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).

The current project focuses on analyzing the water quality of the main Colorado River before and after it flows through the reservation over the past 5 years. Taking into account the tribe's persistent efforts to compel the federal government to meet its obligations, aiding in the quantification of the tribe's water rights on the Colorado River and ensuring access to high-quality water, we have chosen to focus our quality analysis on the Colorado River. This decision stems from the river's current water rights litigation and the availability of data. A five-year analysis period was selected to provide a more current evaluation. This analysis aims to establish the following hypotheses:

> 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, measurements have been conducted for the water quantity of the rivers over the last 5 years (2019-2024) to assess water availability in both the Colorado River and the San Juan River. In order to broaden the scope of our analysis of water availability, the San Juan River was also selected, 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 analysis, data was extracted from the years 2019 to 2024, capturing Uranium, Magnesium, and Boron levels at both stations during this period. The reason for selecting these components was the availability of data at both stations. It was necessary for both stations to have the same components during the same period to enable a comparative analysis. Also, those component represent a high risk for human health and the environment at high levels.

Below is the information on the stations worked: - 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 form the station 1 as well, extracting data of water flow in cf/s on that period.

Exploratory Analysis

Water Quantity

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

Data Wrangling

Data Visualization

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

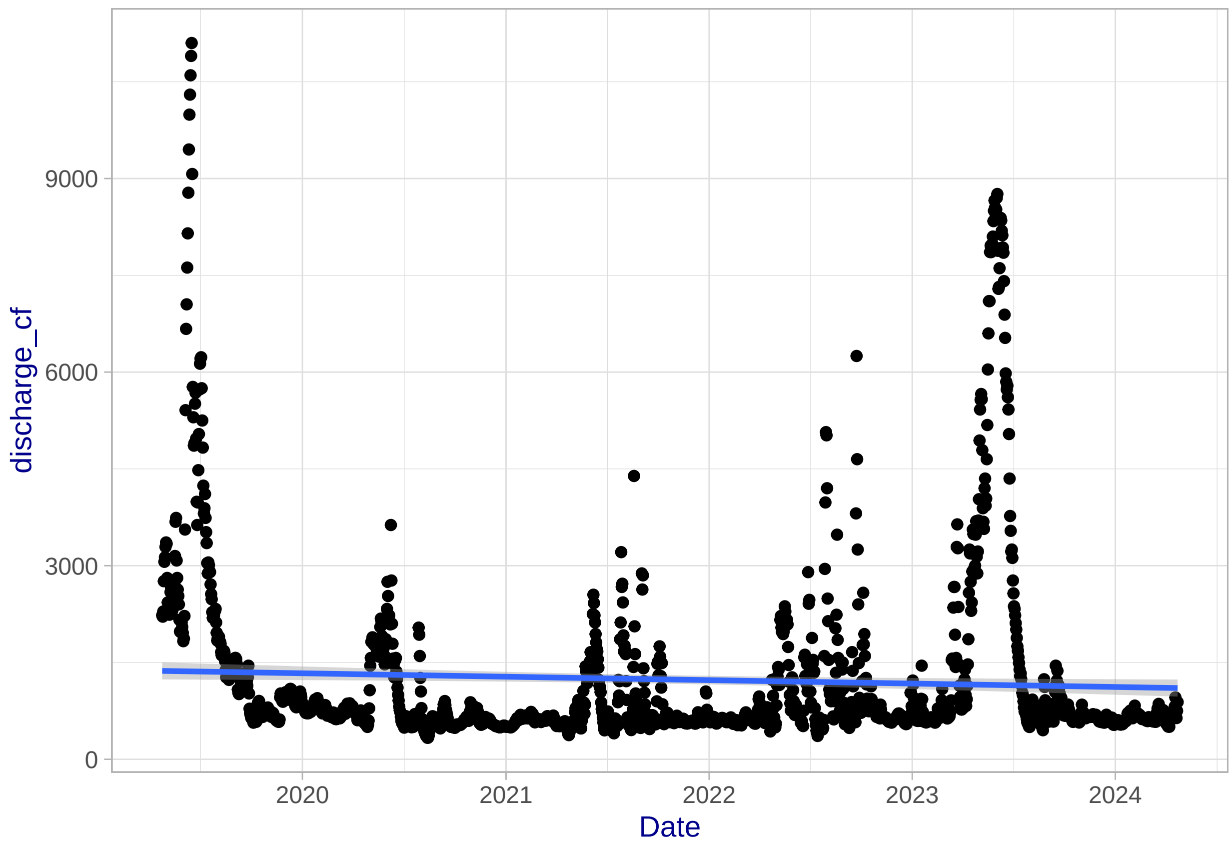

Figure 1: Water Levels in San Juan River, 2019-2024

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

The downwarded 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.

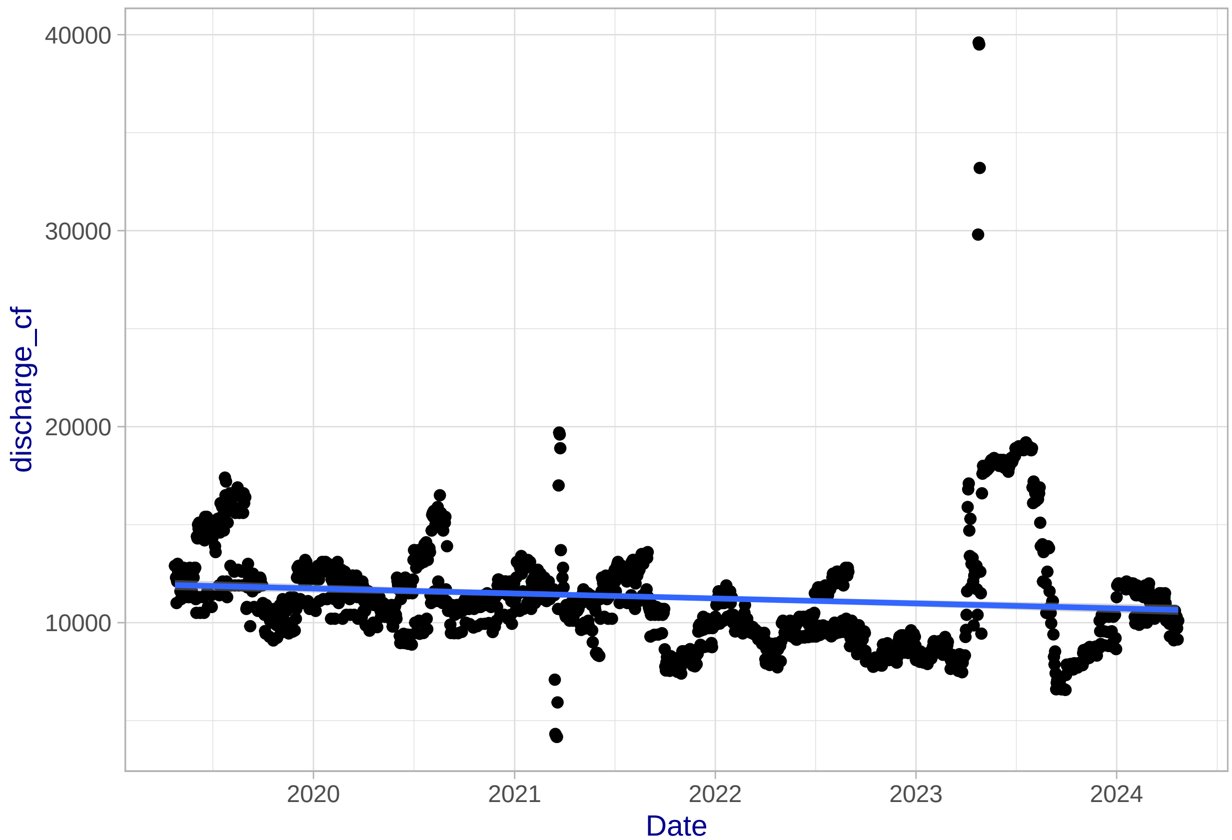

Figure 2: Water Levels in Colorado River, 2019-2024

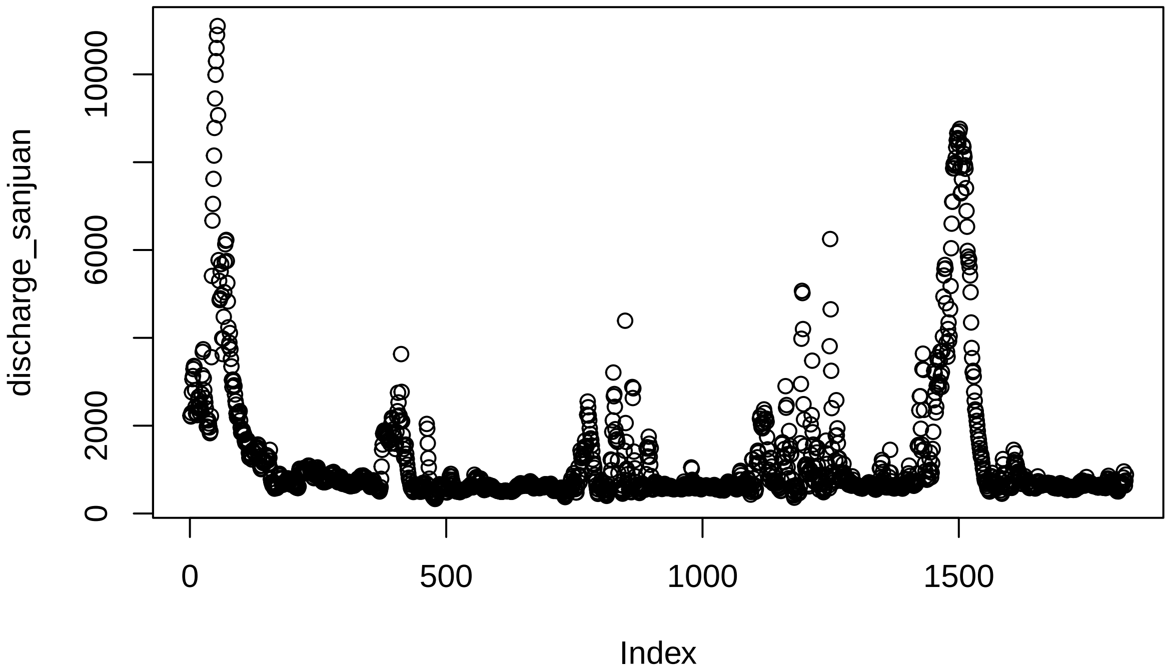

Figure 3: Discharge Index of San Juan River

Time Series Analysis

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

```
# 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
```

```
## 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)
```

> 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.

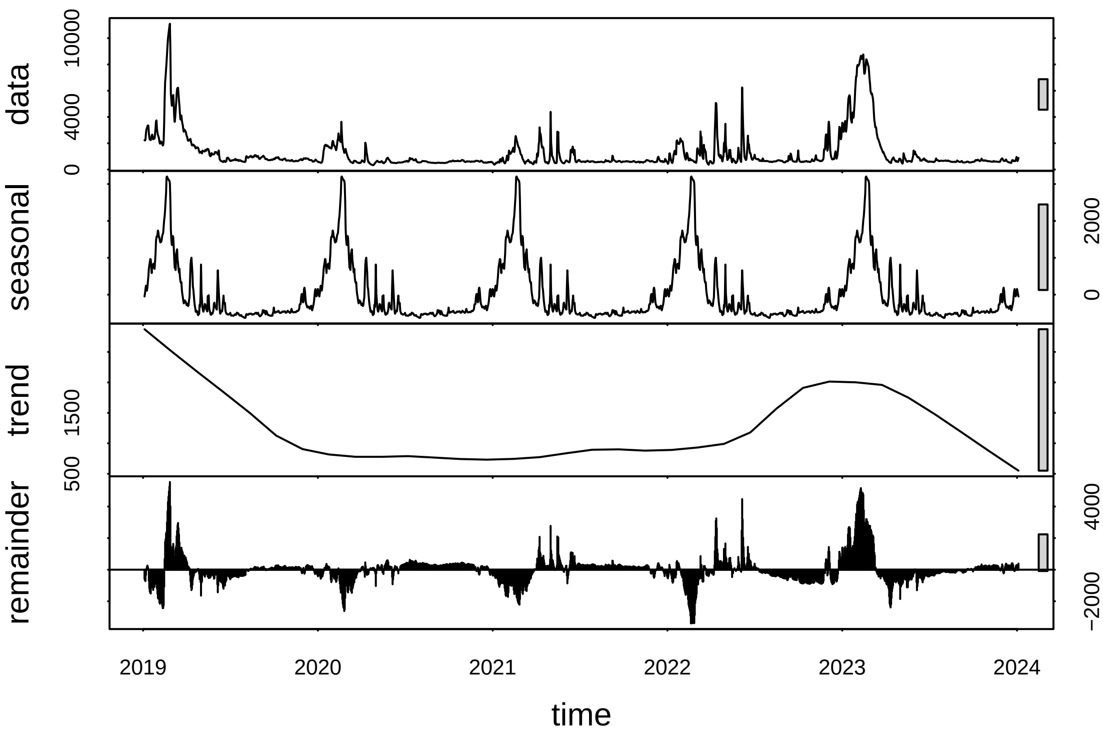

Figure 4: Time Series Analysis of San Juan River, 2019-2024

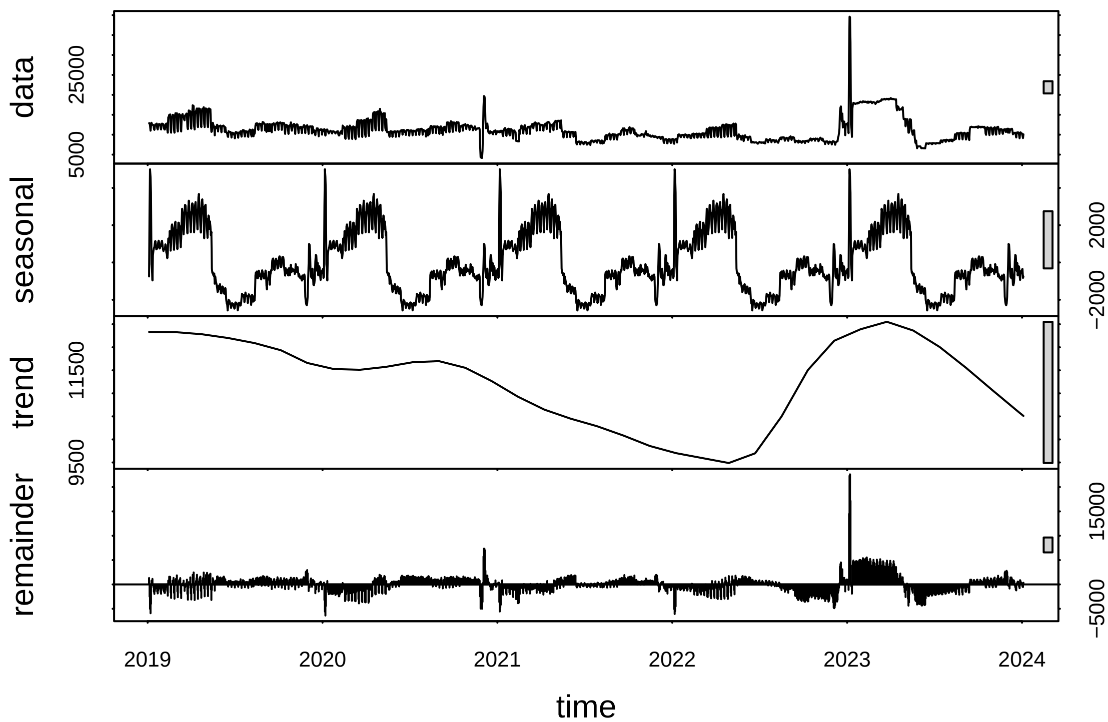

Figure 5: Time Series Analysis of Colorado River, 2019-2024

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 allows 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.

Manual data collection

```r
#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
```

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

```r
#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_

pop_chapters_SJ #18728
```

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

Note: It was intended to 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]

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

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

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

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

cubic meters per second 1 cubic meter = 264.2 gallons

```r
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 Colorado River before, and after it pass through the reservation in the past 5 years?>

Data Preparation

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

```
## [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"
```

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

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

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

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

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

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

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

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

```r
#Merger Datasets respectivelly
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))
```

Data Visualization

```r
#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
```

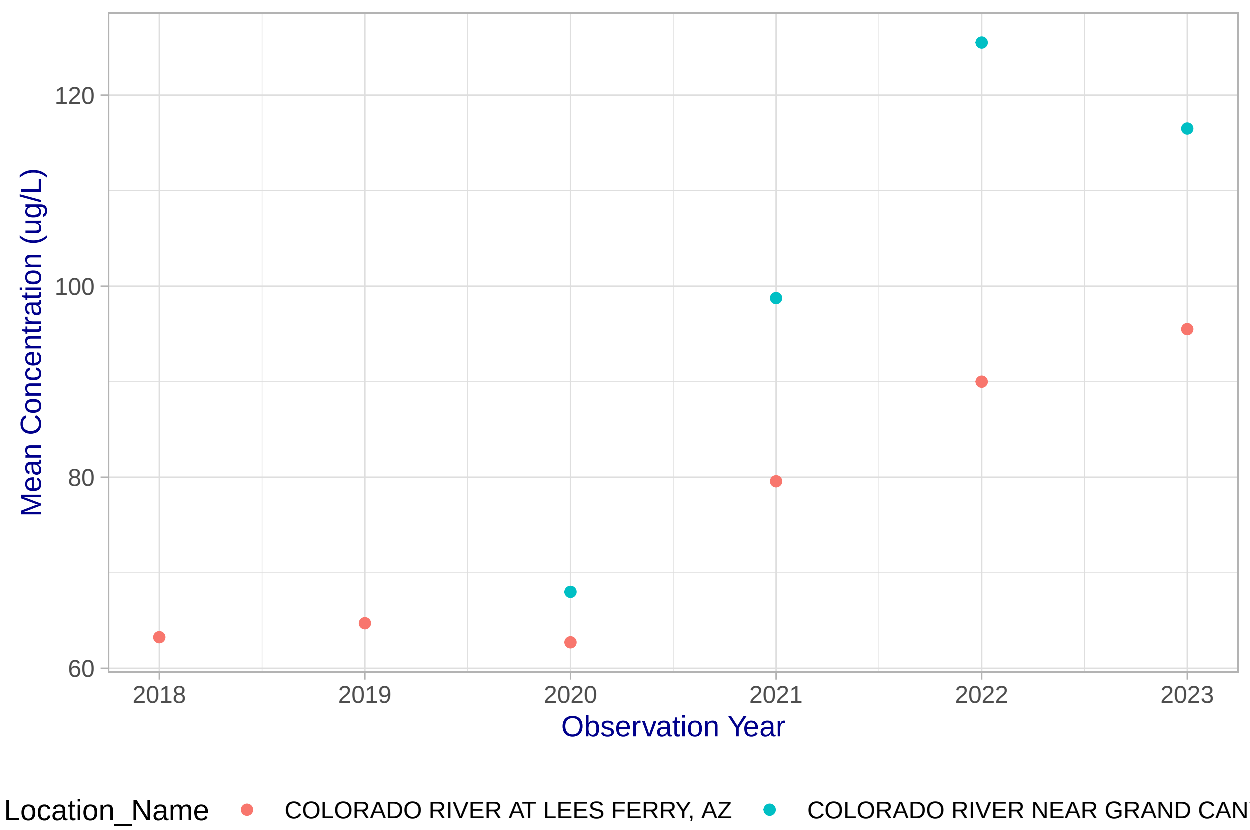

Figure 6: Boron Concentration before and after passing through the Navajo Nation

```r
#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
```

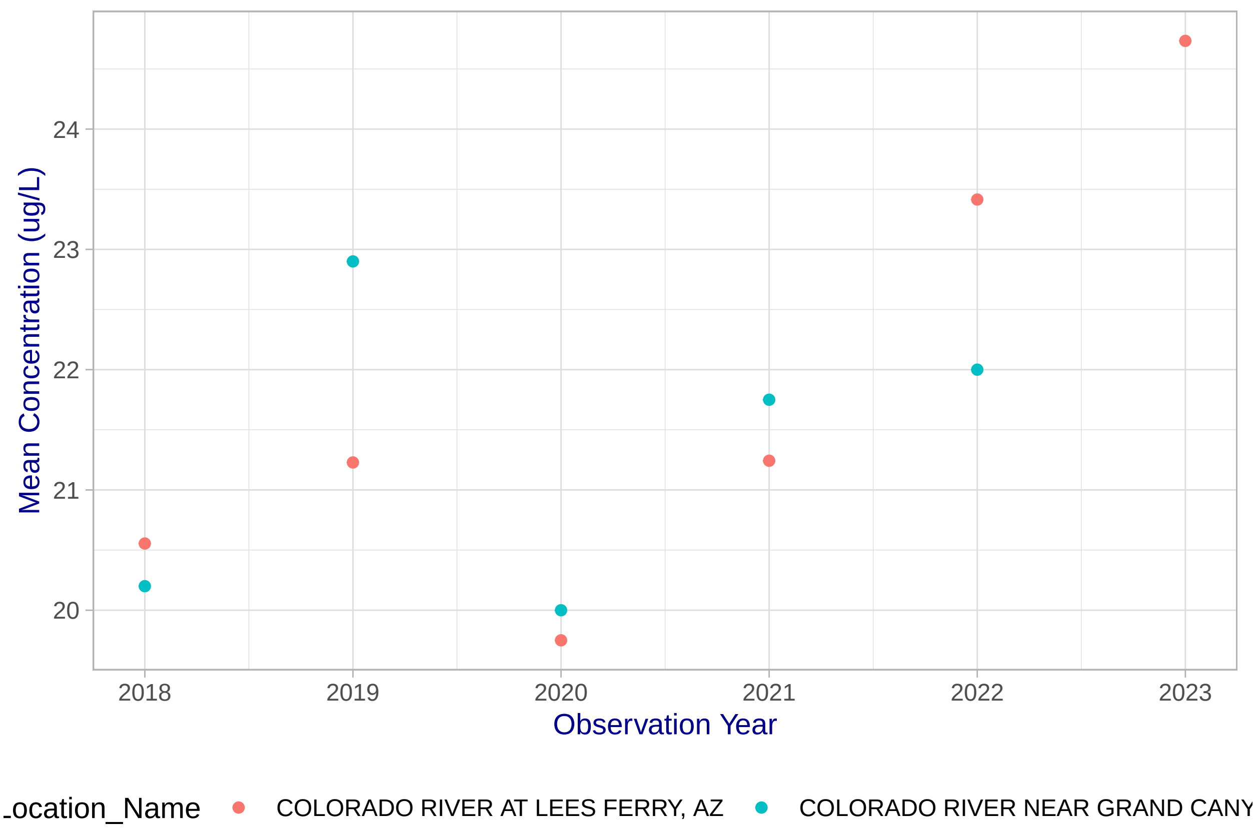

Figure 7: Magnesium Concentration before and after passing through the Navajo Nation

```r
#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
```

Make analysis

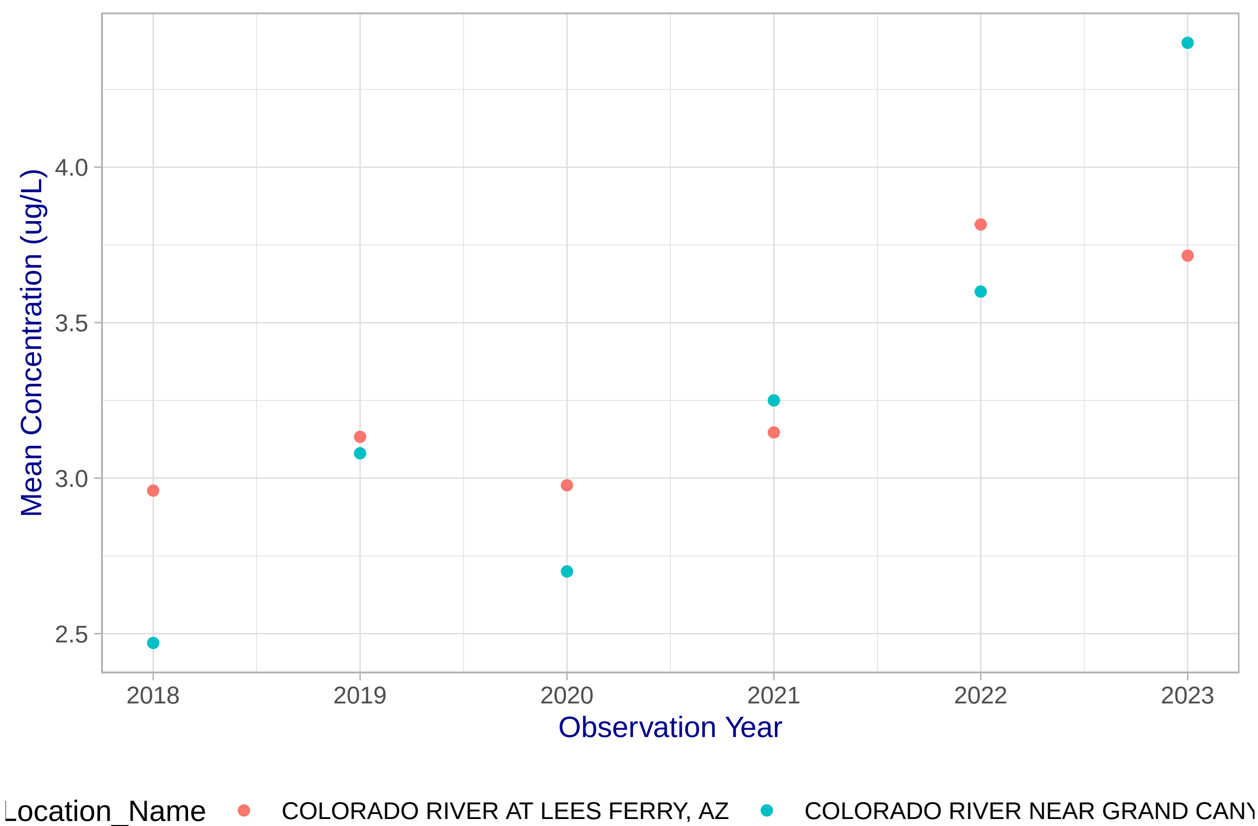

Figure 8: Uranium Concentration before and after passing through the Navajo Nation

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)
```