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 Navajo Nation mainly gets its water from the Colorado and San Juan Rivers, but faces legal difficulties in getting its interests met within inter-state negotiations on water rights. The Colorado River Compact set in 1922 gives seven states the right to draw water, and are grouped into two, the Upper Basin States (namely Colorado, New Mexico, Utah and Wyoming) and Lower Basin States (namely Arizona, Nevada and California) (https://www.sltrib.com/news/environment/2024/03/06/utah-says-it-shouldnt-have-take/). The Navajo Nation is not formally included in these agreements. As the post-2026 operations of the river are being negotiated, the Navajo Nation is engaging in persistent legal efforts to compel the US government to meet its obligation to set aside water for its people. [***Sami please fact-check & edit as you see fit. Then we need to cite.]

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 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 2018 to 2023, capturing Uranium, Magnesium, and Boron levels detected at both stations. 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. For the San Juan river, the data was extracted from the gage on site 09379500.

Wrangling: For water quantity, the data was wrangled to have more understandable column names for the discharge. The data was parsed to include only relevant variables, namely, discharge and date. No additional wrangling was needed since the dates and discharge were already in the correct format (Year-mm-dd) and class (Date and number respectively), and the dataset contained no missing data.

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 downward slope measured at both gages shows that the discharge volume for both San Juan and Colorado Rivers have declined in the last five years (Figures # and #). This corroborates with previous years where drought conditions have affected water quantity, posing a continued challenge to water availability for the people in the Navajo Nation and impacting aquatic ecosystems. While both rivers experience seasonal variability, the San Juan River has more frequent periods of high discharge (eg. mid-2023 and mid-2019) compared to the Colorado River.

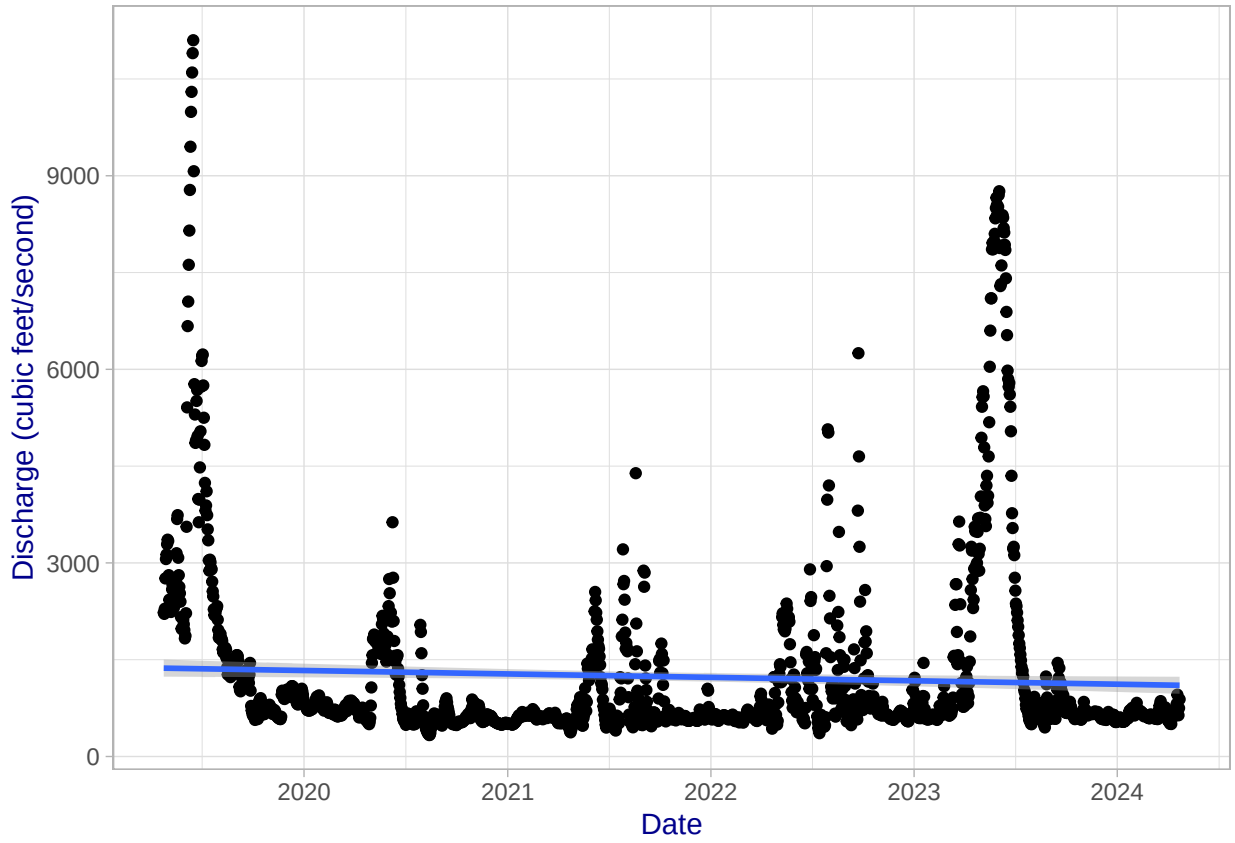

Figure 1: Water Levels in San Juan River

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).

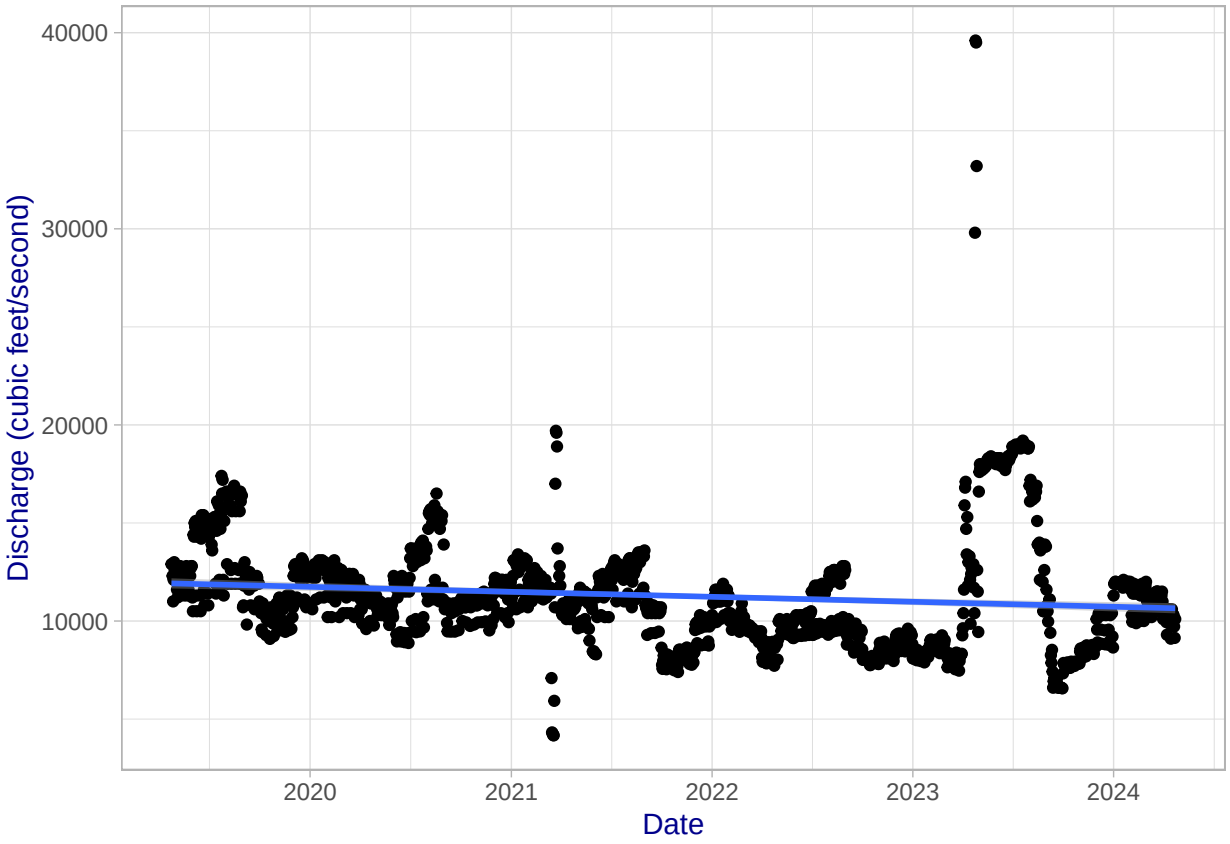

Figure 2: Water Levels in Colorado River

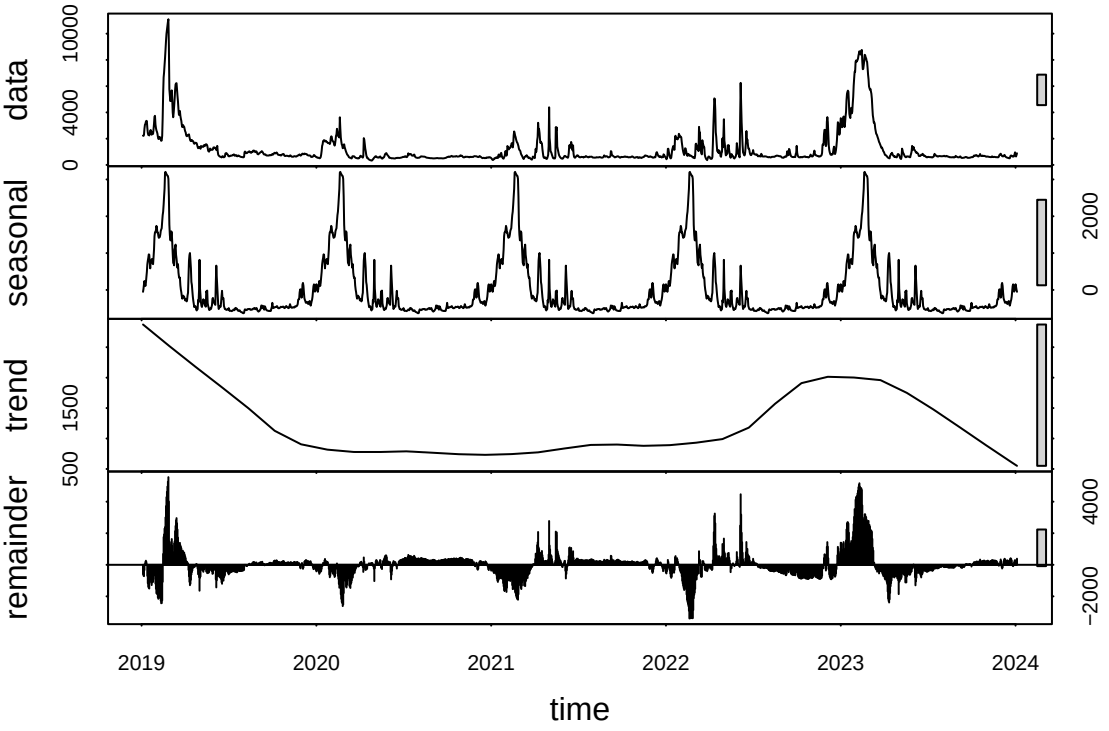

Figure 3: Time Series Analysis of San Juan River, 2019-2024

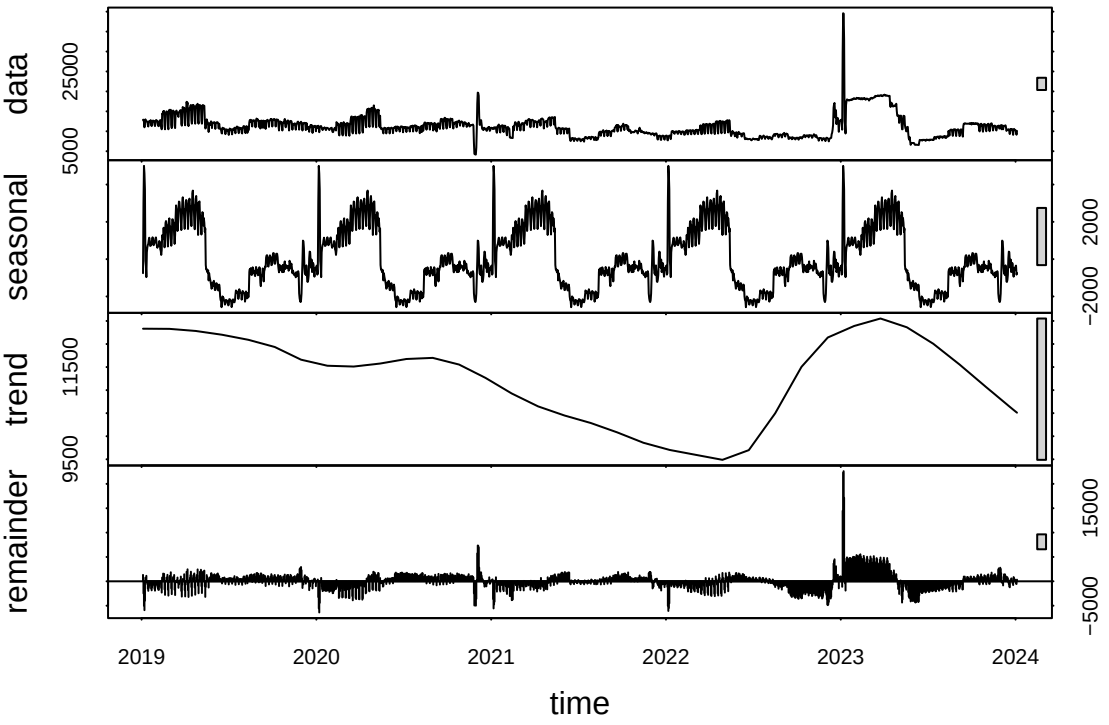

Figure 4: Time Series Analysis of Colorado River, 2019-2024

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 allows 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...

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, having in general a mean concentration along the river of 74.81 ug/L. The statistically significant difference (p-value = 0.002834 < 0.05) indicates that the Navajo Nation engages in activities that result in Boron discharge in the Colorado river.

```
##
##  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
```

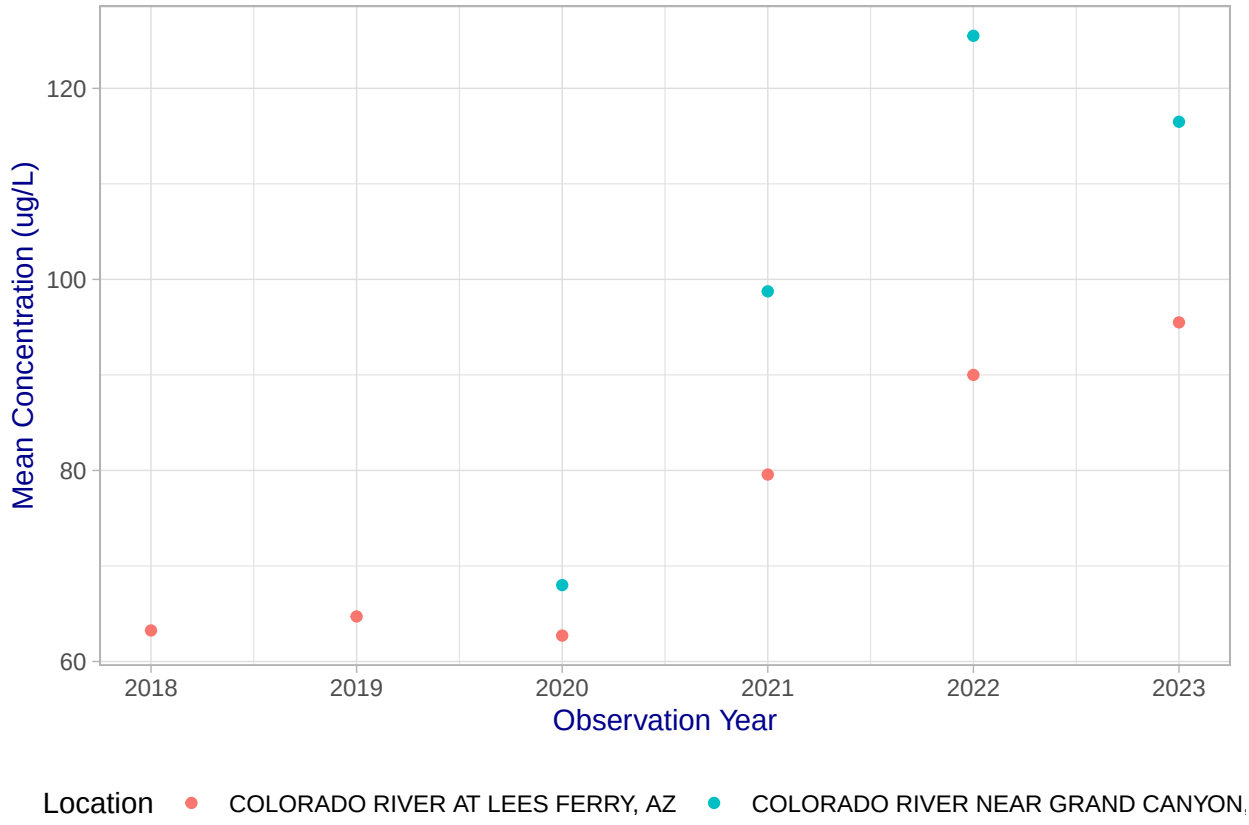

Figure 5: Boron Concentration before and after passing through the Navajo Nation

Mean annual Magnesium concentrations increased on the Colorado river (Figure 6) from 2020-2023, having a low concentration on 2018 and high increase in 2019 up to 22.9 mg/L.

Throughout this 5-year period, Magnesium concentration is lower when entering the tribe territory than when it exits, with a significant difference between both sides of 93.61%, having in general a mean concentration along the river of 21.55 mg/L,

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

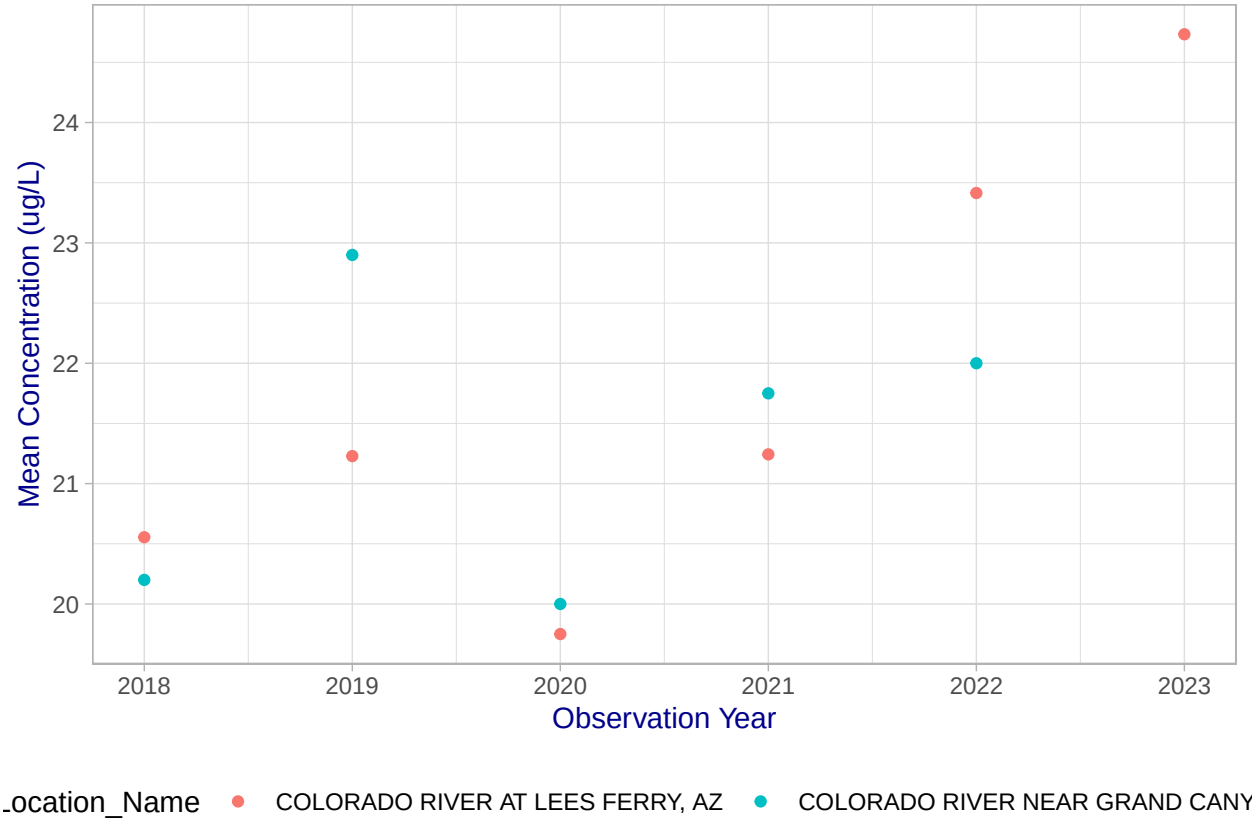

Figure 6: Magnesium Concentration before and after passing through the Navajo Nation

Mean annual Uranium concentrations have increased on the Colorado River (see Figure 5) from 2019 to 2024. Nevertheless, the concentrations have not yet exceeded concerning levels for human health according to the recommended maximum levels for drinking water by The World Health Organization and the EPA. However, the goal concentrations are zero (World Health Organization, 2009; US EPA, 2024). Considering that the water used from the Colorado River is for direct human consumption and other activities, accumulation of

this element can potentially generate radiological toxicity, and high concentrations of that accumulation can generate impacts on human health such as kidney diseases (Vengosh, 2024). The low concentrations of this component at this location indicates a positive environmental stage considering the historical mining in the Navajo territories (Doug Brugge, Rob Goble. 2002).

Throughout this 5-year period, Uranium concentration is lower when entering the tribe territory than when it exits (except 2021 and 2023), reaching a maximum concentration of 5.80 ug/L, having in general a mean concentration along the river of 3.47 ug/L. The statistically significant difference (p-value = 8.993 e-5) indicates a difference in uranium measurements between the entrance to the reservation and the exit of the water concentrations of the Colorado river. Suggesting that there are activities or natural occurring uranium discharge.

```
##
##  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
```

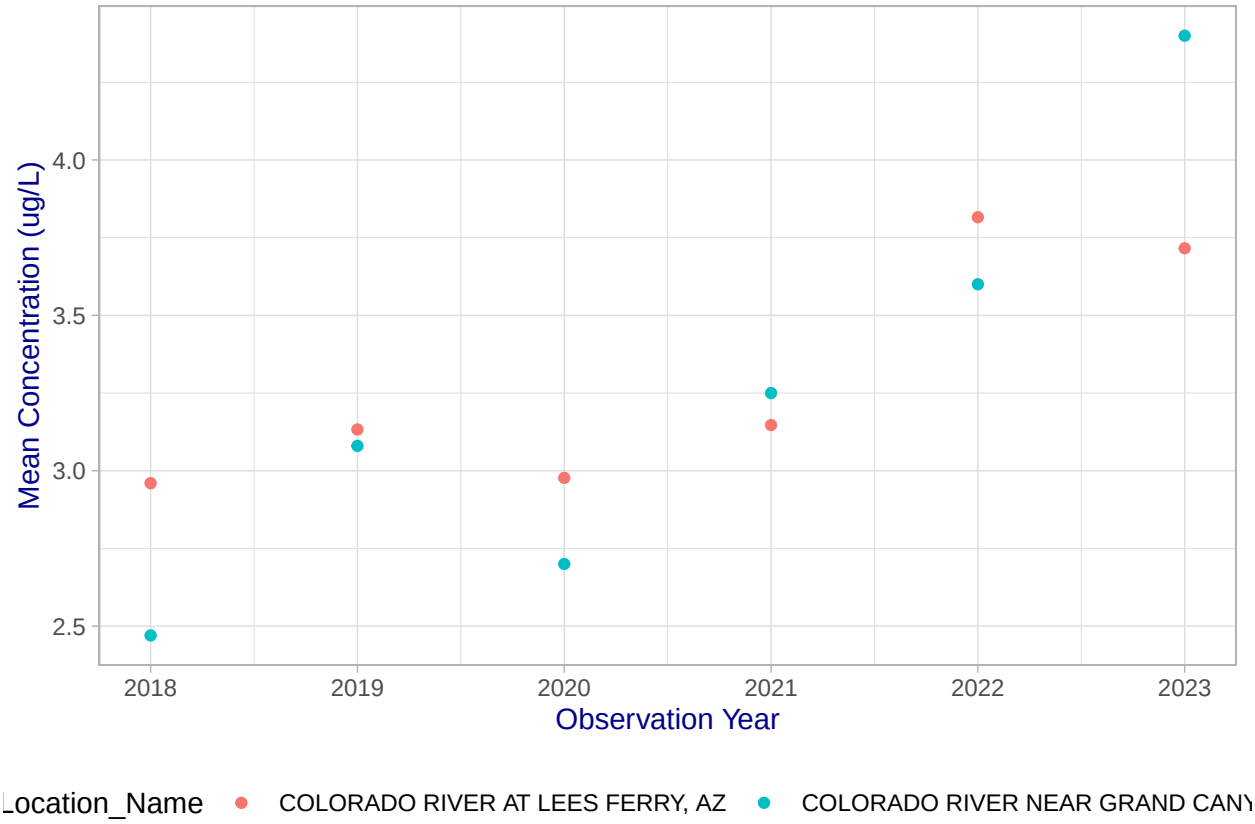

Figure 7: Uranium Concentration before and after passing through the Navajo Nation

Summary and Conclusions

References

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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)
```