0.282  0.670 0.5030014
## Season 96:   S = 0    0 43.3  0.000  0.000 1.0000000
## Season 97:   S = 0   11 44.3  0.524  1.502 0.1331285
## Season 98:   S = 0   15 44.3  0.714  2.103 0.0354981  *
## Season 99:   S = 0   -4 43.3 -0.195 -0.456 0.6485822
## Season 100:   S = 0  -9 44.3 -0.429 -1.202 0.2295562
## Season 101:   S = 0  -3 44.3 -0.143 -0.300 0.7638906
## Season 102:   S = 0   8 43.3  0.390  1.063 0.2876113
## Season 103:   S = 0  -2 43.3 -0.098 -0.152 0.8792572
## Season 104:   S = 0  -4 43.3 -0.195 -0.456 0.6485822
## Season 105:   S = 0  -4 40.7 -0.206 -0.470 0.6380425
## Season 106:   S = 0  -5 35.7 -0.282 -0.670 0.5030014
## Season 107:   S = 0  -7 44.3 -0.333 -0.901 0.3675207
## Season 108:   S = 0   0 40.7  0.000  0.000 1.0000000
## Season 109:   S = 0   2 40.7  0.103  0.157 0.8753926
## Season 110:   S = 0   7 44.3  0.333  0.901 0.3675207
## Season 111:   S = 0 -10 43.3 -0.488 -1.367 0.1715632
## Season 112:   S = 0  -3 44.3 -0.143 -0.300 0.7638906
## Season 113:   S = 0  -1 44.3 -0.048  0.000 1.0000000
## Season 114:   S = 0   7 42.3  0.350  0.922 0.3564410
## Season 115:   S = 0  -8 43.3 -0.390 -1.063 0.2876113
## Season 116:   S = 0  -7 42.3 -0.350 -0.922 0.3564410
## Season 117:   S = 0   3 27.7  0.197  0.380 0.7037713
## Season 118:   S = 0   1 35.7  0.056  0.000 1.0000000
```

```
## Season 119:   S = 0   2 43.3  0.098  0.152 0.8792572
## Season 120:   S = 0  -6 43.3 -0.293 -0.760 0.4475209
## Season 121:   S = 0 -13 44.3 -0.619 -1.802 0.0715054  .
## Season 122:   S = 0 -10 40.7 -0.514 -1.411 0.1581525
## Season 123:   S = 0   2 43.3  0.098  0.152 0.8792572
## Season 124:   S = 0 -12 40.7 -0.617 -1.725 0.0845387  .
## Season 125:   S = 0  -3 44.3 -0.143 -0.300 0.7638906
## Season 126:   S = 0   8 40.7  0.411  1.098 0.2723409
## Season 127:   S = 0   1 44.3  0.048  0.000 1.0000000
## Season 128:   S = 0   3 44.3  0.143  0.300 0.7638906
## Season 129:   S = 0   2 43.3  0.098  0.152 0.8792572
## Season 130:   S = 0   1 44.3  0.048  0.000 1.0000000
## Season 131:   S = 0   8 43.3  0.390  1.063 0.2876113
## Season 132:   S = 0   3 44.3  0.143  0.300 0.7638906
## Season 133:   S = 0   9 42.3  0.451  1.230 0.2188629
## Season 134:   S = 0 -16 43.3 -0.781 -2.279 0.0226871  *
## Season 135:   S = 0  -4 43.3 -0.195 -0.456 0.6485822
## Season 136:   S = 0   9 44.3  0.429  1.202 0.2295562
## Season 137:   S = 0  -3 44.3 -0.143 -0.300 0.7638906
## Season 138:   S = 0   6 43.3  0.293  0.760 0.4475209
## Season 139:   S = 0   1 44.3  0.048  0.000 1.0000000
## Season 140:   S = 0   2 43.3  0.098  0.152 0.8792572
## Season 141:   S = 0  -4 43.3 -0.195 -0.456 0.6485822
## Season 142:   S = 0  -2 43.3 -0.098 -0.152 0.8792572
## Season 143:   S = 0   0 43.3  0.000  0.000 1.0000000
## Season 144:   S = 0  -8 40.7 -0.411 -1.098 0.2723409
## Season 145:   S = 0   1 44.3  0.048  0.000 1.0000000
## Season 146:   S = 0   8 40.7  0.411  1.098 0.2723409
## Season 147:   S = 0  -6 43.3 -0.293 -0.760 0.4475209
## Season 148:   S = 0  -2 43.3 -0.098 -0.152 0.8792572
## Season 149:   S = 0   3 44.3  0.143  0.300 0.7638906
## Season 150:   S = 0  -4 40.7 -0.206 -0.470 0.6380425
## Season 151:   S = 0 -18 43.3 -0.878 -2.582 0.0098092 **
## Season 152:   S = 0  -3 44.3 -0.143 -0.300 0.7638906
## Season 153:   S = 0  -3 44.3 -0.143 -0.300 0.7638906
## Season 154:   S = 0   8 43.3  0.390  1.063 0.2876113
## Season 155:   S = 0  -5 35.7 -0.282 -0.670 0.5030014
## Season 156:   S = 0   8 40.7  0.411  1.098 0.2723409
## Season 157:   S = 0   0 40.7  0.000  0.000 1.0000000
## Season 158:   S = 0   4 40.7  0.206  0.470 0.6380425
## Season 159:   S = 0  -3 35.7 -0.169 -0.335 0.7377101
## Season 160:   S = 0   6 43.3  0.293  0.760 0.4475209
## Season 161:   S = 0 -11 44.3 -0.524 -1.502 0.1331285
## Season 162:   S = 0  -3 44.3 -0.143 -0.300 0.7638906
## Season 163:   S = 0  -4 40.7 -0.206 -0.470 0.6380425
## Season 164:   S = 0   1 35.7  0.056  0.000 1.0000000
## Season 165:   S = 0  -3 44.3 -0.143 -0.300 0.7638906
## Season 166:   S = 0  -5 42.3 -0.250 -0.615 0.5387009
## Season 167:   S = 0  -1 44.3 -0.048  0.000 1.0000000
## Season 168:   S = 0   3 44.3  0.143  0.300 0.7638906
## Season 169:   S = 0   5 42.3  0.250  0.615 0.5387009
## Season 170:   S = 0  -6 43.3 -0.293 -0.760 0.4475209
## Season 171:   S = 0 -10 43.3 -0.488 -1.367 0.1715632
## Season 172:   S = 0  -8 40.7 -0.411 -1.098 0.2723409
```

```
## Season 173:   S = 0   2 43.3  0.098  0.152 0.8792572
## Season 174:   S = 0   6 43.3  0.293  0.760 0.4475209
## Season 175:   S = 0   2 40.7  0.103  0.157 0.8753926
## Season 176:   S = 0   3 39.7  0.159  0.318 0.7508235
## Season 177:   S = 0  -9 44.3 -0.429 -1.202 0.2295562
## Season 178:   S = 0   3 42.3  0.150  0.307 0.7585471
## Season 179:   S = 0   3 44.3  0.143  0.300 0.7638906
## Season 180:   S = 0   6 43.3  0.293  0.760 0.4475209
## Season 181:   S = 0  -1 44.3 -0.048  0.000 1.0000000
## Season 182:   S = 0   8 40.7  0.411  1.098 0.2723409
## Season 183:   S = 0   9 44.3  0.429  1.202 0.2295562
## Season 184:   S = 0  -9 44.3 -0.429 -1.202 0.2295562
## Season 185:   S = 0  -4 40.7 -0.206 -0.470 0.6380425
## Season 186:   S = 0 -12 40.7 -0.617 -1.725 0.0845387  .
## Season 187:   S = 0   8 41.3  0.411  1.089 0.2762424
## Season 188:   S = 0   4 40.7  0.206  0.470 0.6380425
## Season 189:   S = 0  13 42.3  0.651  1.844 0.0651342  .
## Season 190:   S = 0  11 42.3  0.551  1.537 0.1243064
## Season 191:   S = 0   8 40.7  0.411  1.098 0.2723409
## Season 192:   S = 0  -2 40.7 -0.103 -0.157 0.8753926
## Season 193:   S = 0  13 42.3  0.651  1.844 0.0651342  .
## Season 194:   S = 0   8 40.7  0.411  1.098 0.2723409
## Season 195:   S = 0  14 40.7  0.720  2.039 0.0414937  *
## Season 196:   S = 0   3 44.3  0.143  0.300 0.7638906
## Season 197:   S = 0 -14 43.3 -0.683 -1.975 0.0482861  *
## Season 198:   S = 0  -2 41.3 -0.103 -0.156 0.8763935
## Season 199:   S = 0 -12 43.3 -0.586 -1.671 0.0947177  .
## Season 200:   S = 0   1 42.3  0.050  0.000 1.0000000
## Season 201:   S = 0  15 44.3  0.714  2.103 0.0354981  *
## Season 202:   S = 0   0 43.3  0.000  0.000 1.0000000
## Season 203:   S = 0   9 42.3  0.451  1.230 0.2188629
## Season 204:   S = 0   1 42.3  0.050  0.000 1.0000000
## Season 205:   S = 0   1 35.7  0.056  0.000 1.0000000
## Season 206:   S = 0   9 42.3  0.451  1.230 0.2188629
## Season 207:   S = 0  11 44.3  0.524  1.502 0.1331285
## Season 208:   S = 0  10 43.3  0.488  1.367 0.1715632
## Season 209:   S = 0  14 40.7  0.720  2.039 0.0414937  *
## Season 210:   S = 0   8 40.7  0.411  1.098 0.2723409
## Season 211:   S = 0   3 27.7  0.197  0.380 0.7037713
## Season 212:   S = 0   7 39.7  0.370  0.953 0.3407618
## Season 213:   S = 0   2 34.7  0.117  0.170 0.8651347
## Season 214:   S = 0  10 40.7  0.514  1.411 0.1581525
## Season 215:   S = 0   2 40.7  0.103  0.157 0.8753926
## Season 216:   S = 0   9 39.7  0.476  1.270 0.2040082
## Season 217:   S = 0   4 40.7  0.206  0.470 0.6380425
## Season 218:   S = 0   3 39.7  0.159  0.318 0.7508235
## Season 219:   S = 0   4 40.7  0.206  0.470 0.6380425
## Season 220:   S = 0   4 43.3  0.195  0.456 0.6485822
## Season 221:   S = 0  -1 39.7 -0.053  0.000 1.0000000
## Season 222:   S = 0  -8 40.7 -0.411 -1.098 0.2723409
## Season 223:   S = 0  -9 35.7 -0.507 -1.340 0.1803919
## Season 224:   S = 0  -1 27.7 -0.066  0.000 1.0000000
## Season 225:   S = 0  11 35.7  0.620  1.674 0.0940448  .
## Season 226:   S = 0  12 40.7  0.617  1.725 0.0845387  .
```

```
## Season 227:   S = 0   6 34.7  0.350  0.849 0.3957657
## Season 228:   S = 0   6 40.7  0.309  0.784 0.4330034
## Season 229:   S = 0  -1 27.7 -0.066  0.000 1.0000000
## Season 230:   S = 0  -4 40.7 -0.206 -0.470 0.6380425
## Season 231:   S = 0  -5 27.7 -0.329 -0.760 0.4469742
## Season 232:   S = 0  -1 42.3 -0.050  0.000 1.0000000
## Season 233:   S = 0  14 43.3  0.683  1.975 0.0482861  *
## Season 234:   S = 0   6 40.7  0.309  0.784 0.4330034
## Season 235:   S = 0   7 27.7  0.461  1.141 0.2539933
## Season 236:   S = 0   3 42.3  0.150  0.307 0.7585471
## Season 237:   S = 0  -1 35.7 -0.056  0.000 1.0000000
## Season 238:   S = 0  -6 40.7 -0.309 -0.784 0.4330034
## Season 239:   S = 0   2 40.7  0.103  0.157 0.8753926
## Season 240:   S = 0   7 35.7  0.394  1.005 0.3150596
## Season 241:   S = 0  -1 35.7 -0.056  0.000 1.0000000
## Season 242:   S = 0   6 40.7  0.309  0.784 0.4330034
## Season 243:   S = 0  -3 35.7 -0.169 -0.335 0.7377101
## Season 244:   S = 0  -1 35.7 -0.056  0.000 1.0000000
## Season 245:   S = 0  -6 43.3 -0.293 -0.760 0.4475209
## Season 246:   S = 0   4 43.3  0.195  0.456 0.6485822
## Season 247:   S = 0  11 35.7  0.620  1.674 0.0940448  .
## Season 248:   S = 0  -3 35.7 -0.169 -0.335 0.7377101
## Season 249:   S = 0  -9 35.7 -0.507 -1.340 0.1803919
## Season 250:   S = 0 -14 40.7 -0.720 -2.039 0.0414937  *
## Season 251:   S = 0   4 40.7  0.206  0.470 0.6380425
## Season 252:   S = 0   6 43.3  0.293  0.760 0.4475209
## Season 253:   S = 0  -6 40.7 -0.309 -0.784 0.4330034
## Season 254:   S = 0  -6 40.7 -0.309 -0.784 0.4330034
## Season 255:   S = 0  -5 35.7 -0.282 -0.670 0.5030014
## Season 256:   S = 0   7 35.7  0.394  1.005 0.3150596
## Season 257:   S = 0   5 27.7  0.329  0.760 0.4469742
## Season 258:   S = 0   6 40.7  0.309  0.784 0.4330034
## Season 259:   S = 0  -8 43.3 -0.390 -1.063 0.2876113
## Season 260:   S = 0   3 35.7  0.169  0.335 0.7377101
## Season 261:   S = 0   5 42.3  0.250  0.615 0.5387009
## Season 262:   S = 0   7 35.7  0.394  1.005 0.3150596
## Season 263:   S = 0   1 39.7  0.053  0.000 1.0000000
## Season 264:   S = 0  -2 40.7 -0.103 -0.157 0.8753926
## Season 265:   S = 0   8 43.3  0.390  1.063 0.2876113
## Season 266:   S = 0   2 40.7  0.103  0.157 0.8753926
## Season 267:   S = 0  -2 40.7 -0.103 -0.157 0.8753926
## Season 268:   S = 0   0 43.3  0.000  0.000 1.0000000
## Season 269:   S = 0   5 42.3  0.250  0.615 0.5387009
## Season 270:   S = 0   6 43.3  0.293  0.760 0.4475209
## Season 271:   S = 0   8 40.7  0.411  1.098 0.2723409
## Season 272:   S = 0   7 35.7  0.394  1.005 0.3150596
## Season 273:   S = 0   0  0.0    NaN    NaN        NA  ?
## Season 274:   S = 0  -2 16.0 -0.178 -0.250 0.8025873
## Season 275:   S = 0   7 35.7  0.394  1.005 0.3150596
## Season 276:   S = 0   9 35.7  0.507  1.340 0.1803919
## Season 277:   S = 0   0 43.3  0.000  0.000 1.0000000
## Season 278:   S = 0  -4 43.3 -0.195 -0.456 0.6485822
## Season 279:   S = 0  -5 42.3 -0.250 -0.615 0.5387009
## Season 280:   S = 0  -7 27.7 -0.461 -1.141 0.2539933
```

```
## Season 281:   S = 0  -1 27.7 -0.066  0.000 1.0000000
## Season 282:   S = 0  -1 39.7 -0.053  0.000 1.0000000
## Season 283:   S = 0  -1 35.7 -0.056  0.000 1.0000000
## Season 284:   S = 0   1 35.7  0.056  0.000 1.0000000
## Season 285:   S = 0   3 39.7  0.159  0.318 0.7508235
## Season 286:   S = 0  -2 40.7 -0.103 -0.157 0.8753926
## Season 287:   S = 0  -4 43.3 -0.195 -0.456 0.6485822
## Season 288:   S = 0   3 39.7  0.159  0.318 0.7508235
## Season 289:   S = 0   4 43.3  0.195  0.456 0.6485822
## Season 290:   S = 0   0 43.3  0.000  0.000 1.0000000
## Season 291:   S = 0  -4 40.7 -0.206 -0.470 0.6380425
## Season 292:   S = 0  -9 44.3 -0.429 -1.202 0.2295562
## Season 293:   S = 0   3 42.3  0.150  0.307 0.7585471
## Season 294:   S = 0  10 40.7  0.514  1.411 0.1581525
## Season 295:   S = 0 -11 42.3 -0.551 -1.537 0.1243064
## Season 296:   S = 0   5 35.7  0.282  0.670 0.5030014
## Season 297:   S = 0   2 40.7  0.103  0.157 0.8753926
## Season 298:   S = 0  -5 39.7 -0.265 -0.635 0.5253584
## Season 299:   S = 0   2 40.7  0.103  0.157 0.8753926
## Season 300:   S = 0  -3 39.7 -0.159 -0.318 0.7508235
## Season 301:   S = 0  -3 35.7 -0.169 -0.335 0.7377101
## Season 302:   S = 0   7 35.7  0.394  1.005 0.3150596
## Season 303:   S = 0   1 26.3  0.072  0.000 1.0000000
## Season 304:   S = 0  10 24.7  0.745  1.812 0.0699674  .
## Season 305:   S = 0  -3 28.3 -0.200 -0.376 0.7071142
## Season 306:   S = 0  -1 19.7 -0.086  0.000 1.0000000
## Season 307:   S = 0   5 19.7  0.430  0.902 0.3670700
## Season 308:   S = 0   3 28.3  0.200  0.376 0.7071142
## Season 309:   S = 0  -1 28.3 -0.067  0.000 1.0000000
## Season 310:   S = 0  -1 23.7 -0.078  0.000 1.0000000
## Season 311:   S = 0   7 26.3  0.501  1.169 0.2423127
## Season 312:   S = 0   8 24.7  0.596  1.409 0.1587087
## Season 313:   S = 0   8 24.7  0.596  1.409 0.1587087
## Season 314:   S = 0   5 19.7  0.430  0.902 0.3670700
## Season 315:   S = 0  14 27.3  0.966  2.487 0.0128989  *
## Season 316:   S = 0   4 27.3  0.276  0.574 0.5660903
## Season 317:   S = 0   4 27.3  0.276  0.574 0.5660903
## Season 318:   S = 0  -1 28.3 -0.067  0.000 1.0000000
## Season 319:   S = 0   5 26.3  0.358  0.779 0.4356948
## Season 320:   S = 0   6 27.3  0.414  0.956 0.3388878
## Season 321:   S = 0   1 28.3  0.067  0.000 1.0000000
## Season 322:   S = 0   0 24.7  0.000  0.000 1.0000000
## Season 323:   S = 0   0 24.7  0.000  0.000 1.0000000
## Season 324:   S = 0   0 24.7  0.000  0.000 1.0000000
## Season 325:   S = 0  -5 23.7 -0.389 -0.822 0.4109480
## Season 326:   S = 0   4 27.3  0.276  0.574 0.5660903
## Season 327:   S = 0   4 27.3  0.276  0.574 0.5660903
## Season 328:   S = 0  -7 19.7 -0.602 -1.353 0.1760675
## Season 329:   S = 0  -6 27.3 -0.414 -0.956 0.3388878
## Season 330:   S = 0 -11 28.3 -0.733 -1.879 0.0602892  .
## Season 331:   S = 0   2 24.7  0.149  0.201 0.8404274
## Season 332:   S = 0  -8 27.3 -0.552 -1.339 0.1805996
## Season 333:   S = 0   2 27.3  0.138  0.191 0.8483117
## Season 334:   S = 0  -1 28.3 -0.067  0.000 1.0000000
```

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## Season 335:   S = 0   3 19.7  0.258  0.451 0.6519985
## Season 336:   S = 0  -4 27.3 -0.276 -0.574 0.5660903
## Season 337:   S = 0   0 27.3  0.000  0.000 1.0000000
## Season 338:   S = 0  -4 27.3 -0.276 -0.574 0.5660903
## Season 339:   S = 0   0 27.3  0.000  0.000 1.0000000
## Season 340:   S = 0  -3 28.3 -0.200 -0.376 0.7071142
## Season 341:   S = 0  -1 26.3 -0.072  0.000 1.0000000
## Season 342:   S = 0  -2 27.3 -0.138 -0.191 0.8483117
## Season 343:   S = 0   2 27.3  0.138  0.191 0.8483117
## Season 344:   S = 0   6 24.7  0.447  1.007 0.3140626
## Season 345:   S = 0  -5 28.3 -0.333 -0.751 0.4523704
## Season 346:   S = 0  -2 27.3 -0.138 -0.191 0.8483117
## Season 347:   S = 0  -1 28.3 -0.067  0.000 1.0000000
## Season 348:   S = 0   4 27.3  0.276  0.574 0.5660903
## Season 349:   S = 0  -1 28.3 -0.067  0.000 1.0000000
## Season 350:   S = 0   2 27.3  0.138  0.191 0.8483117
## Season 351:   S = 0  -8 27.3 -0.552 -1.339 0.1805996
## Season 352:   S = 0  -5 28.3 -0.333 -0.751 0.4523704
## Season 353:   S = 0   6 27.3  0.414  0.956 0.3388878
## Season 354:   S = 0  -5 28.3 -0.333 -0.751 0.4523704
## Season 355:   S = 0 -10 27.3 -0.690 -1.721 0.0851679  .
## Season 356:   S = 0   8 27.3  0.552  1.339 0.1805996
## Season 357:   S = 0   4 27.3  0.276  0.574 0.5660903
## Season 358:   S = 0   0 27.3  0.000  0.000 1.0000000
## Season 359:   S = 0  -8 24.7 -0.596 -1.409 0.1587087
## Season 360:   S = 0   1 28.3  0.067  0.000 1.0000000
## Season 361:   S = 0  -2 24.7 -0.149 -0.201 0.8404274
## Season 362:   S = 0   0 27.3  0.000  0.000 1.0000000
## Season 363:   S = 0   1 28.3  0.067  0.000 1.0000000
## Season 364:   S = 0   7 28.3  0.467  1.127 0.2596564
## Season 365:   S = 0  -2 27.3 -0.138 -0.191 0.8483117
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1       ## NA: '?'
```

Calculate the cumulative annual precip for each year by site and then multiply by drainage area (in NWIS_SiteInfo.csv under raw data) to get a volume of water for each year? We can compare with some cumulative discharge.

Calculate Cumulative Annual Precipitation for each year by Site and Create Dataframe

```
CumAnnualPrecip<- AlaskaTempPrecipDischarge%>%
  mutate(Year = year(DATE)) %>%
  group_by(site_no, Year)%>%
  summarize(CumPrecip=sum(PRCP, na.rm=TRUE))
```

Load in NWIS_SiteInfo.csv which has Drainage Areas for each Station

```
NWIS_SiteInfo<- read.csv("../DATA/RAW/NWIS_SiteInfo.csv")
```

Join NWIS_SiteInfo and CumAnnual Precip by Site Number and multiplt cumulative precip for each station and year by drainage area to determine water volume for each year and station

```
PrecipVolume<-CumAnnualPrecip%>%
  merge(NWIS_SiteInfo, by='site_no')%>%
  mutate(Water_Volume=CumPrecip*drain_area_va)%>%
  select(site_no:dec_long_va, drain_area_va, Water_Volume )
```