ADC_Code

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Set up your system

```r
# load packages
library(dplyr)
```

```
## Warning: package 'dplyr' was built under R version 3.5.2

##
## Attaching package: 'dplyr'

## The following objects are masked from 'package:stats':
##
##     filter, lag

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

```r
library(tidyverse)
```

```
## Warning: package 'tidyverse' was built under R version 3.5.2

## -- Attaching packages ---------------------------------------------------------------------------- t

## v ggplot2 3.1.1     v readr   1.3.1
## v tibble  2.1.1     v purrr   0.3.2
## v tidyr   0.8.3     v stringr 1.4.0
## v ggplot2 3.1.1     v forcats 0.4.0

## Warning: package 'tibble' was built under R version 3.5.3

## Warning: package 'tidyr' was built under R version 3.5.2

## Warning: package 'readr' was built under R version 3.5.2

## Warning: package 'purrr' was built under R version 3.5.3

## Warning: package 'stringr' was built under R version 3.5.2

## Warning: package 'forcats' was built under R version 3.5.2

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

```r
library(ggplot2)
library(FSA)
```

```
## Warning: package 'FSA' was built under R version 3.5.3

## ## FSA v0.8.22. See citation('FSA') if used in publication.
## ## Run fishR() for related website and fishR('IFAR') for related book.
```

```r
library(lme4)
```

```
## Warning: package 'lme4' was built under R version 3.5.3
```

```
## Loading required package: Matrix

##
## Attaching package: 'Matrix'

## The following object is masked from 'package:tidyr':
##
##     expand
```

```r
library(trend)
```

```
## Warning: package 'trend' was built under R version 3.5.2
```

```r
# set working directory
setwd("~/Duke/Year 2/Spring 2019/Data Analytics/ADC_Analysis/Code")

#check wd
getwd()
```

```
## [1] "C:/Users/Sarah/Documents/Duke/Year 2/Spring 2019/Data Analytics/ADC_Analysis/Code"
```

```r
# create ggplot theme
SKotheme <- theme_gray(base_size = 15) +
  theme(axis.text = element_text(color = "black"),
        legend.position = "right",
        plot.title = element_text(hjust = 0.5))

# set ggplot theme
theme_set(SKotheme)
```

Import & Explore

```r
# import dataset
ADC_raw <- read.csv("../Raw_Data/CalRecycle_ADC_raw.csv")

# explore dataset
view(ADC_raw)
class(ADC_raw)
```

```
## [1] "data.frame"
```

```r
colnames(ADC_raw)
```

```
##  [1] "Report.Year"
##  [2] "Report.Quarter"
##  [3] "Ash"
##  [4] "Auto.Shredder.Waste"
##  [5] "Construction.and.Demolition.Waste"
##  [6] "Compost"
##  [7] "Contaminated.Sediment"
##  [8] "Green.Material"
##  [9] "Mixed"
## [10] "Other"
## [11] "Tires"
## [12] "Sludge"
## [13] "Total"
```

```r
dim(ADC_raw)
```

```
## [1] 92 13
```

```r
# per the CalRecycle website, segregation into ADC types started in 1998
# therefore, for the analysis, remove data from before 1998
class(ADC_raw$Report.Year)
```

```
## [1] "integer"
```

```r
ADC_data <- filter(ADC_raw, Report.Year >= 1998)
dim(ADC_data)
```

```
## [1] 80 13
```

```r
# explore new dataset
head(ADC_data)
```

```
##   Report.Year Report.Quarter      Ash Auto.Shredder.Waste
## 1        2017              1 32511.83            153270.6
## 2        2017              2 37294.78            159759.7
## 3        2017              3 33349.25            153342.6
## 4        2017              4 22248.85            123203.5
## 5        2016              1 31423.40            123193.3
## 6        2016              2 45504.45            126040.9
##   Construction.and.Demolition.Waste  Compost Contaminated.Sediment
## 1                          173548.6  6128.89               3396.36
## 2                          199486.8  2746.22               7585.58
## 3                          164028.4  1796.97               4280.92
## 4                          198901.7 15993.13               2979.12
## 5                          160446.5 15681.63              20203.18
## 6                          144982.9 42215.62              18089.73
##   Green.Material    Mixed    Other    Tires    Sludge    Total
## 1       380686.2     0.00 71983.68 3771.40  68063.34 893360.9
## 2       401034.3  1516.12 71066.46 5066.35  65585.25 951141.6
## 3       362474.4 10891.73 78980.55 5323.75  79967.05 894435.6
## 4       347204.0  7964.83 56849.63 4575.75 141423.92 921344.5
## 5       334512.7 12756.90 82081.97 3402.03  83424.85 867126.5
## 6       310959.5 17946.71 75803.52 3616.26  72882.61 858042.2
```

```r
tail(ADC_data)
```

```
##    Report.Year Report.Quarter     Ash Auto.Shredder.Waste
## 75        1999              3 1578.70            69300.25
## 76        1999              4 2718.22            63910.19
## 77        1998              1 2631.85            39181.17
## 78        1998              2  878.63            49391.25
## 79        1998              3 2457.00            35573.00
## 80        1998              4 2418.00            38495.89
##    Construction.and.Demolition.Waste Compost Contaminated.Sediment
## 75                          48321.13       0                  0.00
## 76                          62057.02     381                 16.50
## 77                           2693.48       0                  0.00
## 78                           6666.70       0                  2.74
## 79                          28278.30       0                 92.17
## 80                          29591.80       0                  0.00
##    Green.Material    Mixed    Other     Tires    Sludge     Total
```

```
## 75       349276.6    0.00 4695.69  1265.82 66864.38 541302.6
## 76       360153.2    0.00 6316.72  3307.48 69058.27 567918.6
## 77       191066.3 3907.20 1008.27 14802.71 43391.12 298682.1
## 78       279191.3 3602.22 3305.93 15394.54 92416.47 450849.8
## 79       299986.8    0.00 2706.53  2943.31 99312.34 471349.4
## 80       313452.3 4130.00 3767.93   733.71 57511.25 450100.9
```

```r
# tidy the data by gathering the type columns
ADC_gathered <- gather(ADC_data, "Type", "Quantity", Ash:Sludge) %>%
  select(-Total) # remove Total column

# save the tidy dataset
write.csv(ADC_data, row.names = FALSE, file = "../Processed_Data/CalRecycle_ADC_tidy_processed.csv")

# generate summary data
ADC_summary_by_type <- ADC_gathered %>%
  group_by(Type) %>% # group the data by lakename
  filter(!is.na(Quantity)) %>% #remove the records when there are nas Quantity
  summarise(MeanQuarterlyQuantity = mean(Quantity),
            MinQuarterlyQuantity = min(Quantity),
            MaxQuarterlyQuantity = max(Quantity),
            sdQuarterlyQuantity = sd(Quantity),
            medianQuarterlyQuantity = median(Quantity))

ADC_summary_by_year <- ADC_gathered %>%
  group_by(Report.Year) %>% # group the data by year
  filter(!is.na(Quantity)) %>% #remove the records when there are nas Quantity
  summarise(MeanQuarterlyQuantity = mean(Quantity),
            MinQuarterlyQuantity = min(Quantity),
            MaxQuarterlyQuantity = max(Quantity),
            sdQuarterlyQuantity = sd(Quantity),
            medianQuarterlyQuantity = median(Quantity))
```

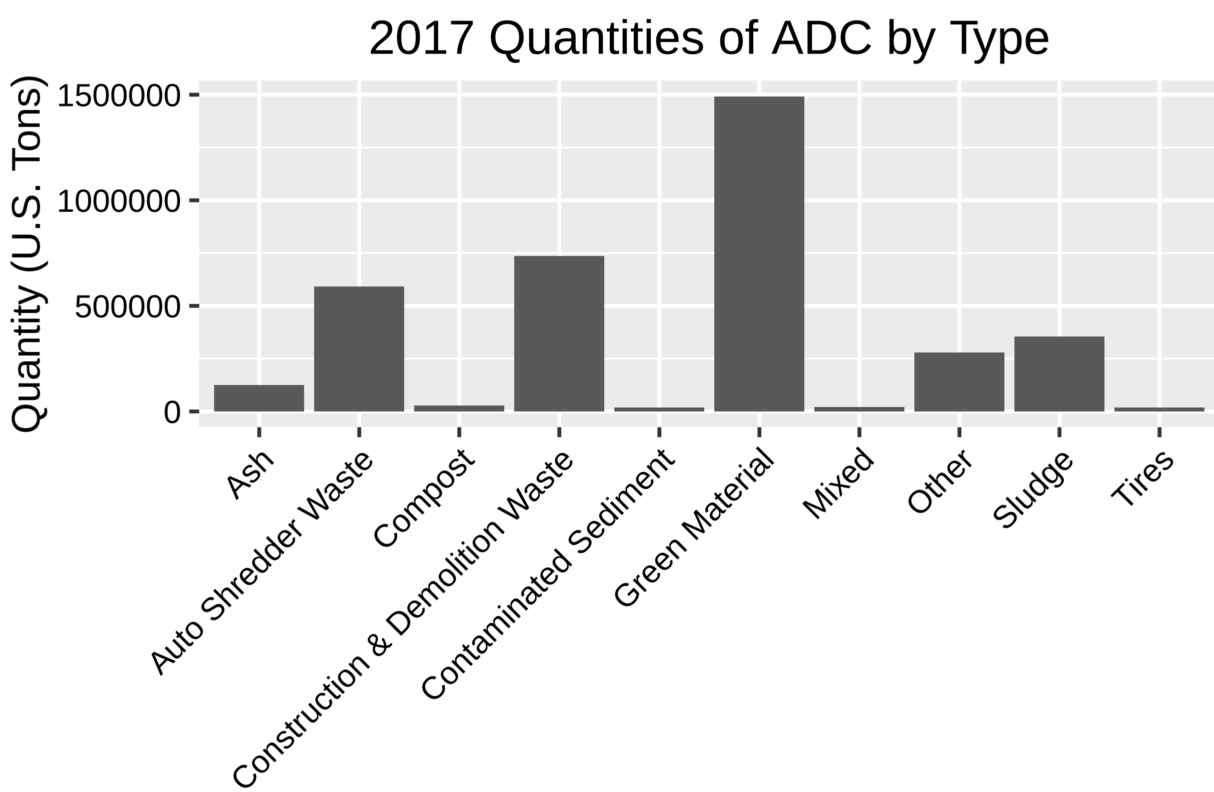
Create Graphs

```r
# Graph 1: for 2017 data, display total by type
total_bytype_2017 <- ADC_gathered %>%
  filter(Report.Year == 2017) %>%
  group_by(Type) %>%
  summarize(Quantity = sum(Quantity))

# save 2017 dataset
write.csv(total_bytype_2017, row.names = FALSE, file = "../Processed_Data/CalRecycle_ADC_2017only_proce

# convert column Type into factor
class(total_bytype_2017$Type)
```

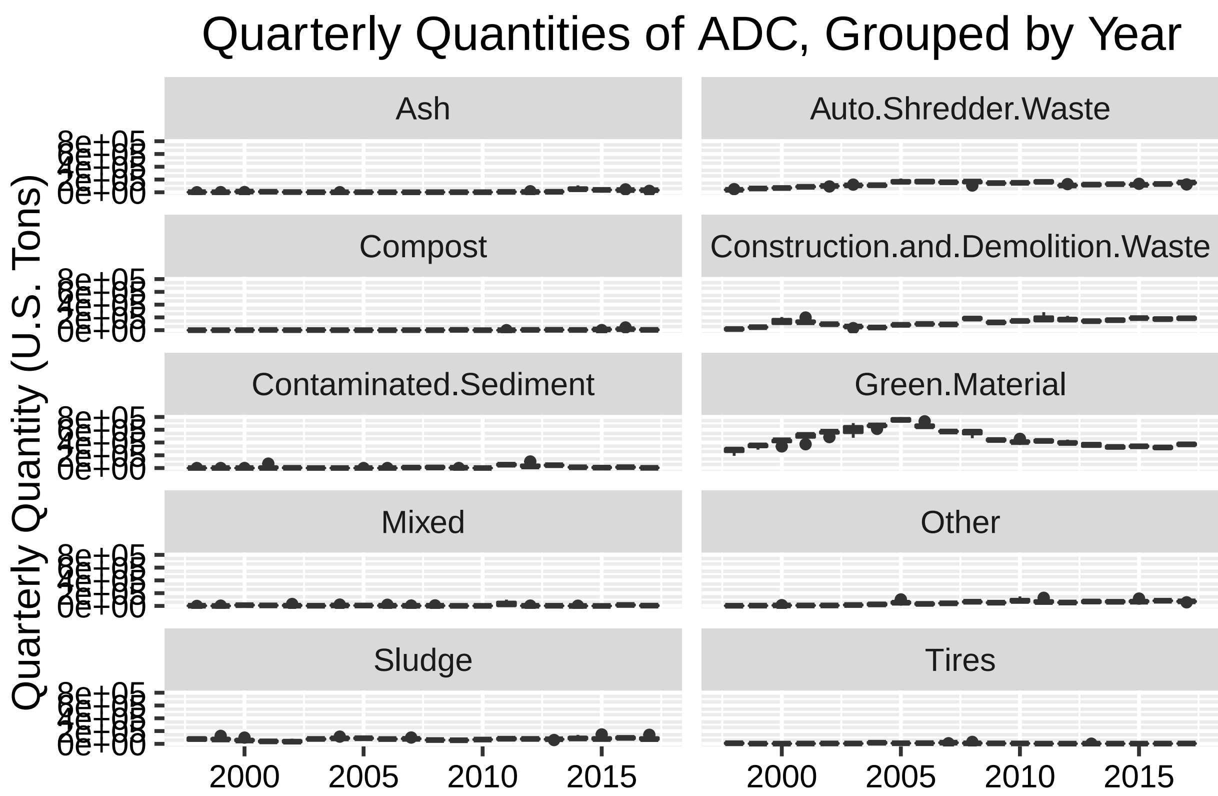
```
## [1] "character"
```

```r
total_bytype_2017$Type <- as.factor(total_bytype_2017$Type)

# plot as a bar chart
total_bytype_2017_plot <-
    ggplot(data=total_bytype_2017, aes(x=Type, y=Quantity)) +
    geom_bar(stat="identity") +
```

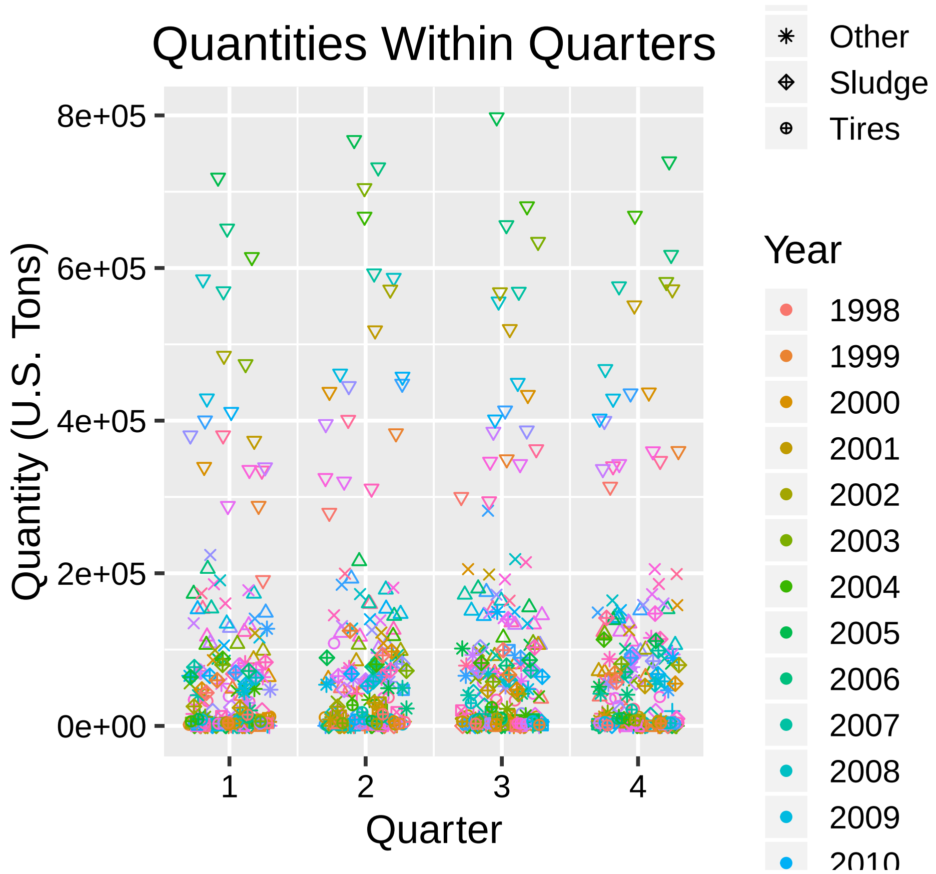
```
    xlab('') +
    ylab("Quantity (U.S. Tons)") +
    ggtitle("2017 Quantities of ADC by Type") +
    theme(axis.text.x = element_text(angle = 45, hjust = 1)) +
    scale_x_discrete(labels = c('Ash','Auto Shredder Waste','Compost', 'Construction & Demolition Waste
print(total_bytype_2017_plot)
```




```
# save figure
ggsave("2017ADCbytype_alltypes.jpg", total_bytype_2017_plot, path = "../Output", height = 4, width = 6,

# Graph 2: faceted by Type, display spread of quarterly values by year
quarterlyvalues_byyear_plot <- ggplot(ADC_gathered) +
  geom_boxplot(aes(x = Report.Year, y = Quantity, group = Report.Year)) +
  facet_wrap(vars(Type), nrow = 5) +
  xlab("") +
  ylab("Quarterly Quantity (U.S. Tons)") +
  ggtitle("Quarterly Quantities of ADC, Grouped by Year")
print(quarterlyvalues_byyear_plot)
```




```
# save figure
ggsave("ADCyeardistribution_alltypes.jpg", quarterlyvalues_byyear_plot, path = "../Output", height = 8,

# Graph 3: display data by quarter, all Types on same plot
quarterlyvalues_alltypes_plot <-
  ggplot(ADC_gathered) +
  geom_jitter(aes(x = Report.Quarter, y = Quantity, shape = as.factor(Type), color = as.factor(Report.Ye
  labs(shape="Type", colour="Year") +
  xlab("Quarter") +
  ylab("Quantity (U.S. Tons)") +
  ggtitle("Quantities Within Quarters") +
  scale_shape_manual(values=c(1, 2, 3, 4, 5, 6, 7, 8, 9, 10), labels = c("Ash", "Auto Shredder Waste",
  theme(legend.position="right", legend.box = "vertical", legend.direction = "vertical") +
  guides(shape = guide_legend(order = 1), color = guide_legend(order = 2))
print(quarterlyvalues_alltypes_plot)
```




```
# save figure
ggsave("QuarterlyADC_alltypes.jpg", quarterlyvalues_alltypes_plot, path = "../Output", height = 9, widt
```

Test 1: Statistical Modeling & Data Visualization

Is there a significant difference in total ADC between report quarters? (e.g. 1, 2, 3, 4)

```
# create dataset with only total values, from 1995-2017
ADC_total_only <- ADC_raw %>%
  select(Report.Year, Report.Quarter, Total) # keep all columns except ADC Types

# convert column Report.Quarter into factor
class(ADC_total_only$Report.Quarter)
```

```
## [1] "integer"
```

```
ADC_total_only$Report.Quarter <- as.factor(ADC_total_only$Report.Quarter)

# save the dataset
write.csv(ADC_total_only, row.names = FALSE, file = "../Processed_Data/CalRecycle_ADC_totalsonly_proces

# perform one-way ANOVA
# assumption #0: observations are independent (cannot be tested, but assumed to be independent)

# test assumption #1: normality
# null hypothesis is that the dataset is normally distributed
shapiro.test(ADC_total_only$Total[ADC_total_only$Report.Quarter == 1]) # p-value = 0.03312
```

```
##
##  Shapiro-Wilk normality test
##
## data:  ADC_total_only$Total[ADC_total_only$Report.Quarter == 1]
## W = 0.90566, p-value = 0.03312
```

```r
shapiro.test(ADC_total_only$Total[ADC_total_only$Report.Quarter == 2]) # p-value = 0.02271
```

```
##
##  Shapiro-Wilk normality test
##
## data:  ADC_total_only$Total[ADC_total_only$Report.Quarter == 2]
## W = 0.89774, p-value = 0.02271
```

```r
shapiro.test(ADC_total_only$Total[ADC_total_only$Report.Quarter == 3]) # p-value = 0.00993
```

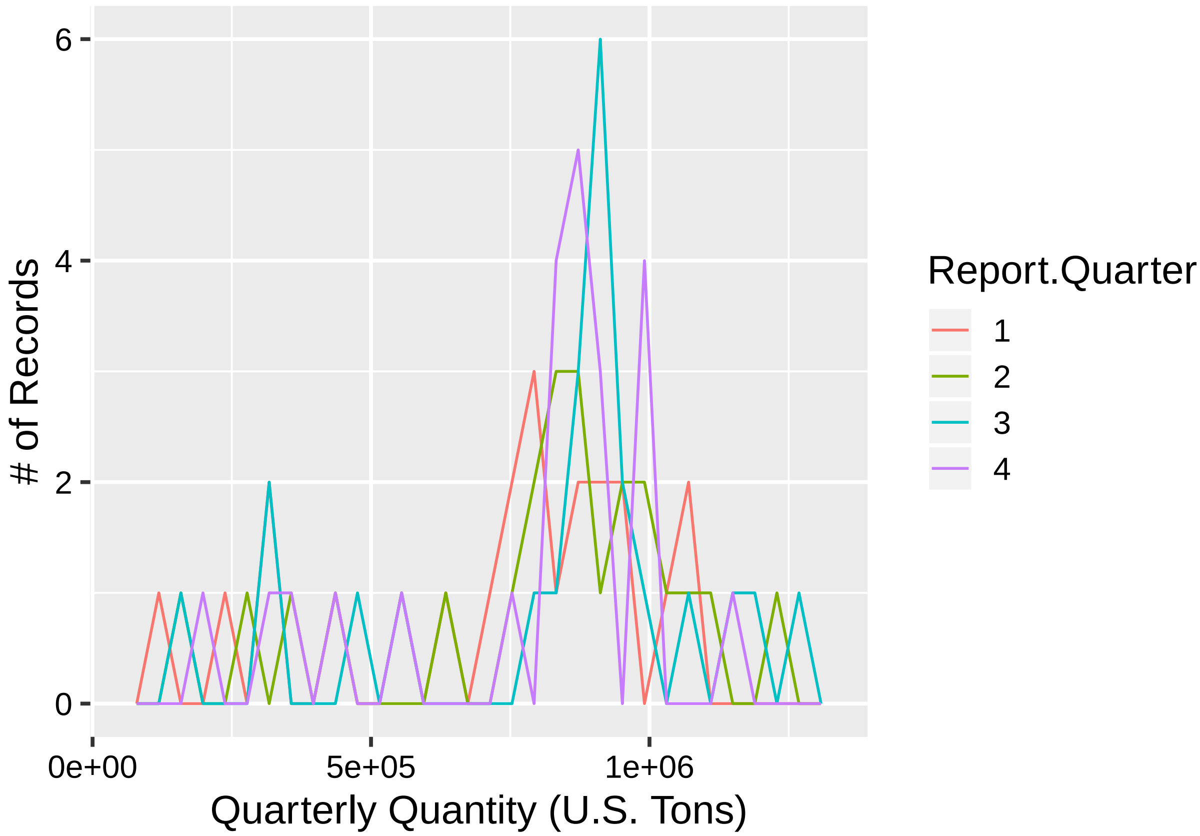
```
##
##  Shapiro-Wilk normality test
##
## data:  ADC_total_only$Total[ADC_total_only$Report.Quarter == 3]
## W = 0.87982, p-value = 0.00993
```

```r
shapiro.test(ADC_total_only$Total[ADC_total_only$Report.Quarter == 4]) # p-value = 0.001305
```

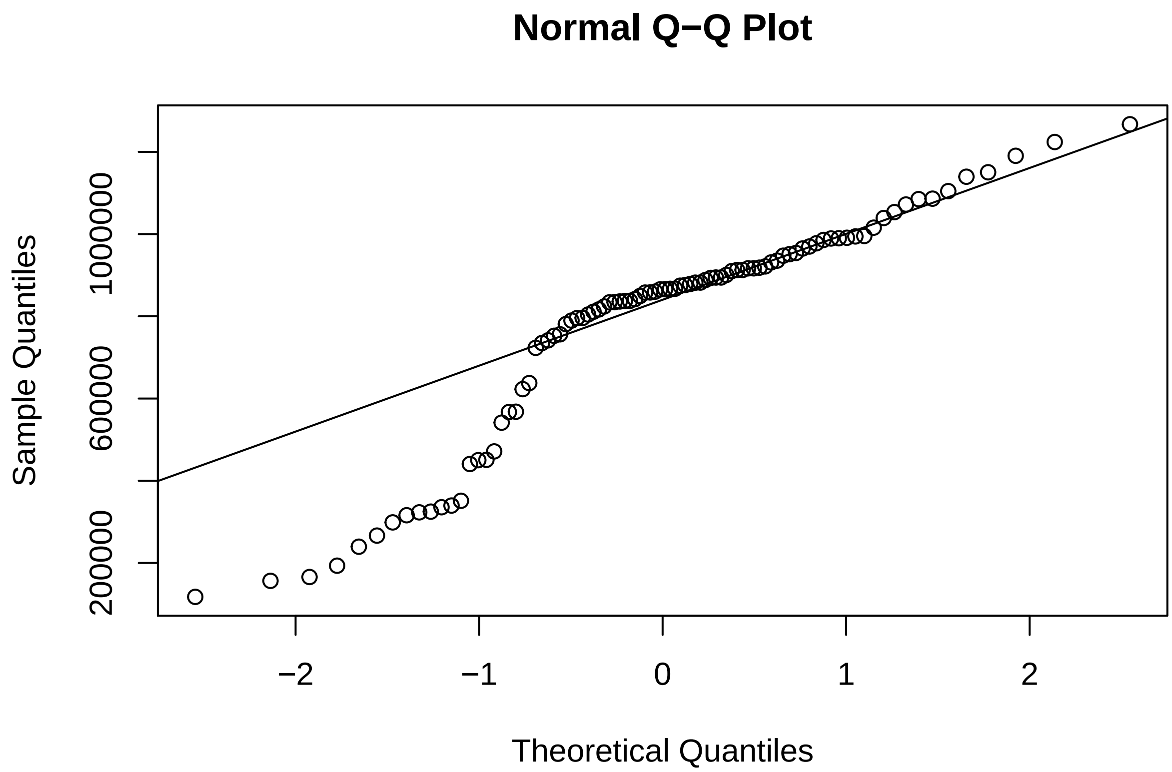
```
##
##  Shapiro-Wilk normality test
##
## data:  ADC_total_only$Total[ADC_total_only$Report.Quarter == 4]
## W = 0.83198, p-value = 0.001305
```

```r
ADC_freq_poly <- ggplot(ADC_total_only) +
  geom_freqpoly(aes(x = Total, color = Report.Quarter)) +
  xlab("Quarterly Quantity (U.S. Tons)") +
  ylab("# of Records")
print(ADC_freq_poly) # appears to be left skewed
```

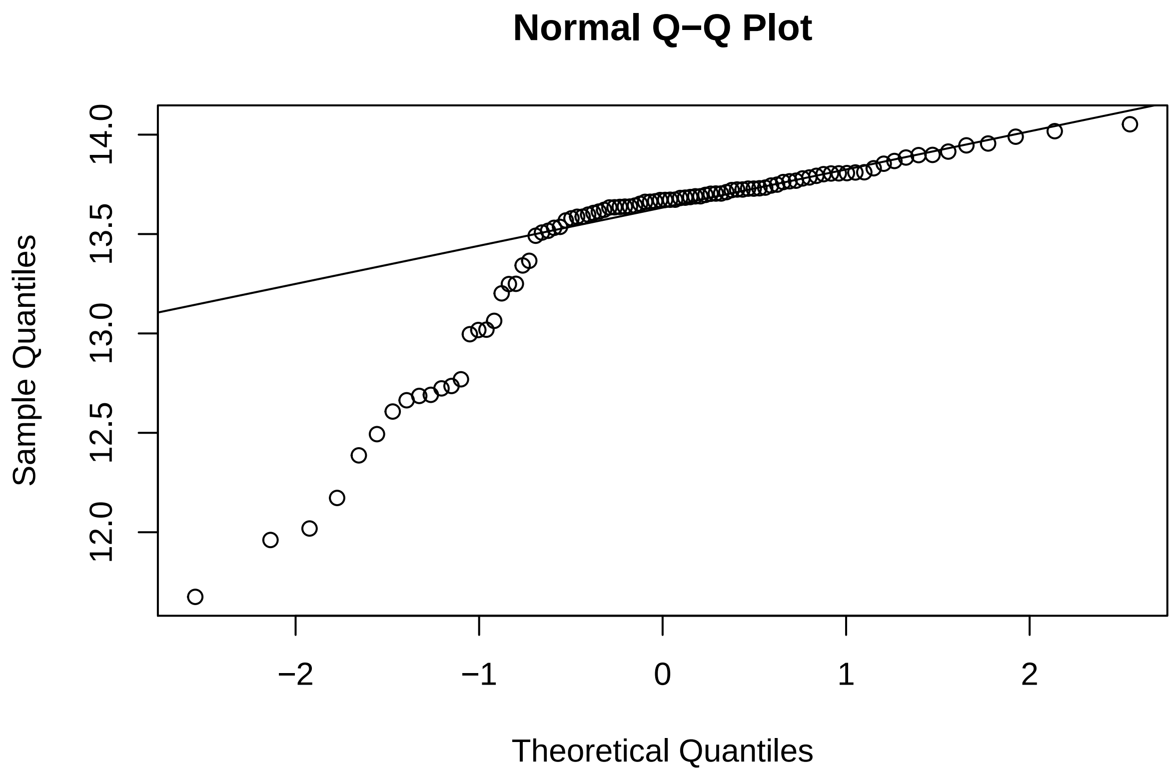
```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```




```
qqnorm(ADC_total_only$Total); qqline(ADC_total_only$Total) # does not match 1:1 ratio
```



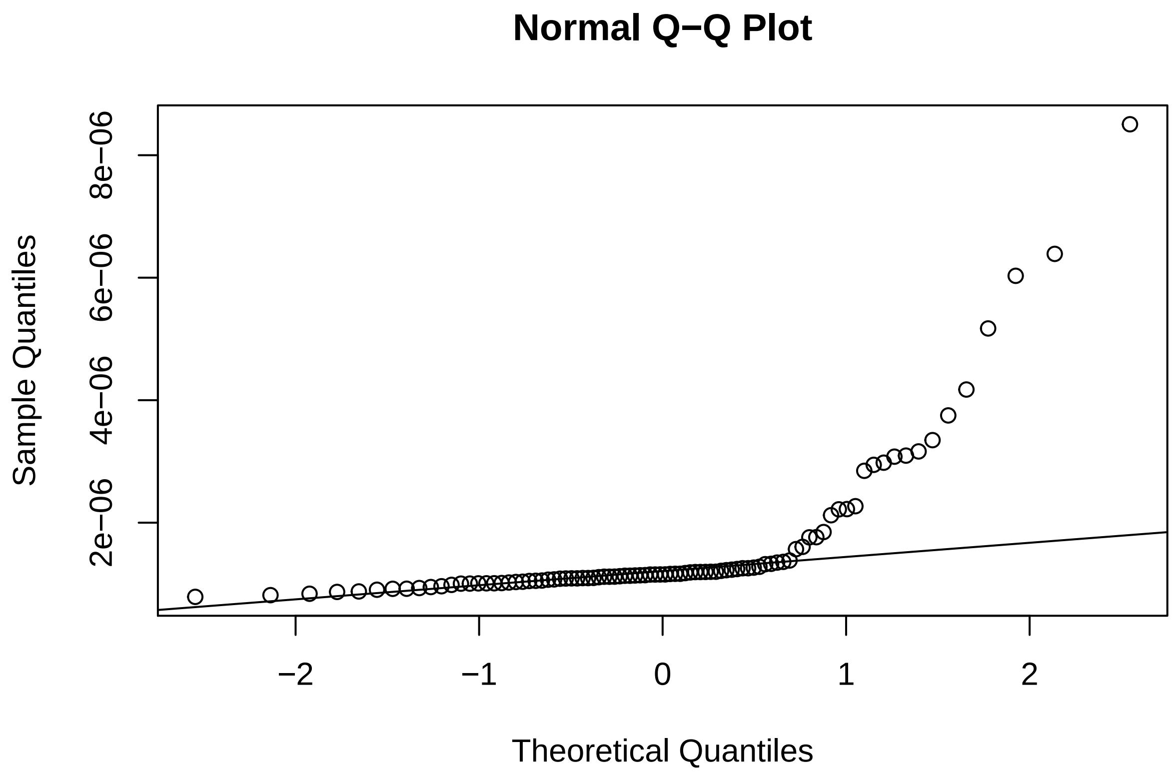

```
# Try to fix departure from normality with ln of Total. Result is not improved, so keep non-transformed
ADC_LogTotal <- mutate(ADC_total_only, LogTotal = log(Total))
qqnorm(ADC_LogTotal$LogTotal); qqline(ADC_LogTotal$LogTotal)
```




```
bartlett.test(ADC_LogTotal$LogTotal ~ ADC_LogTotal$Report.Quarter)
```

```
##
##  Bartlett test of homogeneity of variances
##
## data:  ADC_LogTotal$LogTotal by ADC_LogTotal$Report.Quarter
## Bartlett's K-squared = 1.1435, df = 3, p-value = 0.7666
```

```
# Try to fix departure from normality with 1/Total. Result is not improved, so keep non-transformed dat
ADC_InvTotal <- mutate(ADC_total_only, InvTotal = 1/Total)
qqnorm(ADC_InvTotal$InvTotal); qqline(ADC_InvTotal$InvTotal)
```




```r
bartlett.test(ADC_InvTotal$InvTotal ~ ADC_InvTotal$Report.Quarter)
```

```
##
##  Bartlett test of homogeneity of variances
##
## data:  ADC_InvTotal$InvTotal by ADC_InvTotal$Report.Quarter
## Bartlett's K-squared = 6.519, df = 3, p-value = 0.08892
```

```r
# test assumption #2: equal variances among groups

# null hypothesis is that the variance is the same for the treatment groups
bartlett.test(ADC_total_only$Total ~ ADC_total_only$Report.Quarter) #p-value = 0.9308 # df = 3 (statist
```

```
##
##  Bartlett test of homogeneity of variances
##
## data:  ADC_total_only$Total by ADC_total_only$Report.Quarter
## Bartlett's K-squared = 0.44478, df = 3, p-value = 0.9308
```

```r
# dataset is not normal, but does fulfill requirement for same variances. proceed with non-parametric t

# try non-parametric w/ post hoc, bc sample size is on the smaller end for parametric
ADC_quarter_kw <- kruskal.test(ADC_total_only$Total ~ ADC_total_only$Report.Quarter)
ADC_quarter_kw
```

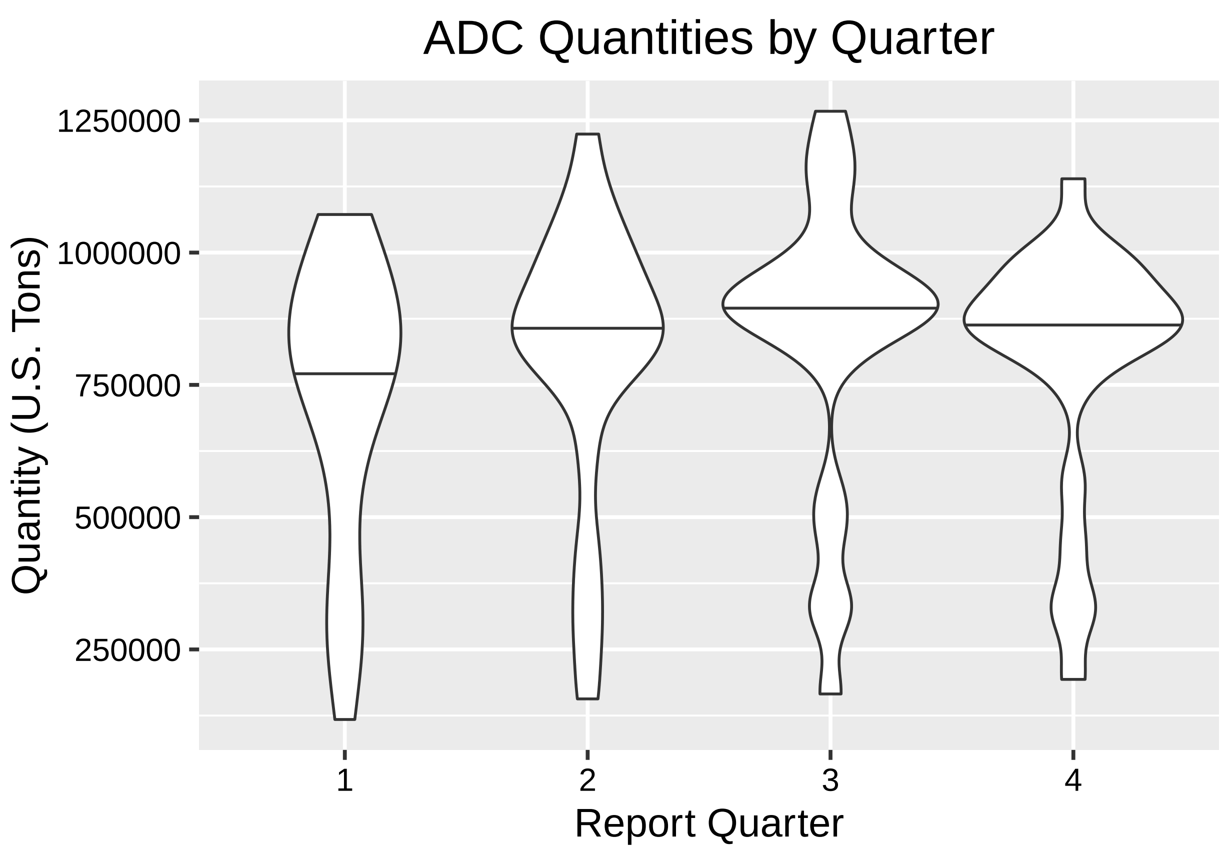
```
##
##  Kruskal-Wallis rank sum test
##
```

```
## data:  ADC_total_only$Total by ADC_total_only$Report.Quarter
## Kruskal-Wallis chi-squared = 3.4581, df = 3, p-value = 0.3262
```

```r
dunnTest(ADC_total_only$Total, ADC_total_only$Report.Quarter)
```

```
## Dunn (1964) Kruskal-Wallis multiple comparison

##   p-values adjusted with the Holm method.

##   Comparison           Z    P.unadj     P.adj
## 1      1 - 2 -1.08778370 0.27669061 1.0000000
## 2      1 - 3 -1.84978446 0.06434462 0.3860677
## 3      2 - 3 -0.76200076 0.44605955 0.8921191
## 4      1 - 4 -1.00495753 0.31491730 1.0000000
## 5      2 - 4  0.08282617 0.93398976 0.9339898
## 6      3 - 4  0.84482693 0.39820748 1.0000000
```

```r
# plot the results
ADC_quarter_plot <- ggplot(ADC_total_only, aes(x = Report.Quarter, y = Total)) +
  geom_violin(draw_quantiles = 0.5) +
  xlab('Report Quarter') +
  ylab('Quantity (U.S. Tons)') +
  ggtitle('ADC Quantities by Quarter')
print(ADC_quarter_plot)
```




```r
# save figure
ggsave("QuarterlyADC_violinplot.jpg", ADC_quarter_plot, path = "../Output", height = 4, width = 6, units
```

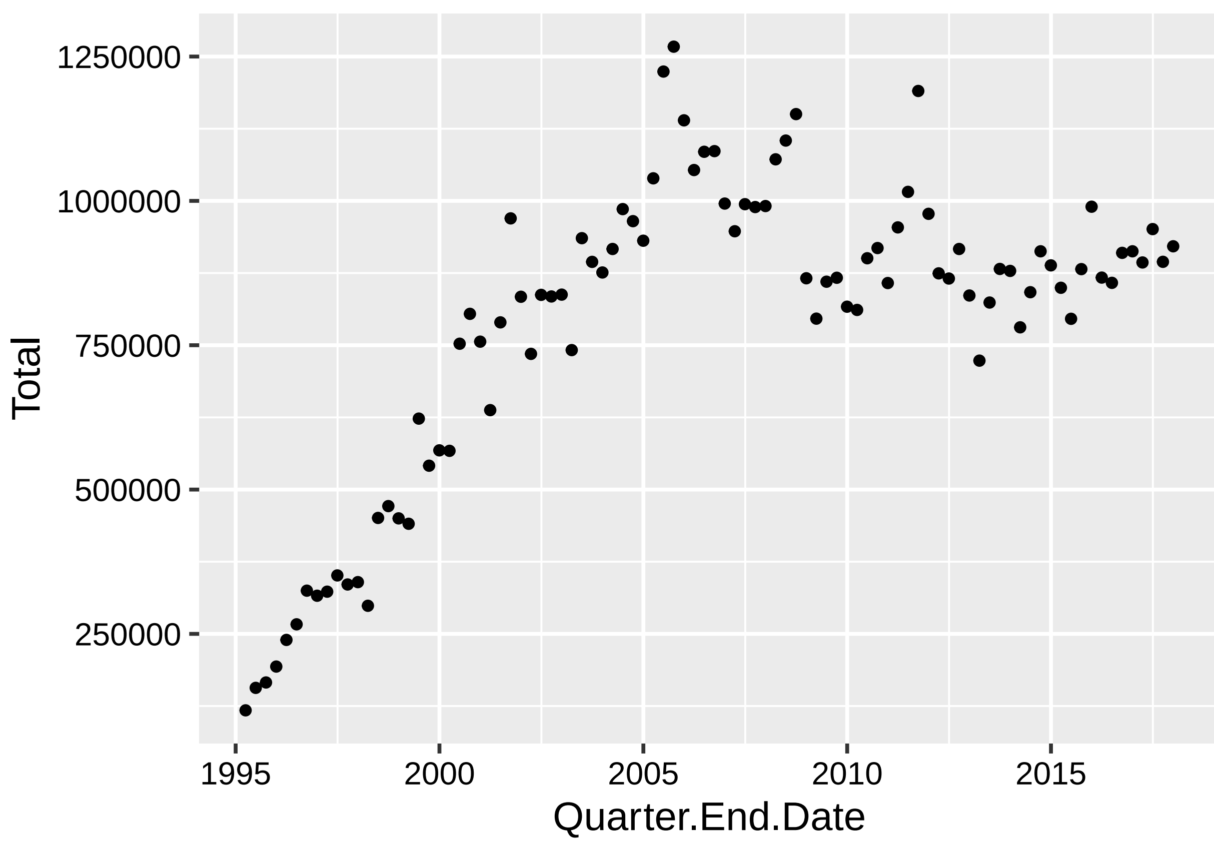
Test 2: Statistical Modeling & Data Visualization

Can total annual ADC be represented with a linear model?

```
# assumptions for lm (independent observation, normal distribution, equal variances among groups) check

# create dates corresponding to year & quarter combination
# Q1: Mar 31
# Q2: Jun 30
# Q3: Sep 30
# Q4: Dec 31

# create dataframe of month-date
quarters_to_dates <- data.frame("Quarter" = as.factor(1:4), "Month.Date" = c('3-31', '6-30', '9-30', '12

# create new dataframe with dates
ADC_fulldate <- ADC_total_only %>%
  inner_join(quarters_to_dates, by = c("Report.Quarter" =  "Quarter")) %>%
  unite('Quarter.End.Date', c(Report.Year, Month.Date), sep = "-", remove = FALSE)

ADC_fulldate$Quarter.End.Date <- as.Date(ADC_fulldate$Quarter.End.Date, "%Y-%m-%d")
class(ADC_fulldate$Quarter.End.Date)
```

```
## [1] "Date"
```

```
# create initial plot to visualize the data
ggplot(ADC_fulldate, aes(x = Quarter.End.Date, y = Total)) +
  geom_point()
```



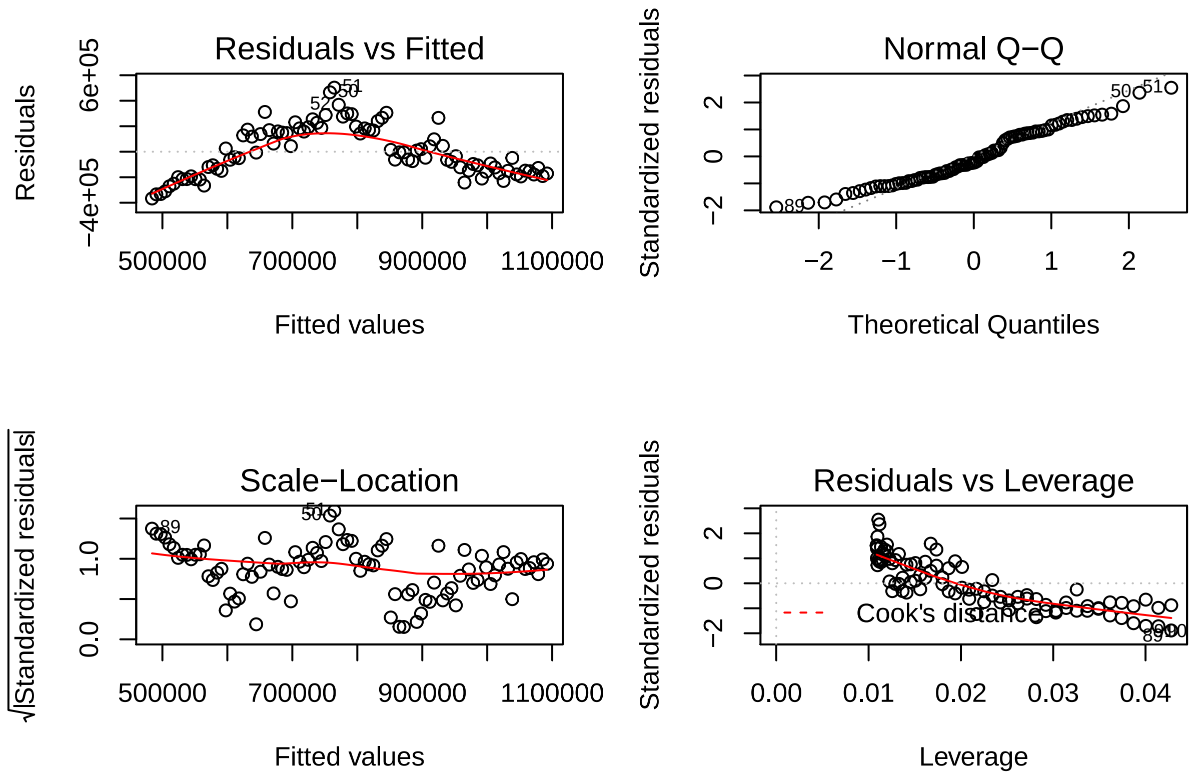
```r
# create lm
ADC_date_lm <- lm(data = ADC_fulldate, Total ~ Quarter.End.Date)
ADC_date_lm # Total = 73.14*Quarter.End.Date - 190264.58
```

```
##
## Call:
## lm(formula = Total ~ Quarter.End.Date, data = ADC_fulldate)
##
## Coefficients:
##      (Intercept)  Quarter.End.Date
##       -190264.58             73.14
```

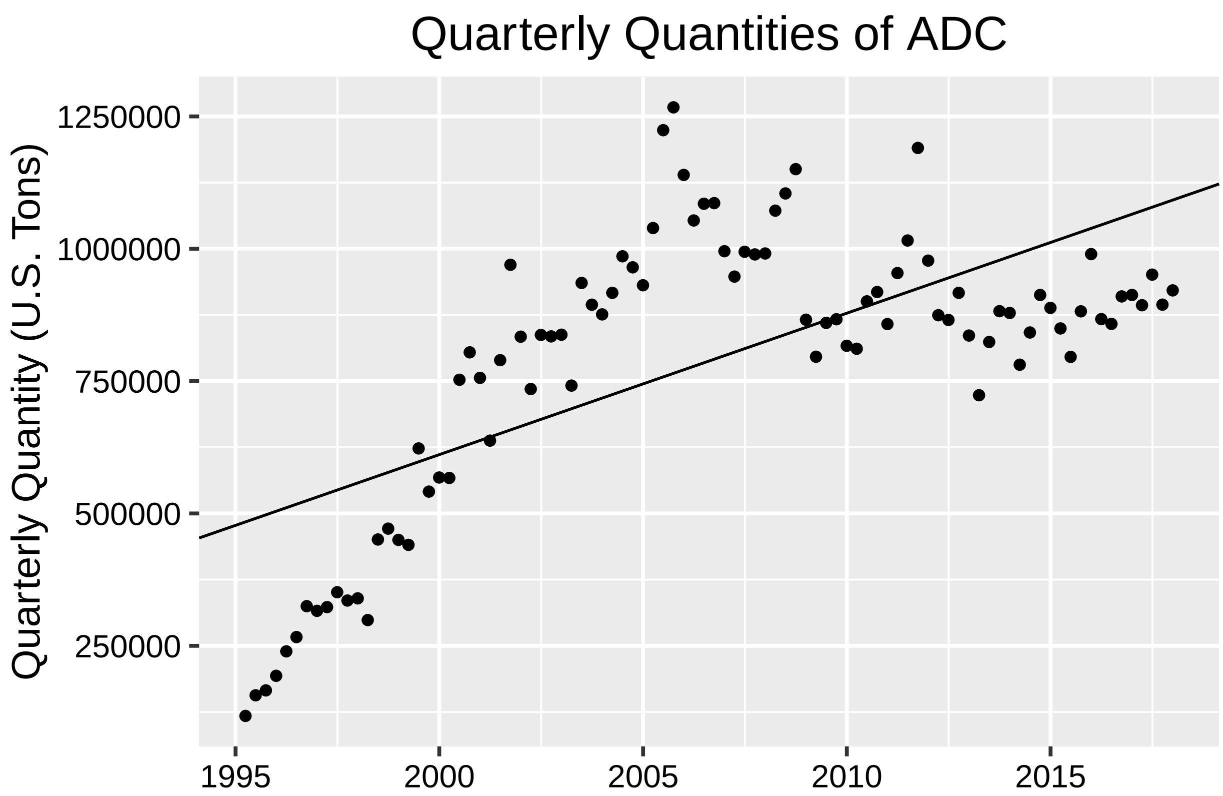
```r
summary(ADC_date_lm) # Adjusted R-squared:  0.4433 (date explains 44.33% of variation in total), p-valu
```

```
##
## Call:
## lm(formula = Total ~ Quarter.End.Date, data = ADC_fulldate)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -366483 -153515  -45160  167108  502499
##
## Coefficients:
##                   Estimate Std. Error t value Pr(>|t|)
## (Intercept)      -1.903e+05  1.160e+05   -1.64    0.104
## Quarter.End.Date  7.314e+01  8.534e+00    8.57 2.69e-13 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 198500 on 90 degrees of freedom
## Multiple R-squared:  0.4494, Adjusted R-squared:  0.4433
## F-statistic: 73.45 on 1 and 90 DF,  p-value: 2.694e-13
```

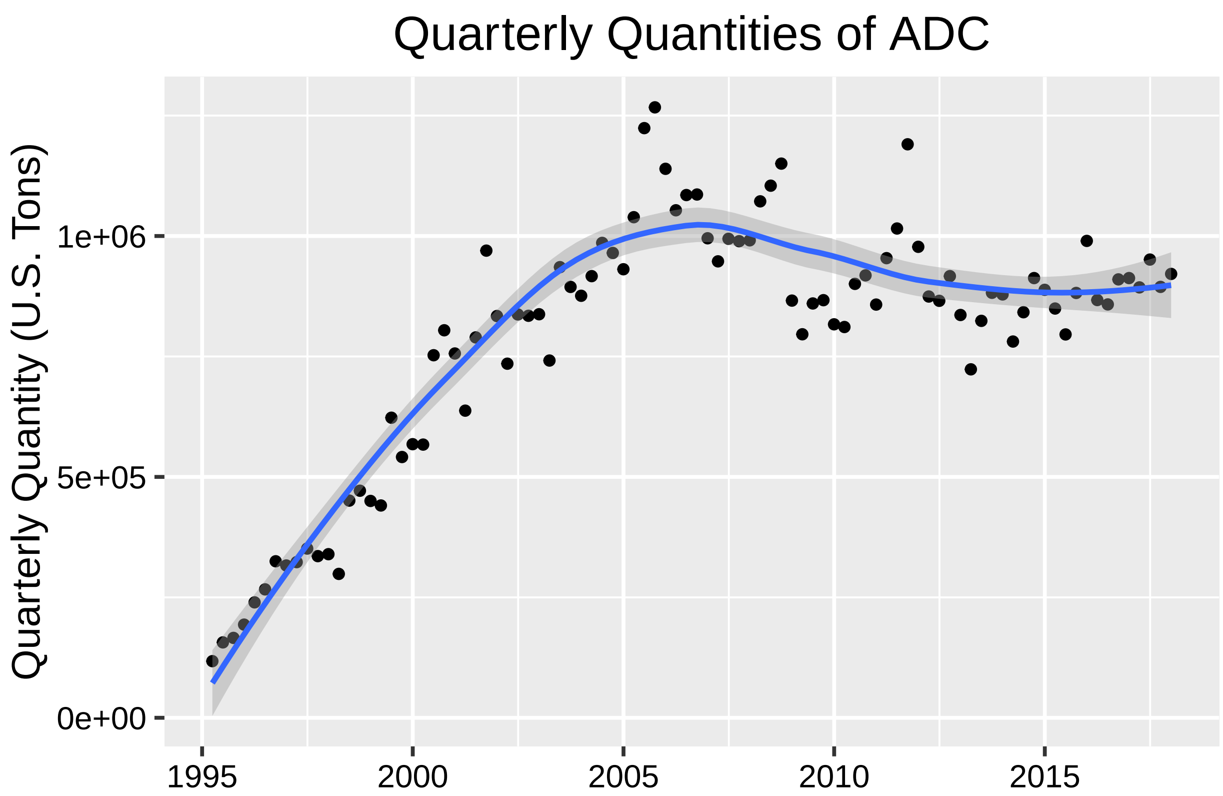
```r
# check normality of residuals
par(mfrow=c(2,2))
plot(ADC_date_lm) # QQ of residuals looks relatively normal
```




```r
# plot data w/ model
ADC_fulldate_plot <- ggplot(ADC_fulldate, aes(x = Quarter.End.Date, y = Total)) +
  geom_abline(intercept = -190264.58, slope = 73.14) +
  geom_point() +
  xlab('') +
  ylab('Quarterly Quantity (U.S. Tons)') +
  ggtitle('Quarterly Quantities of ADC')
print(ADC_fulldate_plot)
```




```
# visually, model does not appear to be a great fit

# save figure
ggsave("TotalADC_plot_calculatedmodel.jpg", ADC_fulldate_plot, path = "../Output", height = 4, width = 6

# plot with loess smoother
ADC_fulldate_plot_loess <- ggplot(ADC_fulldate, aes(x = Quarter.End.Date, y = Total)) +
  geom_point() +
  geom_smooth(method = loess) +
  xlab('') +
  ylab('Quarterly Quantity (U.S. Tons)') +
  ggtitle('Quarterly Quantities of ADC')
print(ADC_fulldate_plot_loess)
```

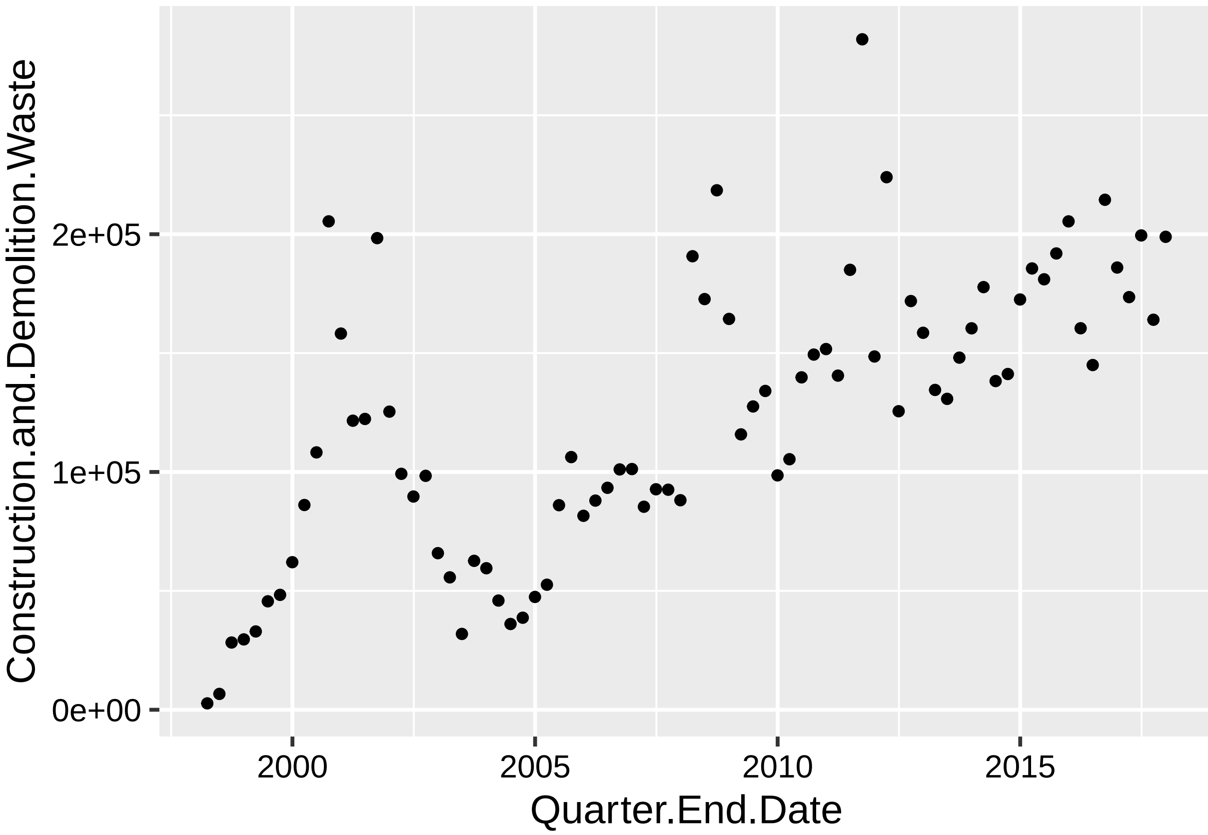



```
# visually, model appears to be a great fit

# save figure
ggsave("TotalADC_plot_loess.jpg", ADC_fulldate_plot_loess, path = "../Output", height = 4, width = 6, ur
```

Test 3: Statistical Modeling & Data Visualization

Is there a changepoint in the Construction & Demolition quantities over time?

```
# create dataframe with dates
quarters_to_dates$Quarter <- as.integer(quarters_to_dates$Quarter)

CD_only <- ADC_data %>%
  select(Report.Year, Report.Quarter, Construction.and.Demolition.Waste) %>%
  inner_join(quarters_to_dates, by = c("Report.Quarter" =  "Quarter")) %>%
  unite('Quarter.End.Date', c(Report.Year, Month.Date), sep = "-") %>%
  select(-Report.Quarter)

CD_only$Quarter.End.Date <- as.Date(CD_only$Quarter.End.Date, '%Y-%m-%d') # format column as date

# arrange data from oldest to newest
CD_only <- CD_only %>%
  arrange(Quarter.End.Date)

# create initial plot to visualize the data
ggplot(CD_only, aes(x = Quarter.End.Date, y = Construction.and.Demolition.Waste)) +
  geom_point()
```

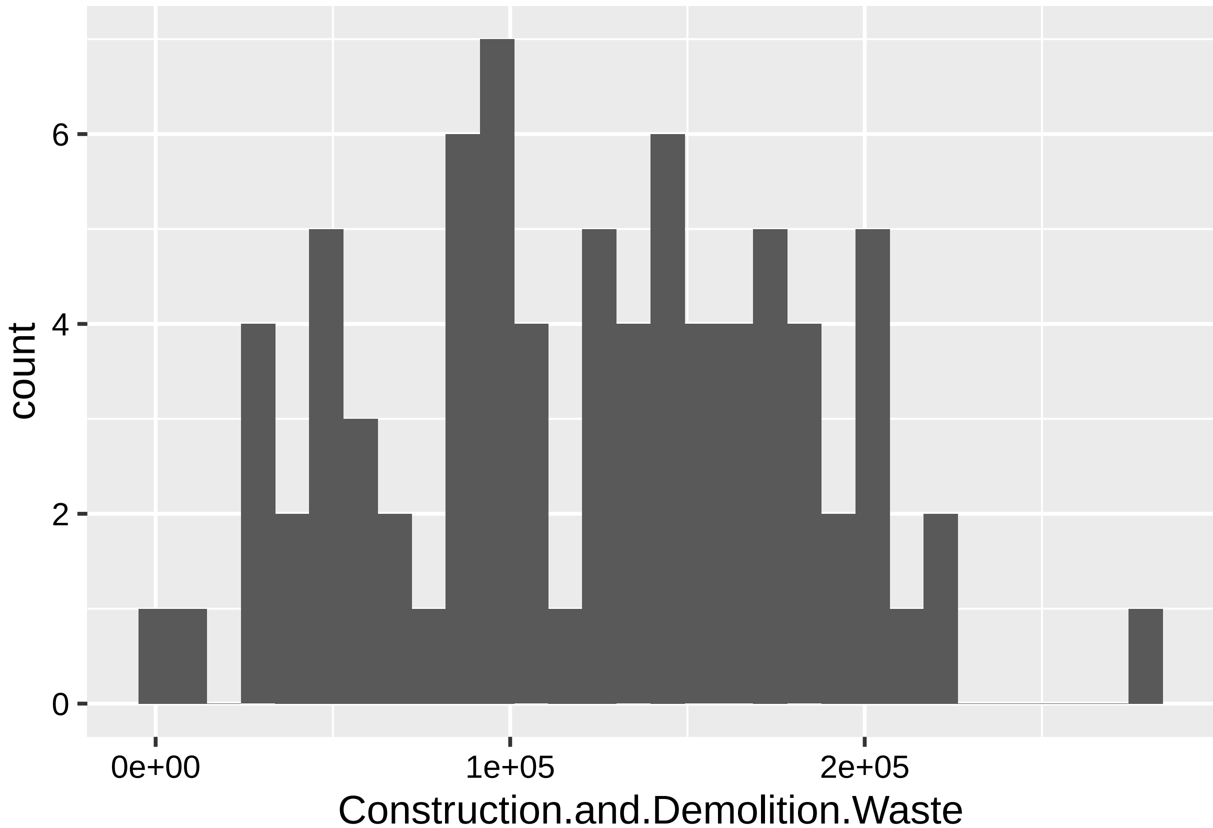



```
# check normality for C&D waste specifically
shapiro.test(CD_only$Construction.and.Demolition.Waste) # p-value = 0.4028, inferring that the data is
```

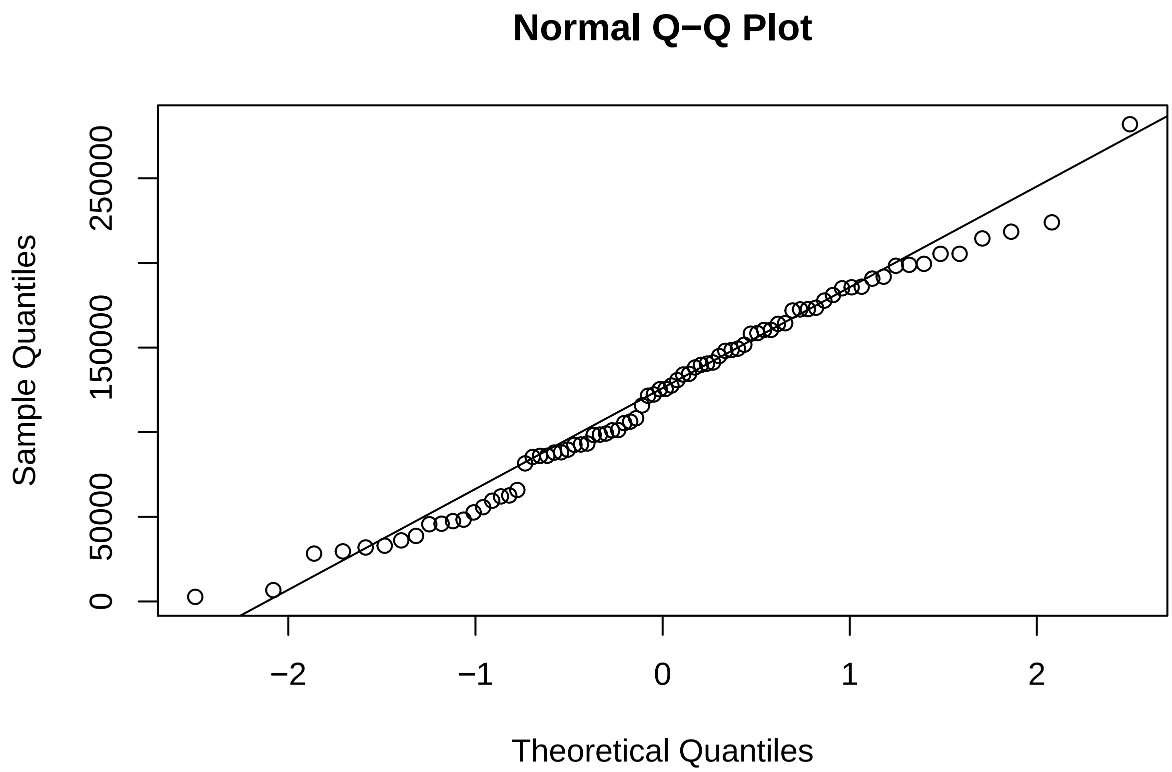
```
##
##  Shapiro-Wilk normality test
##
## data:  CD_only$Construction.and.Demolition.Waste
## W = 0.9837, p-value = 0.4028
```

```
ggplot(CD_only) +
  geom_histogram(aes(x = Construction.and.Demolition.Waste))
```

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```




```
qqnorm(CD_only$Construction.and.Demolition.Waste); qqline(CD_only$Construction.and.Demolition.Waste) #
```




```r
# use Pettitt's test (nonparametric) to determine whether there is a shift in the central tendency of t
pettitt.test(CD_only$Construction.and.Demolition.Waste) # change point at time 40
```

```
##
##  Pettitt's test for single change-point detection
##
## data:  CD_only$Construction.and.Demolition.Waste
## U* = 1396, p-value = 3.2e-10
## alternative hypothesis: two.sided
## sample estimates:
## probable change point at time K
##                               40
```

```r
# Run separate Mann-Kendall for each section
mk.test(CD_only$Construction.and.Demolition.Waste[1:40])
```

```
##
##  Mann-Kendall trend test
##
## data:  CD_only$Construction.and.Demolition.Waste[1:40]
## z = 1.736, n = 40, p-value = 0.08256
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##            S         varS          tau
##  150.0000000 7366.6666667    0.1923077
```

```r
mk.test(CD_only$Construction.and.Demolition.Waste[41:80])
```

```
##
##  Mann-Kendall trend test
##
## data:  CD_only$Construction.and.Demolition.Waste[41:80]
## z = 2.4817, n = 40, p-value = 0.01308
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##           S        varS         tau
##  214.000000 7366.666667    0.274359
```

```
# Is there a second change point?
pettitt.test(CD_only$Construction.and.Demolition.Waste[41:80])
```

```
##
##  Pettitt's test for single change-point detection
##
## data:  CD_only$Construction.and.Demolition.Waste[41:80]
## U* = 203, p-value = 0.04614
## alternative hypothesis: two.sided
## sample estimates:
## probable change point at time K
##                              27
```

```
# position 27, so 41+27 = change point at time 68

# Run separate Mann-Kendall for new section
mk.test(CD_only$Construction.and.Demolition.Waste[69:80]) # p-value = 0.9453, not likely a 3rd change p
```

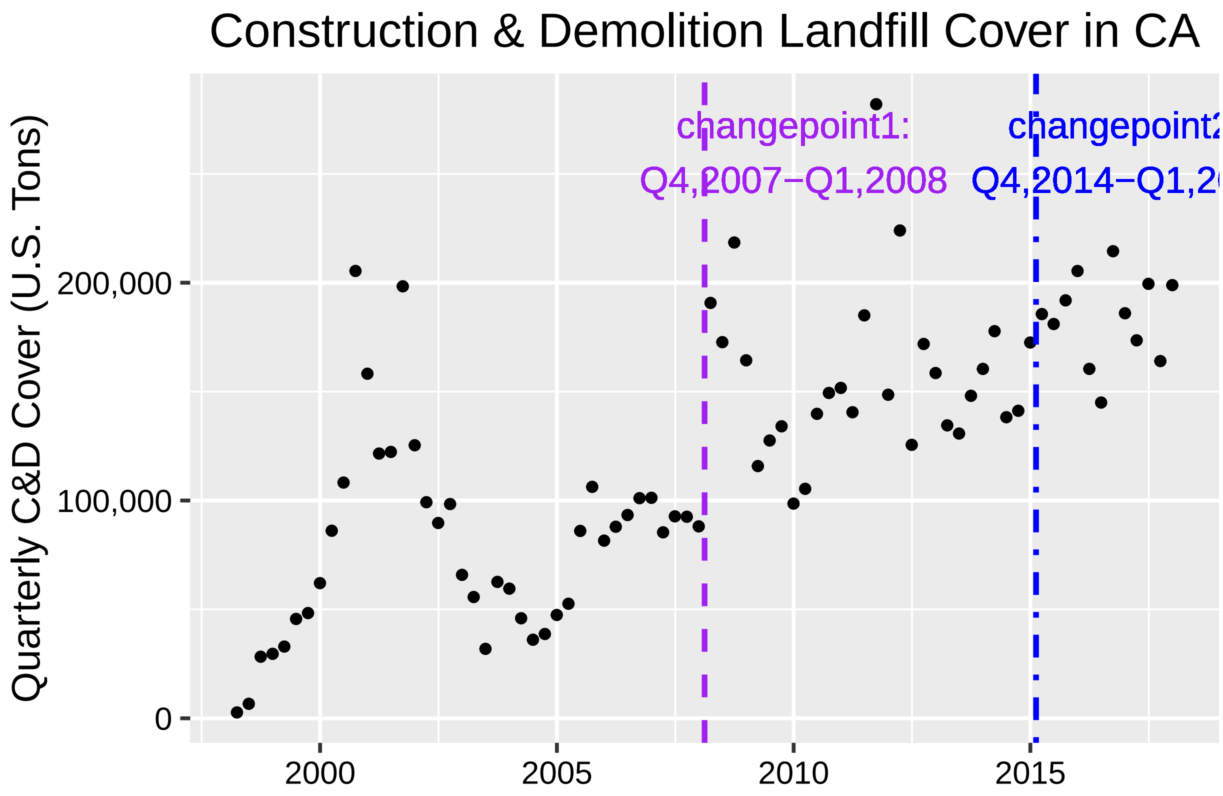
```
##
##  Mann-Kendall trend test
##
## data:  CD_only$Construction.and.Demolition.Waste[69:80]
## z = 0.068573, n = 12, p-value = 0.9453
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##            S         varS          tau
##   2.00000000 212.66666667   0.03030303
```

```
# Is there a third change point?
pettitt.test(CD_only$Construction.and.Demolition.Waste[69:80]) # p-value = p-value = 1.261, no 3rd chan
```

```
##
##  Pettitt's test for single change-point detection
##
## data:  CD_only$Construction.and.Demolition.Waste[69:80]
## U* = 12, p-value = 1.261
## alternative hypothesis: two.sided
## sample estimates:
## probable change point at time K
##                               6
```

```
# years corresponding to changepoints
changepoint1 <- CD_only$Quarter.End.Date[40] # between Q4 2007 & Q1 2008 = ~ 2008-02-14
changepoint2 <- CD_only$Quarter.End.Date[68] # between Q4 2014 & Q1 2015 = ~ 2015-02-14

# Add vertical lines to the original graph to represent change points
CD_plot_changepoints <- ggplot(CD_only, aes(x=Quarter.End.Date, y=Construction.and.Demolition.Waste)) +
```

```
  geom_point() +
  geom_vline(aes(xintercept=as.Date('2008-02-14')), linetype=2, colour="purple", size=1) +
  geom_vline(aes(xintercept=as.Date('2015-02-14')), linetype=4, colour="blue", size=1) +
  geom_text(x=as.Date('2010-1-1'), y=260000, label=stringr::str_wrap('changepoint1: Q4,2007-Q1,2008', 15
  geom_text(x=as.Date('2017-1-1'), y=260000, label=stringr::str_wrap('changepoint2: Q4,2014-Q1,2015', 15
  xlab('') +
  ylab('Quarterly C&D Cover (U.S. Tons)') +
  scale_y_continuous(labels = scales::comma) +
  ggtitle('Construction & Demolition Landfill Cover in CA')
print(CD_plot_changepoints)
```




```
# save figure
ggsave("CD_plot_changepoints.jpg", CD_plot_changepoints, path = "../Output", height = 4, width = 11, uni
```

Misc code for Test 3:

Run separate seasonal Mann-Kendall for each change point

CD_as_ts <- ts(CD_only$Quarter.End.Date, start =1998-03-31, end =2017-12-31, frequency = 4) # convert vector of CD quantities into class ts

smk.test(ts(CD_as_ts[1:39], start =1998-03-31, end =2007-09-30, frequency = 4)) # p-value = 3.573e-05 inferring that there is monotonic trend over time with reporting season smk.test(ts(CD_as_ts[40:80], start =2007-12-31, end =2017-12-31, frequency = 4)) SKO: decided not to use bc the fractions were smaller & smaller as you check changepoints, making the sample size smaller, which is worse for Mann-Kendall

---

SKO: sample size is 22 for each group. used parametric (instead of non-parametric bc https://blog.minitab.com/blog/adventures-in-statistics-2/choosing-between-a-nonparametric-test-and-a-para

Format as an aov

ADC_quarter_anova <- aov(ADC_total_only$Total~ADC_{t}otal_{o}nly$Report.Quarter) ADC_quarter_anova summary(ADC_quarter_anova)

Run a post-hoc test for pairwise differences

TukeyHSD(ADC_quarter_anova) # none of the p values are < 0.05 plot(TukeyHSD(ADC_quarter_anova)) # all of the bars overlap # none of the pairings have significantly different means

---

try Mann-Kendall non-parametric test to detect monotonic trends (H0: there is no trend)

total_oldest_to_newest <- ADC_fulldate %>% select(Quarter.End.Date, Total) %>% arrange(Quarter.End.Date) # arrange data from oldest to newest

mk.test(total_oldest_to_newest$Total) # p-value = 2.326e-09 inferring that there is a monotonic trend over time

run seasonal Mann-Kendall

total_as_ts <- ts(total_oldest_to_newest$Total, start =1995-03-31, end =2017-12-31, frequency = 4) # convert total vector into class ts smk.test(total_as_ts) # p-value < 2.2e-16 inferring that there is monotonic trend over time with reporting season

---

SKO: create figures separately, then grid arrange

Ash

ADC_gathered_Ash <- ADC_gathered %>% filter(Type == 'Ash') quarterlyvalues_byyear_plot_Ash <- ggplot(ADC_gathered_Ash) + geom_boxplot(aes(x = Report.Year, y = Quantity, group = Report.Year)) print(quarterlyvalues_byyear_plot_Ash)

---

group colors by 5 yr chunks: 1998-2002 (magenta), 2003-2007 (turquoise), 2008-2012 (red), 2013-2017 (yellow)

quarterlyvalues_alltypes_plot2 <- ggplot(ADC_gathered) + geom_point(data = subset(ADC_gathered, Report.Year < 2008), aes(x = Report.Quarter, y = Quantity, shape = as.factor(Type), color = as.factor(Report.Year < 2008), group = Report.Year)) #+ scale_color_manual(values = c('Report.Year < 2008' = 'magenta3'))

print(quarterlyvalues_alltypes_plot2)

https://stackoverflow.com/questions/44915362/custom-grouping-for-legend-in-ggplot