

Final Project: Navajo Nation Water Quality Analysis

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Rationale and Research Questions

The Navajo Nation has severe water infrastructure deficiencies that impact the health, economy, and welfare of the Navajo people. The lack of adequate domestic and municipal water is the greatest water resource problem facing the Navajo Nation. Approximately thirty – forty percent of the Navajo Nation population does not have access to clean reliable drinking water, also, 173 thousand people are affected because drinking water sources are limited and abandoned uranium mines have caused contamination of groundwater in the Nation. In addition, many improvements are needed for other areas of water use including water for irrigation, livestock, commercial, businesses, health care, schools and other facilities. (Navajo Nation Department of Water Resources, 2024) (SOURCE, n.d.)

In terms of water quantity, climate change in the Southwest will continue to impact water resources problems. The USGS Disaster Risk Assessment Study concluded that a long-term drying trend and decreasing snow pack, superimposed on the regional drought cycles, will magnify water-related impacts in Navajo Nation and leave the Navajo people increasingly vulnerable (Navajo Nation Department of Water Resources, 2024).

For the above, the present project measures the water quality of the water in the main river Colorado River before, and after it pass through the reservation in the past 5 years, establishing the following hypothesis:

Hypothesis A: The water quality in the Colorado River before and after passing through the Navajo Nation is significantly different. Null hypothesis: no difference

Hypothesis B: The water quality in the Colorado River before and after passing through the Navajo Nation has changed significantly in the last 5 years.

On the other hand, measurement is carried out for the water quantity of the rivers over the last 5 years to evaluate the water availability in Colorado River and San Juan River, establishing the following hypothesis:

Hypothesis C: Water availability changed in the last years for the Navajo Nation due to droughts & climate change.

Dataset Information

The dataset information was taken from the USGS Monitoring the rivers of the Nation (<https://waterdata.usgs.gov/nwis>),

For water quality, the data was extracted from years 2019 to 2023 from the following stations: - Station 1 = Colorado River at Lees Ferry, AZ - 09380000 - Station 2 = Colorado River Near Grand Canyon, AZ - 09402500

For water quantity, the data was extracted from years 2019 to 2023 from the station 1 as well.

Exploratory Analysis

Water Quantity

Question 1: <How have water discharge levels changed in the last 5 years at San Juan and Colorado rivers?>

```
#Renaming columns to be understandable
sanjuan_quantity_df<-rename(sanjuan_quantity_df, discharge_cf = X_00060_00003)
colorado_quantity_df<-rename(colorado_quantity_df, discharge_cf = X_00060_00003)
```

Data Wrangling

```
ggplot(data = sanjuan_quantity_df,
       aes(x = Date,
           y = discharge_cf)) +
  geom_point() +
  geom_smooth(method="lm") +
  my_theme
```

Data Visualization

```
## 'geom_smooth()' using formula = 'y ~ x'
```

```
ggplot(data = colorado_quantity_df,
       aes(x = Date,
           y = discharge_cf)) +
  geom_point() +
  geom_smooth(method="lm") +
  my_theme
```

```
## 'geom_smooth()' using formula = 'y ~ x'
```

```
discharge_sanjuan <- sanjuan_quantity_df$discharge_cf
plot(discharge_sanjuan)
```

The downward slope measured at both gages suggests that discharge volume for both San Juan and Colorado Rivers have declined in the last five years. San Juan appears to have more frequent periods of high discharge than usual (eg. mid-2023 and mid-2019) compared to Colorado.

Time Series Analysis *Note: there is no missing data so it is not necessary to execute linear interpolation.*

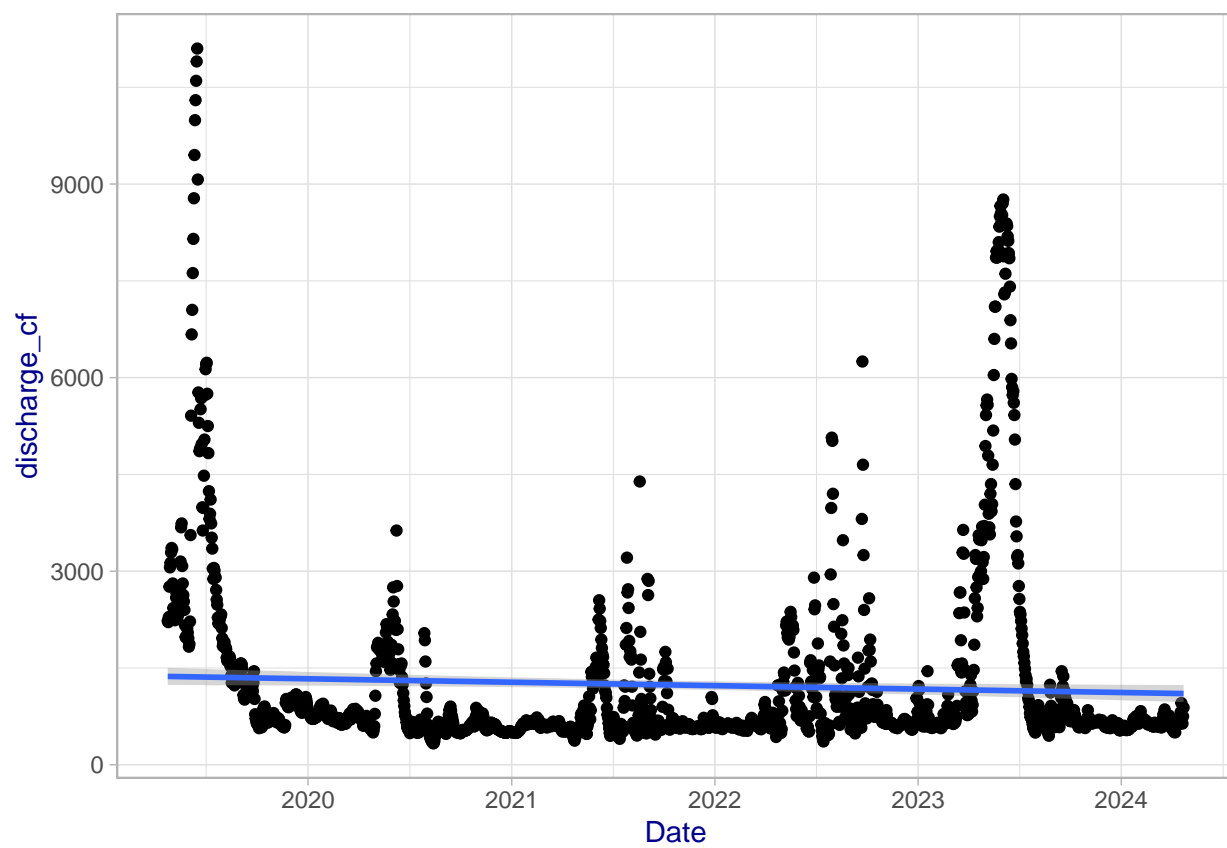


Figure 1: Water Levels in San Juan River, 2019-2024

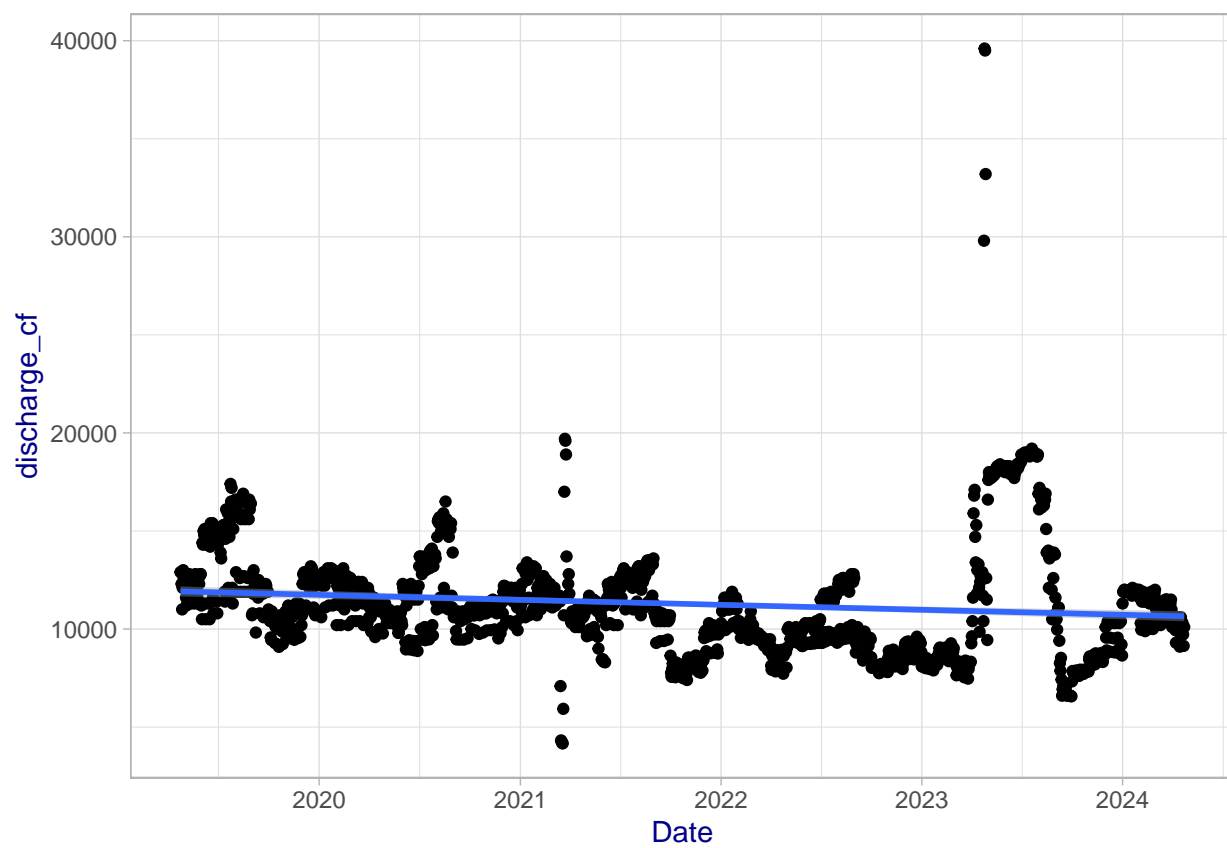


Figure 2: Water Levels in Colorado River, 2019-2024

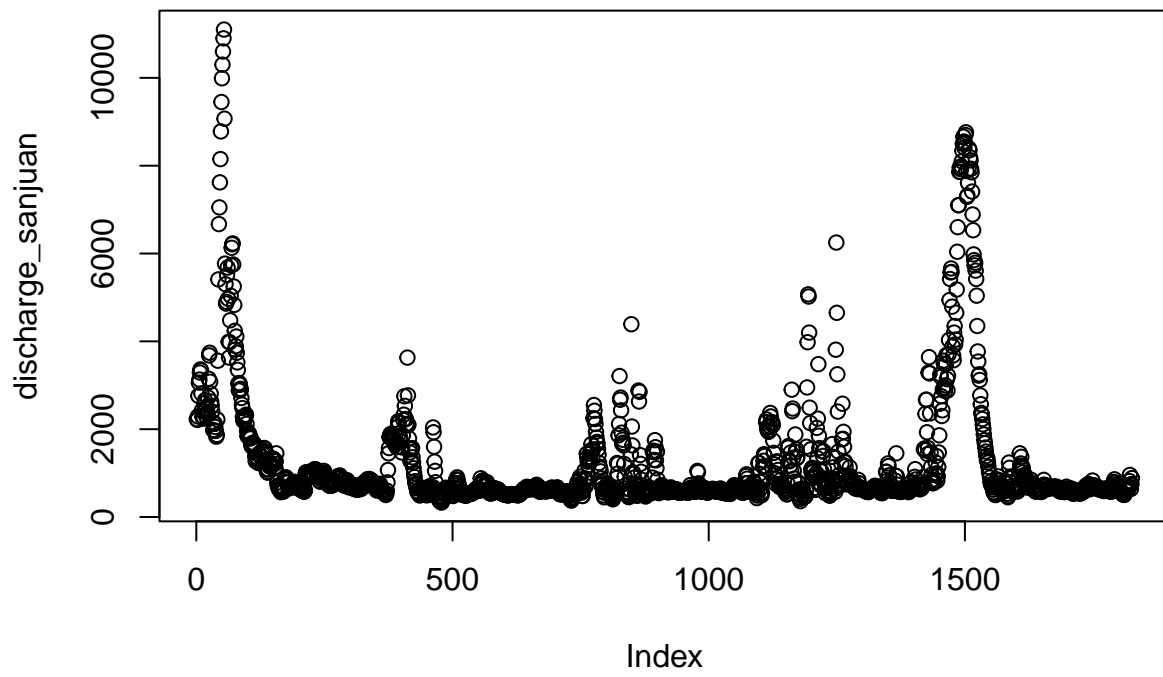


Figure 3: Discharge Index of San Juan River

```

# San Juan River
# Generate time series

f_month <- month(first(sanjuan_quantity_df$Date))
f_year <- year(first(sanjuan_quantity_df$Date))
f_day<- day(first(sanjuan_quantity_df$Date))

l_month <- month(last(sanjuan_quantity_df$Date))
l_year <- year(last(sanjuan_quantity_df$Date))
l_day<- day(last(sanjuan_quantity_df$Date))

sanjuan_quantity_daily_ts <- ts(sanjuan_quantity_df$
    discharge_cf,
    start=c(f_year,f_month),
    frequency=365)

# Decompose

sanjuan_quantity_daily_decomposed<- stl(sanjuan_quantity_daily_ts, s.window = "periodic")
plot(sanjuan_quantity_daily_decomposed) +
  my_theme

```

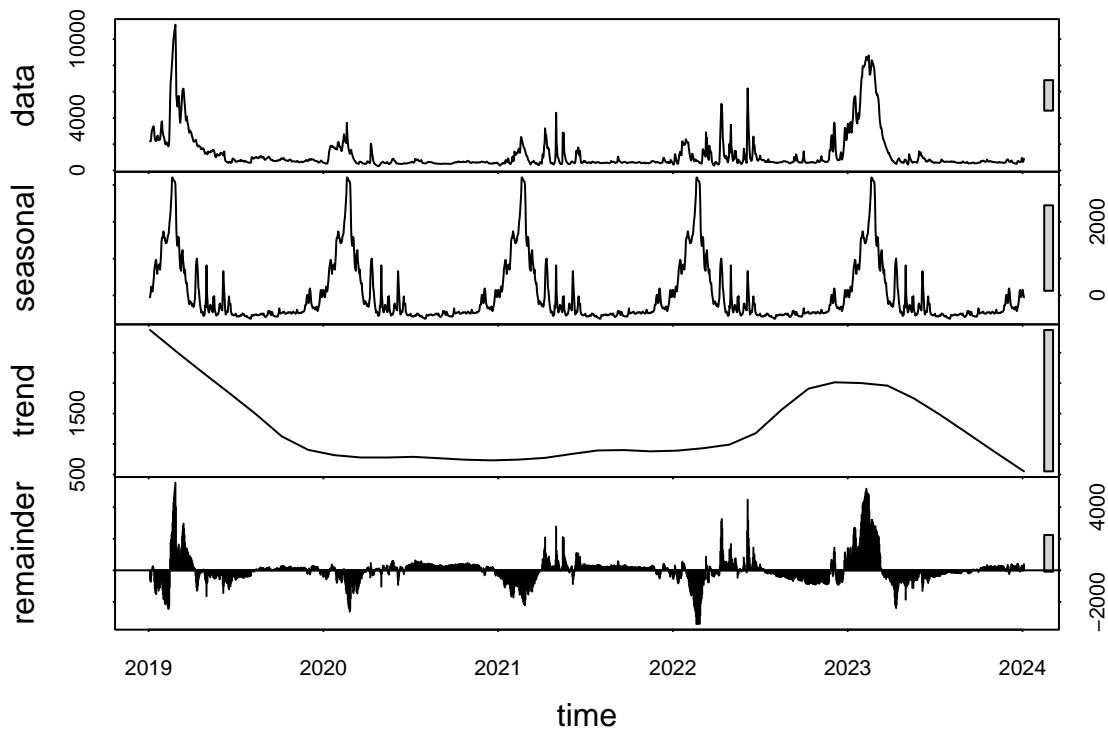


Figure 4: Time Series Analysis of San Juan River, 2019-2024

NULL

```

# Colorado River
# Generate time series
f_month1 <- month(first(colorado_quantity_df$Date))
f_year1 <- year(first(colorado_quantity_df$Date))
f_day1<- day(first(colorado_quantity_df$Date))

l_month1 <- month(last(colorado_quantity_df$Date))
l_year1 <- year(last(colorado_quantity_df$Date))
l_day1<- day(last(colorado_quantity_df$Date))

colorado_quantity_daily_ts<- ts(colorado_quantity_df$
                                discharge_cf,
                                start=c(f_year,f_month),
                                frequency=365)

# Decompose
colorado_quantity_daily_decomposed<- stl(colorado_quantity_daily_ts, s.window = "periodic")
plot(colorado_quantity_daily_decomposed)

```

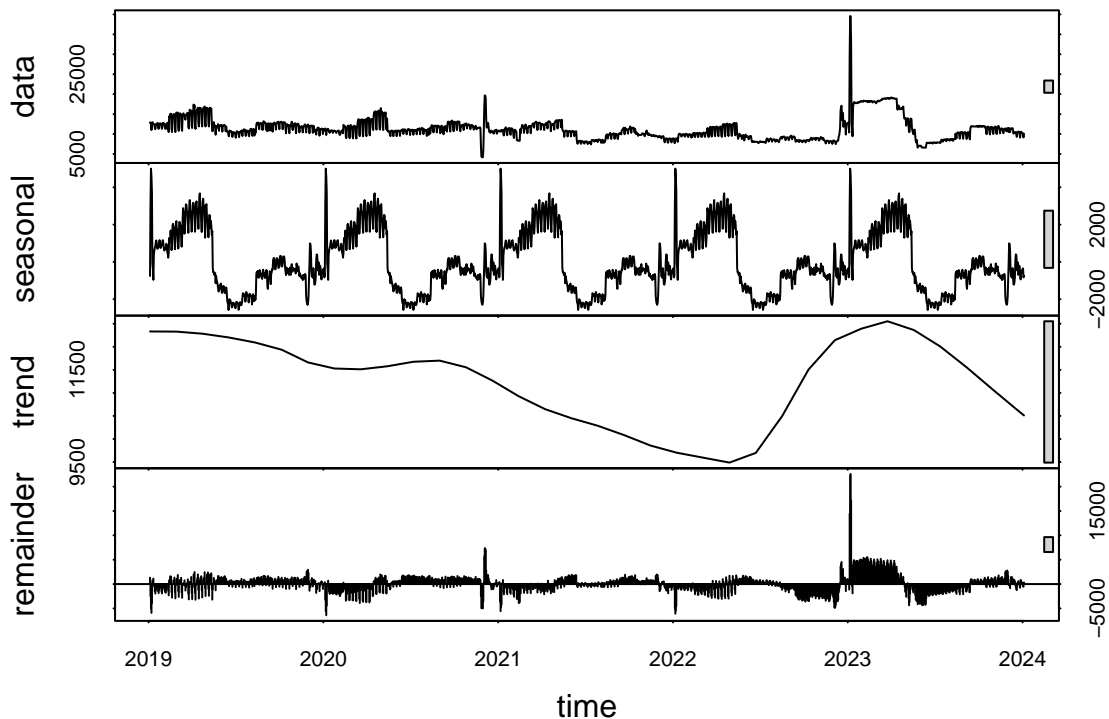


Figure 5: Time Series Analysis of Colorado River, 2019-2024

Colorado River: Water levels have declined from 2019 to mid-2022, then increased to peak at early 2023.

San Juan River: Water levels have declined from 2019 to 2020 and remained steady (at a low

level) up till mid-2022. Water levels then increased to peak at early 2023, and declined since then.

Population Drawing Directly From the Rivers

We examined each of the chapters under the Western and Northern Agency on whether the San Juan and Colorado River passes through their territory. This would allow us to determine how much of the Navajo population collected water from each respective river.

For Colorado River, the following chapters met this criteria: Bodaway-Gap, Coppermine, LeChee, and Navajo Mountain.

For San Juan, the following chapters met this criteria: Kayenta, Oljato, Shonto, Beclabito, Upper Fruitland, Gadii Ahi/to'koi, Mexican Water, Red Mesa, Teec Nos Pos, Tse Daa Kaan.

```
#Population Directly Drawing Water from the Colorado River
pop_Bodaway_Gap<-1705
pop_Coppermine<-690
pop_LeChee<-1762
pop_Navajo_Mt<-359
pop_chapters_Colorado<- pop_Bodaway_Gap+pop_Coppermine+pop_LeChee+pop_Navajo_Mt

pop_chapters_Colorado #4516
```

Manual data collection

```
## [1] 4516
```

```
#Population Directly Drawing Water from the San Juan River
pop_Kayenta<-6035
pop_Oljato<-2729
pop_Shonto<-1645
pop_Beclabito<-724
pop_Upper_Fruitland<-2594
pop_Gadii_Ahi<-430
pop_Mexican_Water<-667
pop_Red_Mesa<-1177
pop_Teec_Nos_Pos<-1454
pop_Tse_Daa_Kaan <-1273

pop_chapters_SJ<-pop_Kayenta+pop_Oljato+pop_Shonto+pop_Beclabito+pop_Upper_Fruitland+pop_Gadii_Ahi+pop_Mexican_Water+pop_Red_Mesa+pop_Teec_Nos_Pos+pop_Tse_Daa_Kaan

pop_chapters_SJ #18728
```

```
## [1] 18728
```

Note: It was intended to be scraping data from the website but it generated empty values. Hence, copy pasting the data was done instead. See appendix 1.

Indian Population drawing water directly from these rivers - Colorado River: Estimated to be 4516 - San Juan River: Estimated to be 18728

Navajo people are estimated to use only 7 gallons of water per day. [CITE Source]

```
#Colorado  
annual_draw_colorado<-4516*7*365  
annual_draw_colorado
```

```
## [1] 11538380
```

```
#San Juan  
annual_draw_SJ<-18728*7*365  
annual_draw_SJ
```

```
## [1] 47850040
```

cubic meters per second 1 cubic meter = 264.2 gallons

```
seconds_per_year<-365*24*60*60  
water_available_SJ_2024<-500*264.2*seconds_per_year  
water_available_SJ_2024
```

```
## [1] 4.165906e+12
```

make analysis

Water Quality

Question 2: <How has been the water quality of the Colorado River before, and after it pass through the reservation in the past 5 years?>

```
#Chage Date Format  
class(Boron_Site1$Activity_StartDate)
```

Data Preparation

```
## [1] "factor"
```

```
class(Boron_Site2$Activity_StartDate)
```

```
## [1] "factor"
```

```
class(Magnesium_Site1$Activity_StartDate)
```

```
## [1] "factor"
```

```
class(Magnesium_Site2$Activity_StartDate)
```

```
## [1] "factor"
```

```
class(Uranium_Site1$Activity_StartDate)
```

```
## [1] "factor"
```

```
class(Uranium_Site2$Activity_StartDate)
```

```
## [1] "factor"
```

```
Boron_Site1$Activity_StartDate <- as.Date(Boron_Site1$Activity_StartDate, format = "%Y-%M-%d")  
Boron_Site2$Activity_StartDate <- as.Date(Boron_Site2$Activity_StartDate, format = "%Y-%M-%d")  
Magnesium_Site1$Activity_StartDate <- as.Date(Magnesium_Site1$Activity_StartDate, format = "%Y-%M-%d")  
Magnesium_Site2$Activity_StartDate <- as.Date(Magnesium_Site2$Activity_StartDate, format = "%Y-%M-%d")  
Uranium_Site1$Activity_StartDate <- as.Date(Uranium_Site1$Activity_StartDate, format = "%Y-%M-%d")  
Uranium_Site2$Activity_StartDate <- as.Date(Uranium_Site2$Activity_StartDate, format = "%Y-%M-%d")
```

```
class(Boron_Site1$Activity_StartDate)
```

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

```
class(Boron_Site2$Activity_StartDate)
```

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

```
class(Magnesium_Site1$Activity_StartDate)
```

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

```
class(Magnesium_Site2$Activity_StartDate)
```

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

```
class(Uranium_Site1$Activity_StartDate)
```

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

```
class(Uranium_Site2$Activity_StartDate)
```

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

```
#Merger Datasets respectively
```

```
Boron_merged <- bind_rows(Boron_Site1, Boron_Site2)
```

```
Magnesium_merged <- bind_rows(Magnesium_Site1, Magnesium_Site2)
```

```
Uranium_merged <- bind_rows(Uranium_Site1, Uranium_Site2)
```

```
#Unify the research time range
```

```
Uranium_filtered <- Uranium_merged %>%
```

```
  filter(Activity_StartDate >= as.Date("2018-01-01") &
```

```
         Activity_StartDate <= as.Date("2023-12-31"))
```

```
#Generate the annual average concentration of three contaminations for both sites
```

```
Boron_merged$Year <- lubridate::year(Boron_merged$Activity_StartDate)
```

```
Boron_annual_average <- Boron_merged %>%
```

```
  group_by(Year, Location_Name) %>%
```

```
  summarise(Avg_Concentration = mean(Result_MeasureValue, na.rm = TRUE))
```

```
Magnesium_merged$Year <- lubridate::year(Magnesium_merged$Activity_StartDate)
```

```
Magnesium_annual_average <- Magnesium_merged %>%
```

```
  group_by(Year, Location_Name) %>%
```

```
  summarise(Avg_Concentration = mean(Result_MeasureValue, na.rm = TRUE))
```

```
Uranium_filtered$Year <- lubridate::year(Uranium_filtered$Activity_StartDate)
```

```
Uranium_annual_average <- Uranium_filtered %>%
```

```
  group_by(Year, Location_Name) %>%
```

```
  summarise(Avg_Concentration = mean(Result_MeasureValue, na.rm = TRUE))
```

```
#Compare Boron
```

```
ggplot(Boron_annual_average,
```

```
  aes(x = Year, y = Avg_Concentration, color = Location_Name)) +
```

```
  geom_point() +
```

```
  labs(x = "Observation Year",
```

```
       y = "Mean Concentration (ug/L)") +
```

```
  my_theme
```

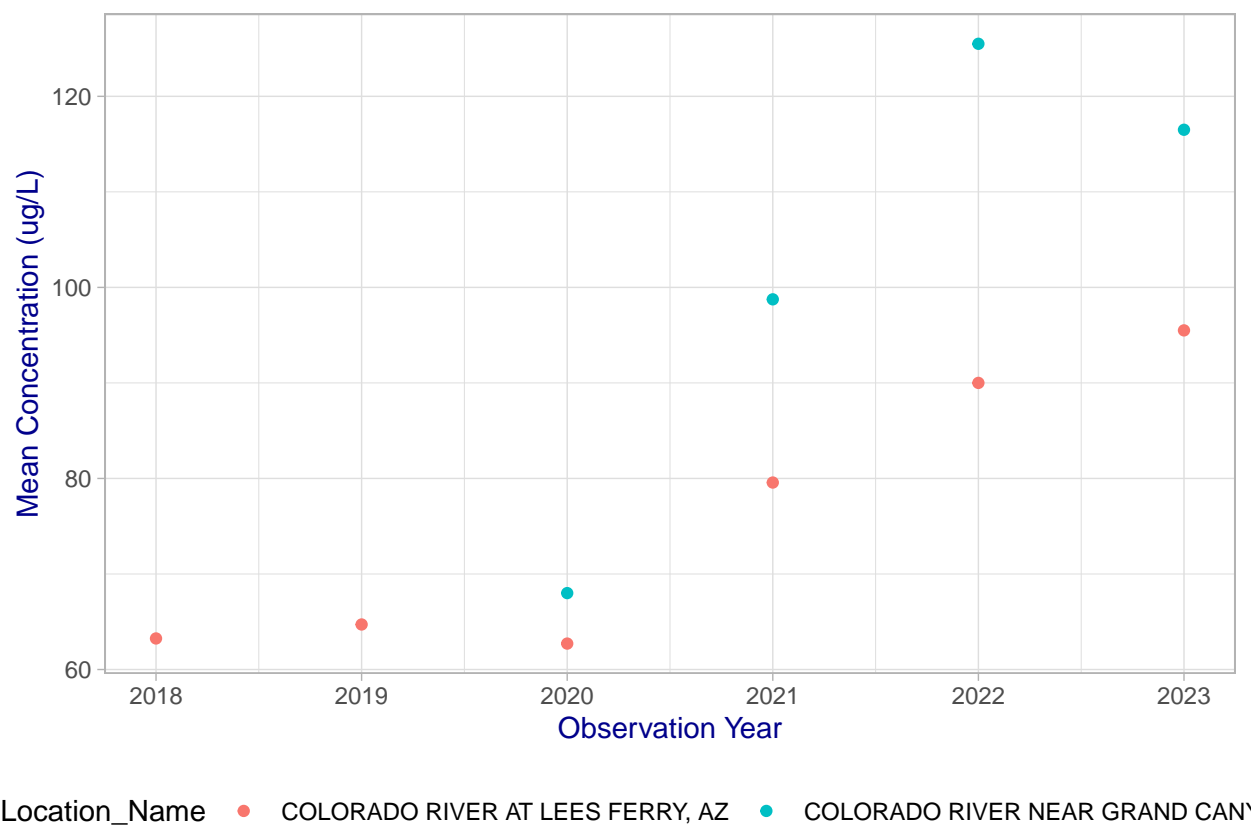
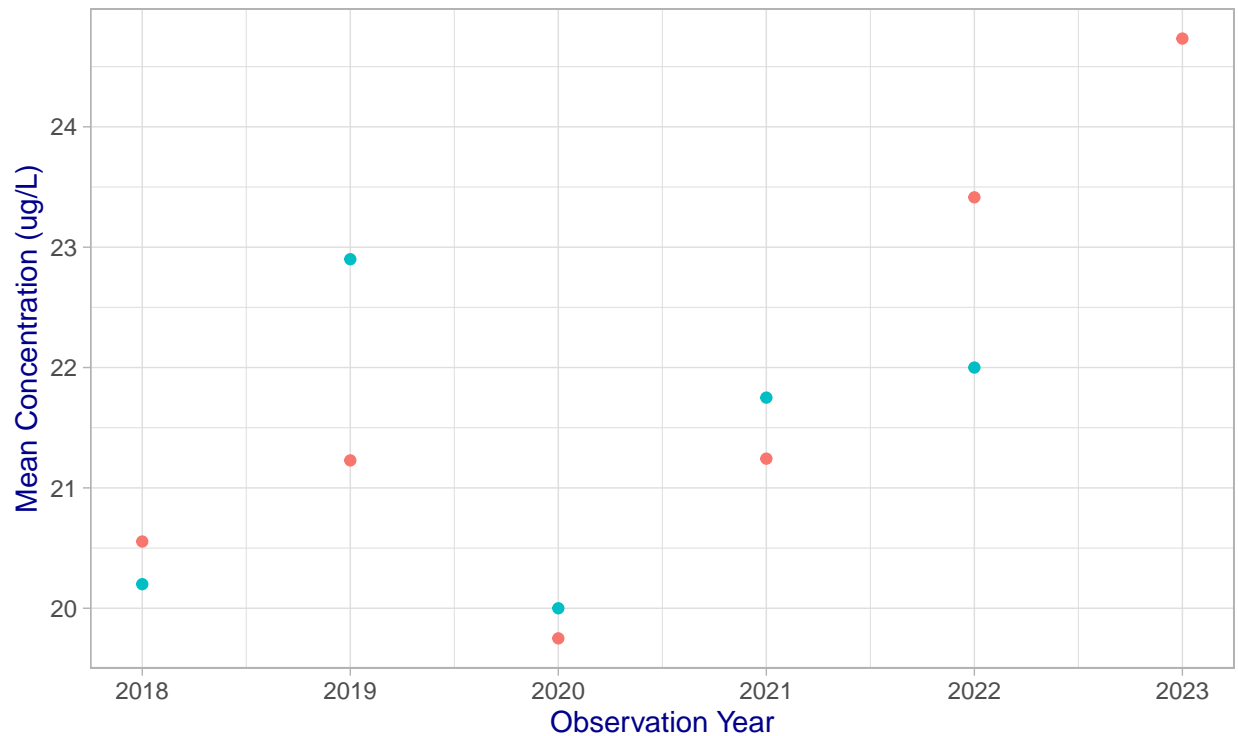


Figure 6: Boron Concentration before and after passing through the Navajo Nation


```
#Compare Magnesium
ggplot(Magnesium_annual_average,
  aes(x = Year, y = Avg_Concentration, color = Location_Name)) +
  geom_point() +
  labs(x = "Observation Year",
    y = "Mean Concentration (ug/L)") +
  my_theme
```



Location_Name ● COLORADO RIVER AT LEES FERRY, AZ ● COLORADO RIVER NEAR GRAND CANY

Figure 7: Magnesium Concentration before and after passing through the Navajo Nation

```
#Compare Uranium
ggplot(Uranium_annual_average,
  aes(x = Year, y = Avg_Concentration, color = Location_Name)) +
  geom_point() +
  labs(x = "Observation Year",
    y = "Mean Concentration (ug/L)") +
  my_theme
```

Data Visualization *Make analysis*

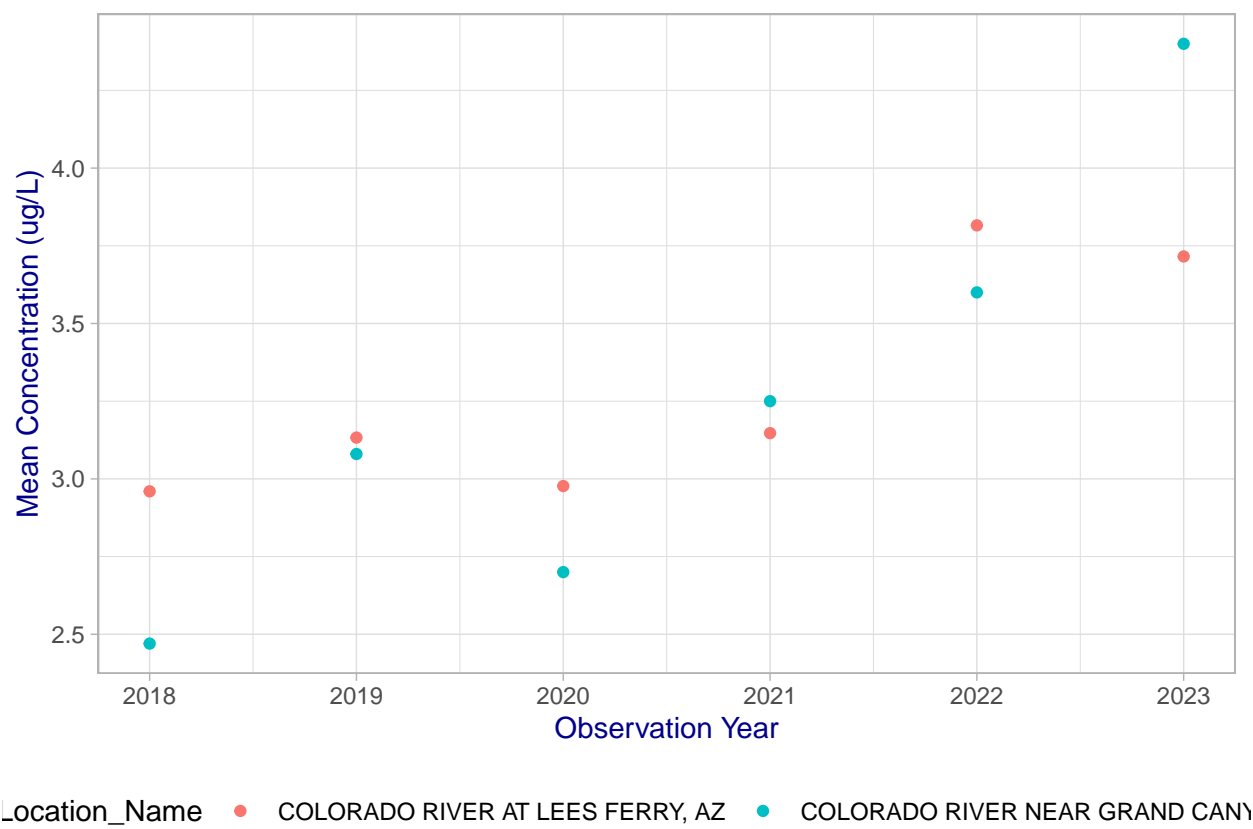


Figure 8: Uranium Concentration before and after passing through the Navajo Nation

Summary and Conclusions

7 gallons per day is not enough to meet basic needs. According to the UN WHO, at least 50 liters per day per person is needed, which is about 13.2 gallons.

References

- UN-Water Decade Programme on Advocacy and Communication and Water Supply and Sanitation Collaborative Council. (2010). The human right to water and sanitation today. In Media Brief. https://www.un.org/waterforlifedecade/pdf/human_right_to_water_and_sanitation_media_brief.pdf
- Williams, A. P., Cook, B. I., & Smerdon, J. E. (2022). Rapid intensification of the emerging southwestern North American megadrought in 2020–2021. *Nature Climate Change*, 12(3), 232–234. <https://doi.org/10.1038/s41558-022-01290-z>
- The Colorado River: Heading into 2024 with hope for a more stable system | Arizona Department of Water Resources. (2023, December 21). <https://www.azwater.gov/news/articles/2023-12-21-0>
- Navajo Nation Water Rights Comission. (2024, 3 22). Navajo Nation Water Rights Comission webpage. Retrieved from <https://nnwrc.navajo-nsn.gov/>
- SOURCE. (n.d.). Los hidropaneles SOURCE llevan agua a la Nación Navajo. Retrieved from <https://www.source.co/resources/case-studies/los-hidropaneles-source-llevan-agua-a-lanacion-navajo/?lang=es>

Appendix

Appendix 1

```
#set scraping website
Water_URL<- read_html('https://navajoprofile.wind.enavajo.org/')
Water_URL

## {html_document}
## <html>
## [1] <head>\n<meta http-equiv="Content-Type" content="text/html; charset=UTF-8 ...
## [2] <body>\r\n          <form id="form1">\r\n          <div class="outerNavCo ...

#scrape the data
navajo_nation_chapter<-Water_URL%>%
  html_nodes("td:nth-child(3)")%>%
  html_text()
navajo_nation_chapter

## character(0)

indian_population<-Water_URL%>%
  html_nodes("td:nth-child(4)")%>%
  html_text()
indian_population

## character(0)

table<-Water_URL%>%
  html_nodes("tabContent001")%>%
  html_text()
table

## character(0)
```