

# Final Project: Navajo Nation Water Quantity and Quality Analysis from 2019-2024

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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 30-40% of the Navajo Nation population does not have access to clean, reliable drinking water (Navajo Nation Department of Water Resources, 2024). Also, 173 thousand people are affected because drinking water sources are limited, and abandoned uranium mines have caused groundwater contamination in the Nation (Ibid.). 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 (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 snowpack, superimposed on the regional drought cycles, will magnify water-related impacts in the 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. A five-year analysis period was selected to provide a more current evaluation. 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 data availability. This analysis aims to test the following hypotheses:

Hypothesis A: The water quality in the Colorado River before and after passing through the Navajo Nation is significantly different.

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.

## 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 2024 from station 1 as well, extracting data of water flow in cf/s.

Since there is no missing data it is not necessary to execute linear interpolation for time series analysis.

# Exploratory Analysis

## Water Quantity

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

### Data Visualization

The observed downward trend in discharge volume, as evidenced by measurements from both gages (figure 1 and 2), presents a notable concern regarding the hydrological health of the San Juan and Colorado Rivers over the preceding half-decade. This declining trend signifies a significant challenge to the sustainability of these crucial aquatic ecosystems.

Of particular interest are changes in discharge levels in the San Juan River. While both rivers exhibit an overall decrease in discharge, the San Juan demonstrates more frequent instances of elevated discharge levels. Noteworthy spikes in discharge, notably observed around the midpoints of 2023 and 2019, highlight the river's seasonal variability and susceptibility to external influences.

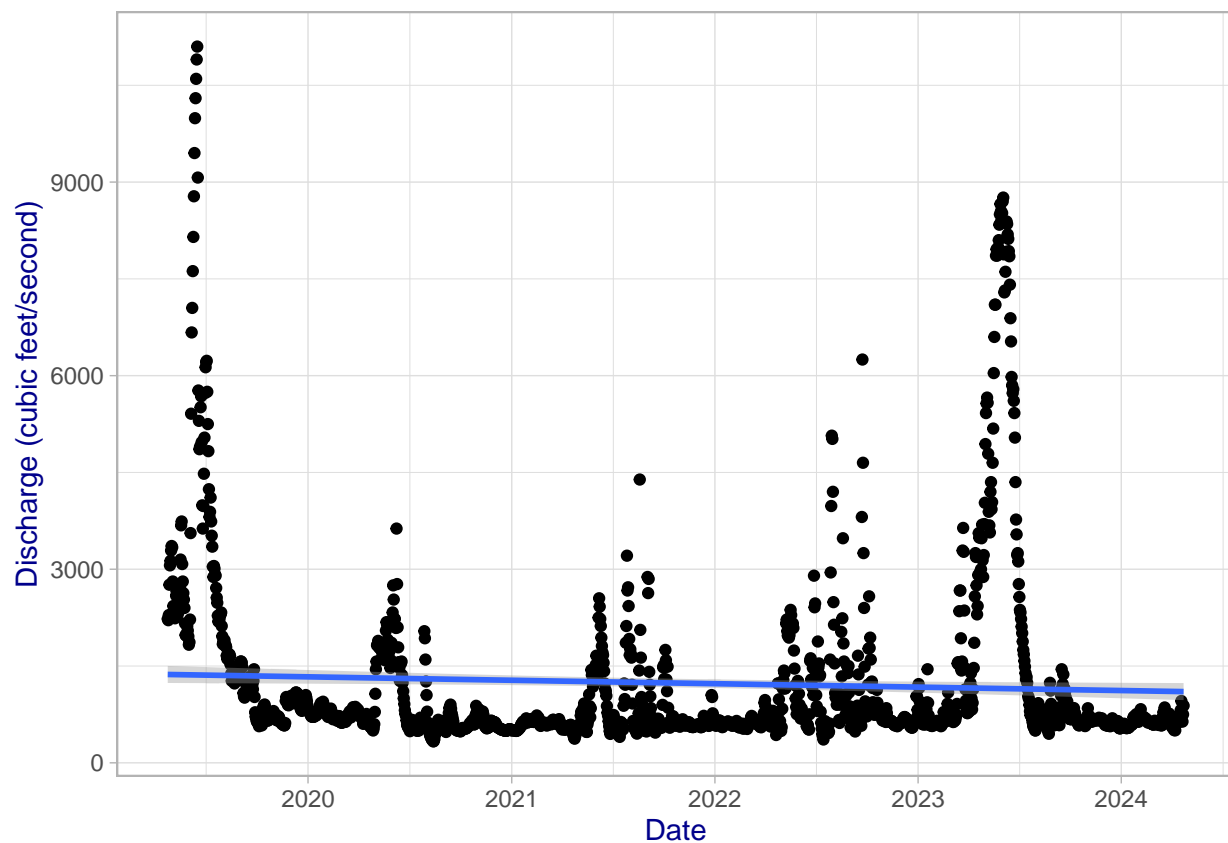


Figure 1: Water Levels in San Juan River

### Time Series Analysis

For Colorado River, water levels have declined from 2019 to mid-2022 and then increased to peak at early 2023 (Figure 4). For San Juan River, water levels have declined from 2019 to 2020 and remained steady (at a low level) up till mid-2022. Suddenly, water levels increased to peak at early 2023, and declined since then (Figure 5).

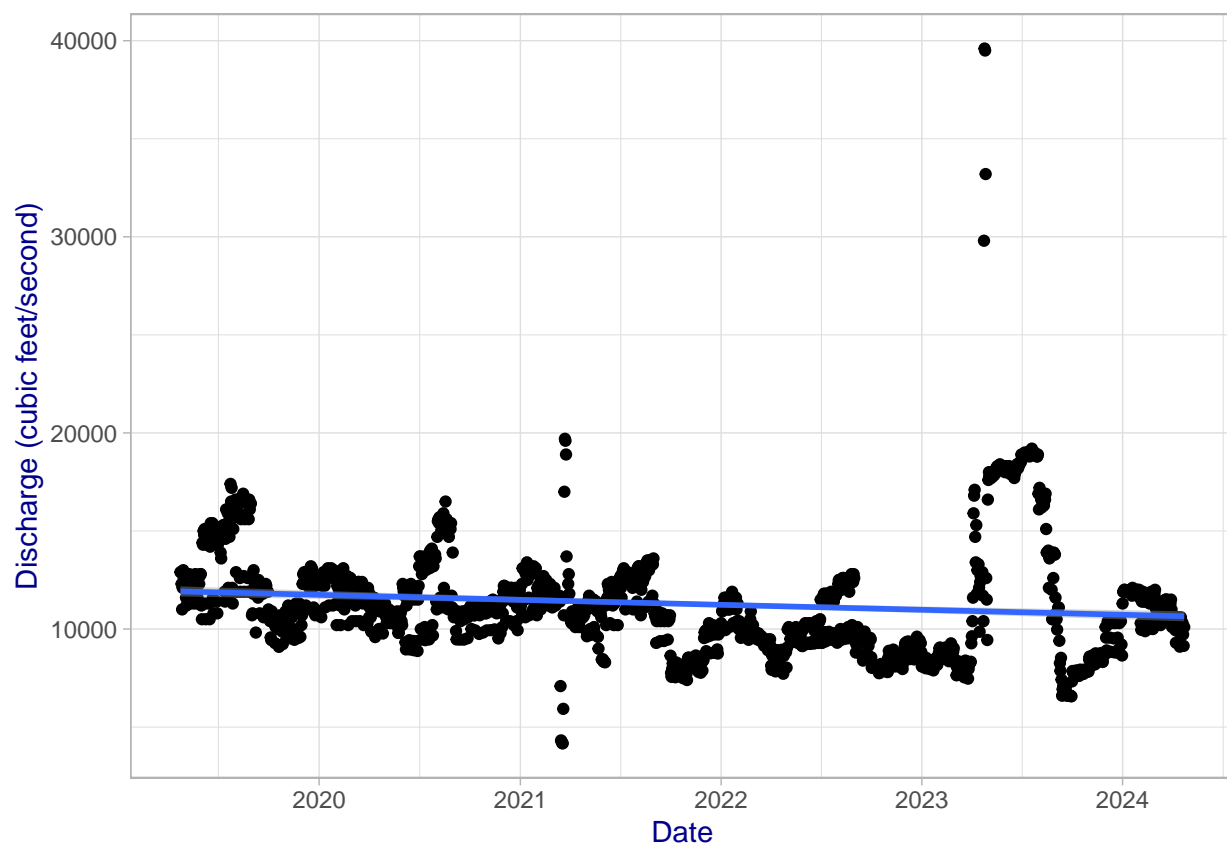


Figure 2: Water Levels in Colorado River

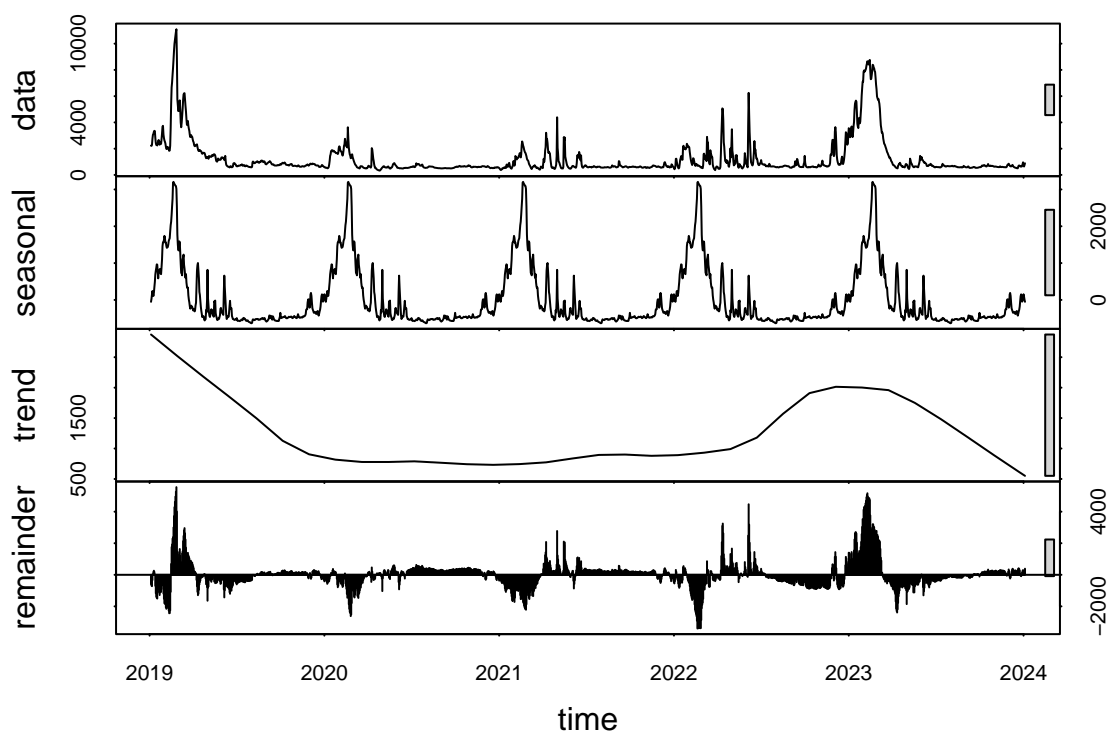


Figure 3: Time Series Analysis of San Juan River, 2019-2024

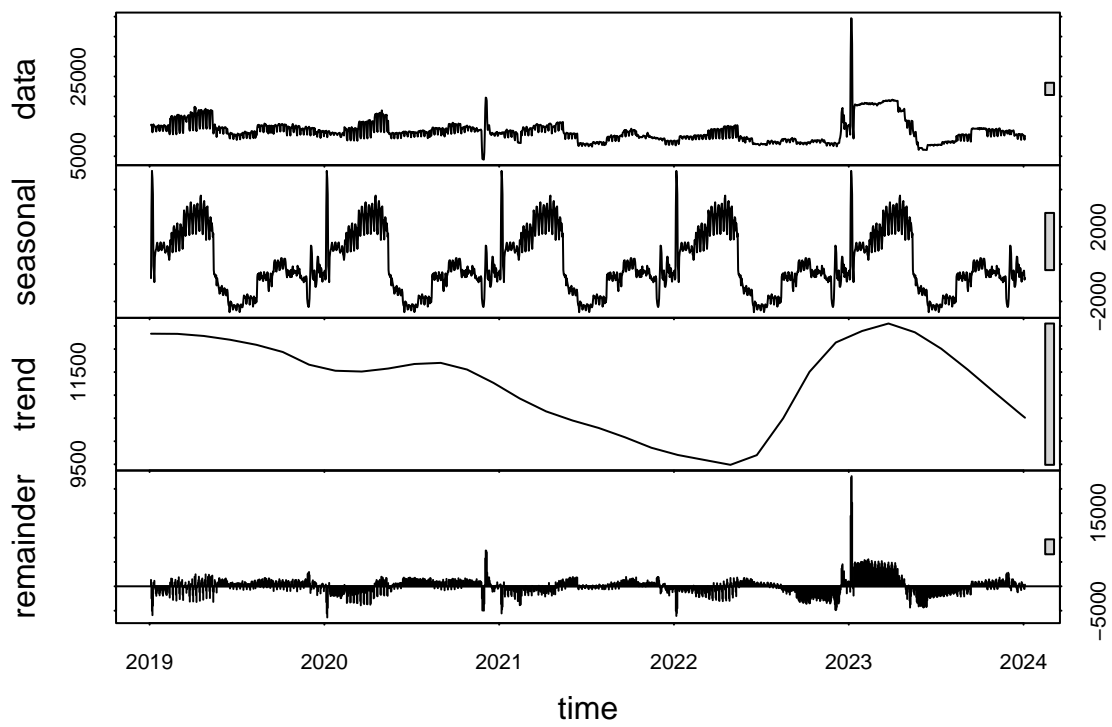


Figure 4: Time Series Analysis of Colorado River, 2019-2024



## 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 (Navajo Nation Division of Community Development, n.d.). This would allow us to determine how much of the Navajo population drew water directly from each 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.

The total Indian population in the Navajo Nation estimated to live in the chapters bordering the Colorado River is about 4516 (Navajo Nation Division of Community Development, n.d.). San Juan River has about 18728 people living close-by (Ibid.).

*Note: We intended to use scrape data from the website but it generated empty values. Hence, copy pasting the data was done instead. See appendix 1.*

Navajo people are estimated to use only 7 gallons of water per day (Supreme Court of the United States, 2022). Based on this estimate, and the estimate of population drawing water directly from the rivers, we can estimate the gallons of annual water withdrawal by the Navajo Nation. About 11538380 gallons in total are directly withdrawn from the Colorado River by the Navajo Nation, while about 47850040 gallons in total are directly withdrawn by the Navajo Nation from the San Juan River. This is a small quantity compared to [\*i think we need a statistic of how much other states withdraw from either river to put these numbers in context]

This estimate applies only for domestic use but since they use water for other activities such as agriculture, the water availability of both rivers is a limiting factor.

Note: we're counting only populations right beside the river, even though with water transport infrastructure, people in chapters far from the river will also be withdrawing, so this estimate of water withdrawing is an underestimate.

```
seconds_per_year<-365*24*60*60
#water available in periods of minimum water discharge from the last 5 years
water_available_SJ_2024<-500*7.48052*seconds_per_year
water_available_SJ_2024
```

```
## [1] 117952839360
```

```
water_available_Colorado_2024<-9500*7.48052*seconds_per_year
water_available_Colorado_2024
```

```
## [1] 2.241104e+12
```

```
#Note to samantha: Do we need this? Cos even at the lowest
```

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

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

```
## [1] 117952839360
```

```
## [1] 2.241104e+12
```

## 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?

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

## Data Visualization Analysis

Mean annual Boron concentrations increased on the Colorado river (Figure 5) from 2019-2024, nevertheless, the concentrations have not yet exceed a concerning level for human health according to the recommended maximum levels for drinking water by Canada and The World Health Organization (World Health Organization, 2009; Health Canada, 2020).

Throughout this 5-year period, Boron concentration is lower when entering the tribe territory than when it exits, reaching a maximum concentration of >120 ug/L, which is still considered low. The statistically significant difference ( $p\text{-value} = 0.002834 < 0.05$ ) indicates that the Navajo Nation engages in activities that result in Boron discharge in the Colorado river. [\*\*\*what sorts of activities might they be? Cite]

```
##
## Welch Two Sample t-test
##
## data: Boron_Site1$Result_MeasureValue and Boron_Site2$Result_MeasureValue
## t = -4.0699, df = 8.9481, p-value = 0.002834
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
## -47.32438 -13.49149
## sample estimates:
## mean of x mean of y
## 74.81429 105.22222
```

Magnesium concentrations in the river show. [\*\*\*Magnesium description and explanations needed. Also mention they're not statistically significant based on the t-test below with p-value of 0.9361]

```
##
## Welch Two Sample t-test
##
## data: Magnesium_Site1$Result_MeasureValue and Magnesium_Site2$Result_MeasureValue
## t = 0.081994, df = 10.893, p-value = 0.9361
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
```

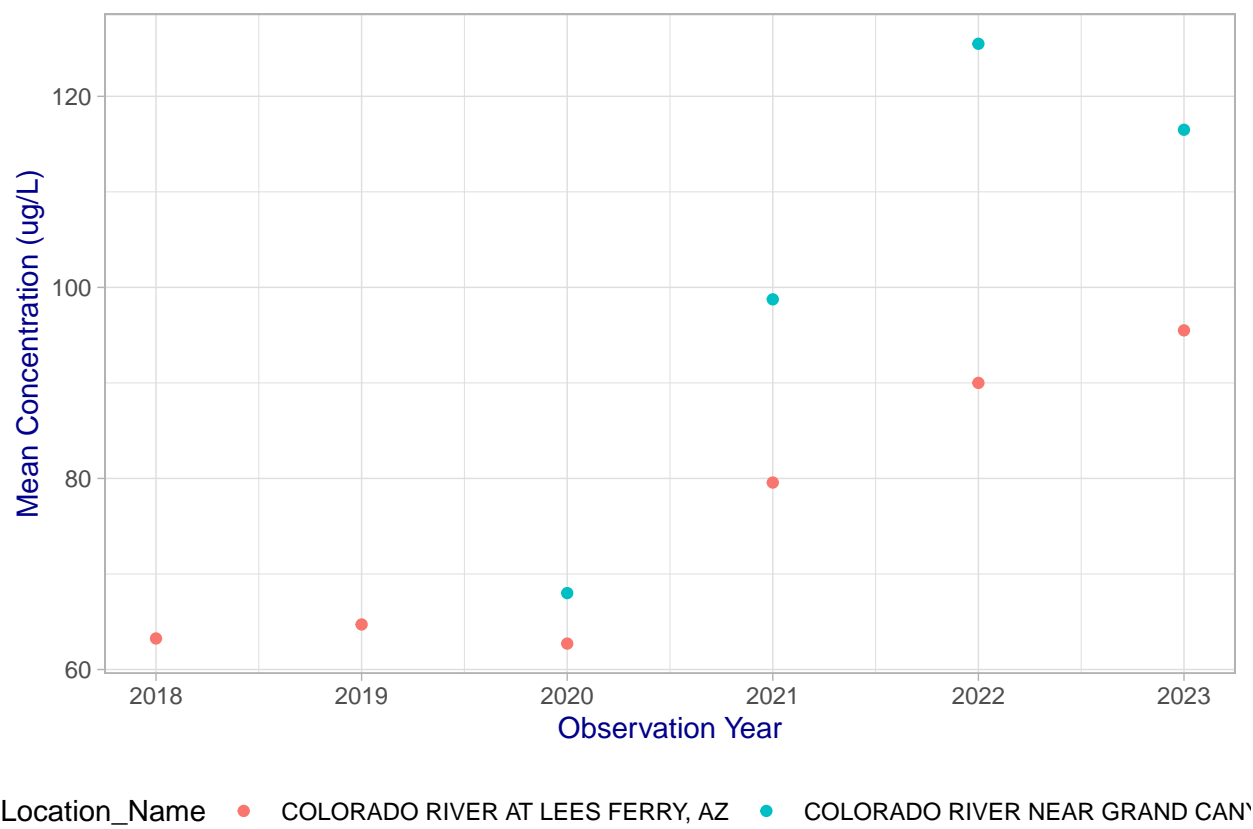
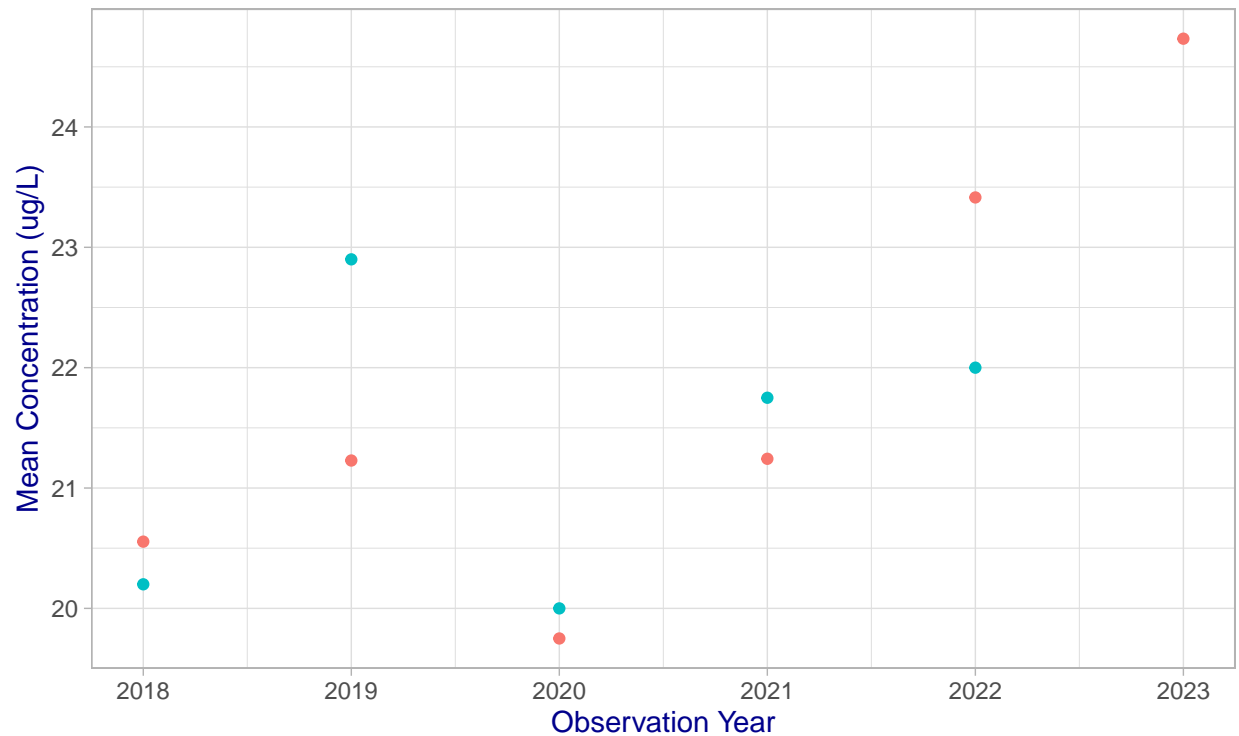


Figure 5: Boron Concentration before and after passing through the Navajo Nation

```
## -1.058932 1.140781
## sample estimates:
## mean of x mean of y
## 21.55342 21.51250
```



location\_Name ● COLORADO RIVER AT LEES FERRY, AZ ● COLORADO RIVER NEAR GRAND CANY

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

[\*\*\*Uranium description and explanations needed. Interestingly, the results are statistically significant based on the t-test below with p-value of 8.993e-05]

```
##
## Welch Two Sample t-test
##
## data: Uranium_Site1$Result_MeasureValue and Uranium_Site2$Result_MeasureValue
## t = -4.4101, df = 35.925, p-value = 8.993e-05
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
## -1.1451507 -0.4236512
## sample estimates:
## mean of x mean of y
## 3.467857 4.252258
```

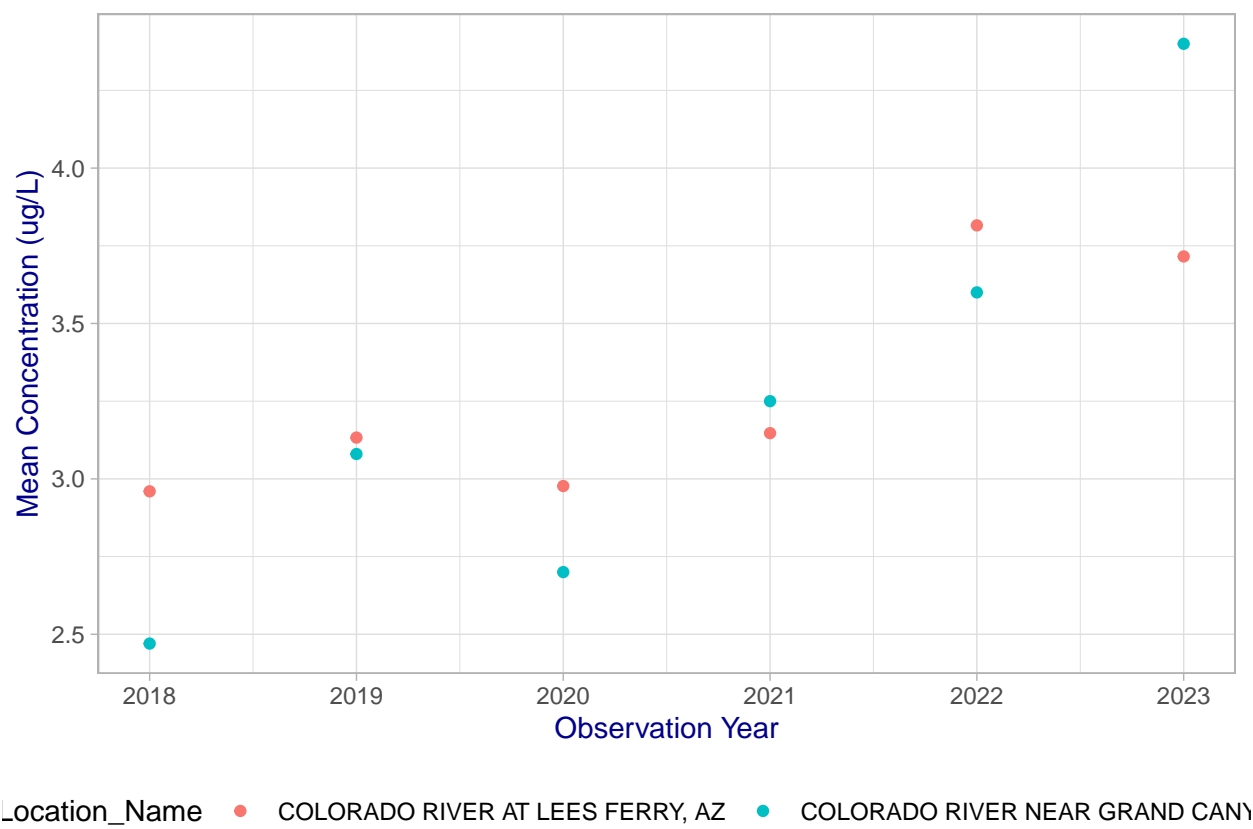


Figure 7: Uranium Concentration before and after passing through the Navajo Nation

## Summary and Conclusions

## References

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- 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>
- World Health Organization. (2009). Boron. Chemical Fact Sheets. [https://www.who.int/docs/default-source/wash-documents/wash-chemicals/boron-chemical-fact-sheet.pdf?sfvrsn=a936384f\\_4](https://www.who.int/docs/default-source/wash-documents/wash-chemicals/boron-chemical-fact-sheet.pdf?sfvrsn=a936384f_4)

# 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)
```