

Changes on the Elwha River During Dam Removal

https://github.com/kfm20/DataProject_ElwhaRiver.git

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1 Rationale and Research Questions

Write 1-2 paragraph(s) detailing the rationale for your study. This should include both the context of the topic as well as a rationale for your choice of dataset (reason for location, variables, etc.). You may choose to include citations if you like (optional). At the end of your rationale, introduce a numbered list of your questions (or an overarching question and sub-questions).

2 Dataset Information

Data was collected daily at the USGS gaging station with identification number 12046260, located on the Elwha River at the diversion near Port Angeles, Washington. Data was published February 7, 2020 by USGS and accessed April 20, 2020. The data was collected from September 15, 2011 to September 30, 2016. The dataset contains daily measurements and estimates of discharge and various parameters of sediment loads. Sediment load parameters include suspended concentration, loads of suspended fine-grained particles and sand particles, and gauged bedload for particles from 0mm to 16mm. The dataset is part of a larger study that created a 5 year sediment budget and morphodynamic analysis of the Elwha River following the two dam removals. Research into the time frame of the two part dam removal process supplied dates for time stamps and classification of “during” the dam removal process, and “after” completion of the project. Removal of the Glines Canyon Dam began on September 15, 2011, and September 17, 2011 for the Elwha Dam (NPS 2019). The entire project was completed on August 26, 2014 (National Park Trips 2015). Therefore, “during” is classified as September 15, 2011 to August 26, 2014, and “after” is classified as August 27, 2014 until the end of sampling, September 30, 2016.

The dataset, coming from USGS, was already pretty neat, no NAs or unneeded symbols were found. The dataset was simply wrangled for a best fit in order to perform useful analyses answering the research questions at hand. To wrangle the data, the most important variables for an analysis focused on observing general changes on the Elwha River during and after the dam removal project were selected. Columns were recoded with shorter and more coding friendly names. The next big wrangling task included dividing the data into two new datasets by date, following the “during” and “after” time stamps mentioned. A new column was created with a character class of text, with the appropriate “during,” or “after” notation signified by the date time frame. These two individual datasets were saved as new processed files to be used in an analysis question later. They were also combined again, giving a dataset of all the sampling points across the entire 5 year sampling period, just with the new time stamp column.

Column name	Data Description	Associated Units
Date	Date of daily recording	YYYY-MM-DD
DailyDischarge	Daily water discharge from the river	m ³ /s
DailySSC	Daily suspended sediment concentration	mg/L
DailySuspendedSediment	Daily total suspended sediment load	tonnes
DailySSfines	Daily suspended fine grained sediment load	tonnes
DailySSsand	Daily suspended sand sediment load	tonnes
TotalSedimentDischarge	Total daily sediment discharge	tonnes
Projectyear	Year of sampling project, extending from 1-5 years	year
TimeStamp	Distinguishes time frame in the dam removal process	“during” or “after”

3 Exploratory Analysis

An initial exploratory analysis is conducted to see general trends in data related to water and sediment discharge, and suspended concentrations in Elwha River during and after the dam removal process. Daily water discharge from the river, *Figure 1*, appears to have higher peaks of discharge in 2015 and 2016, the years after the dam removal project was complete. Embedding the dates involved with the dam removal process, such as start of removal, and completion of each dam removal will help differentiate differences in discharge related to more open flows with dams removed. This data might need to be looked at a different scale, instead of daily, maybe monthly averages will show a different relationship, or a similar one at a different magnitude.

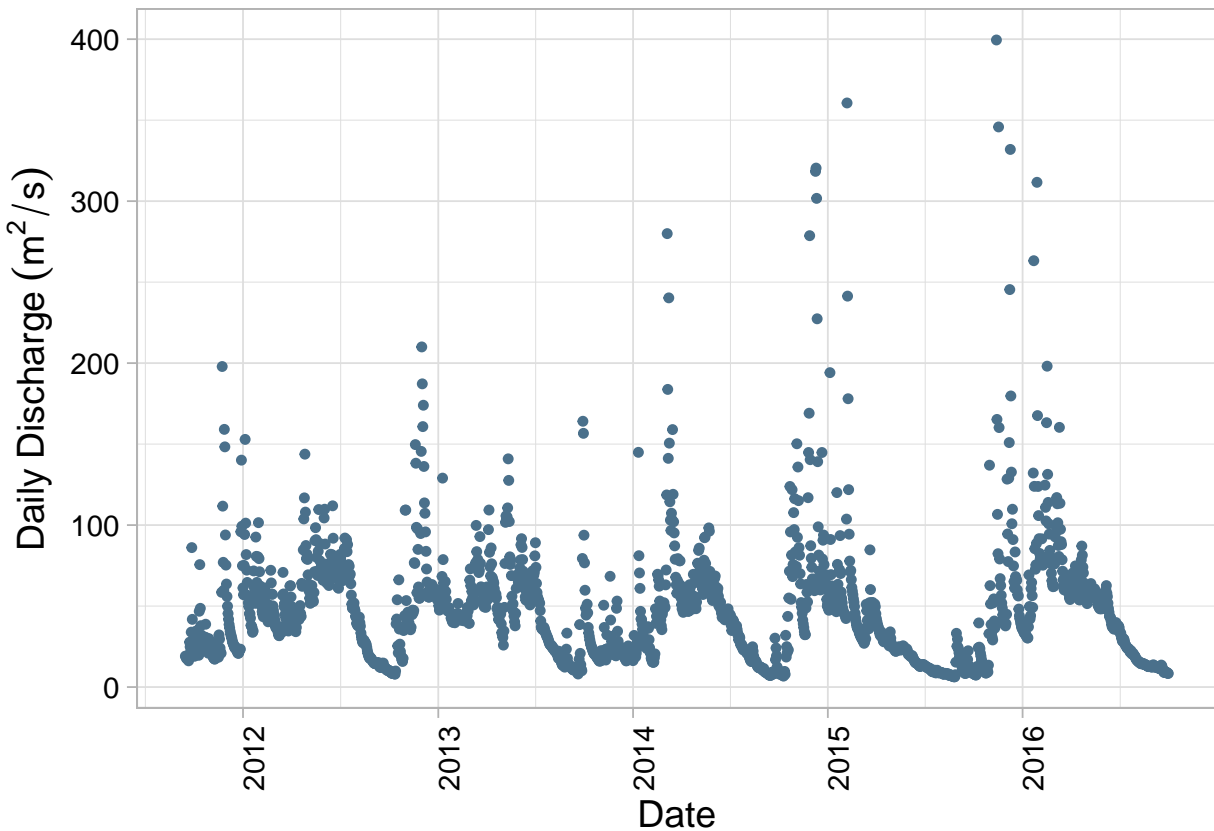


Figure 1: Daily water discharge of the Elwha River, WA, from September 15, 2011 to September 30, 2016.

Suspended sediment concentrations might give a sense of the velocity of the flow heading downstream, and how much sand was stuck behind the dams that is then in movement after their removal. Looking at suspended concentrations over time may show how long it takes for the sediment behind the dam to resettle in the river, allowing the river to reach a new morphological norm. General trends of suspended sediments, *Figure 2*, show more tonnes happening around the year 2013, which is during the removal of the Elwha Dam, and the Glines Canyon Dam had already been removed. However, there still exists some high

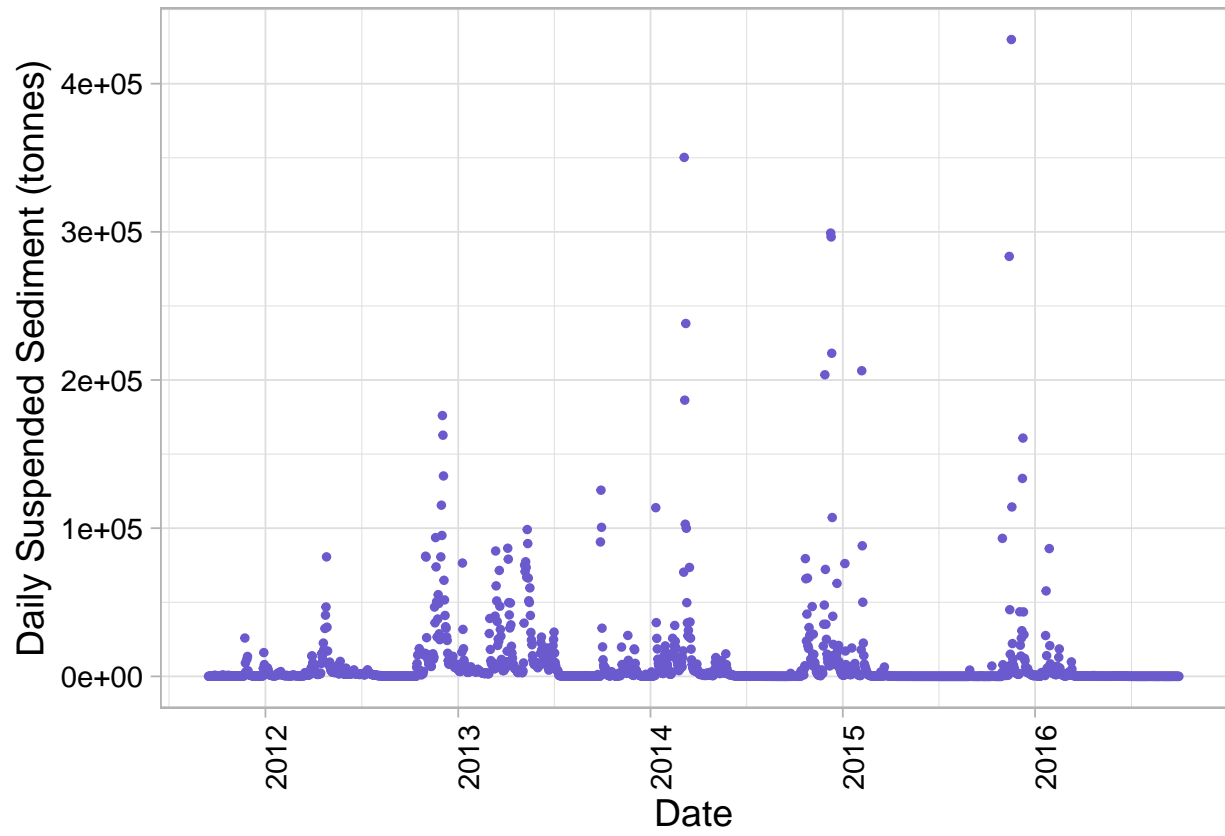


Figure 2: Daily suspended sediment in the Elwha River, WA, from September 15, 2011 to September 30, 2016.

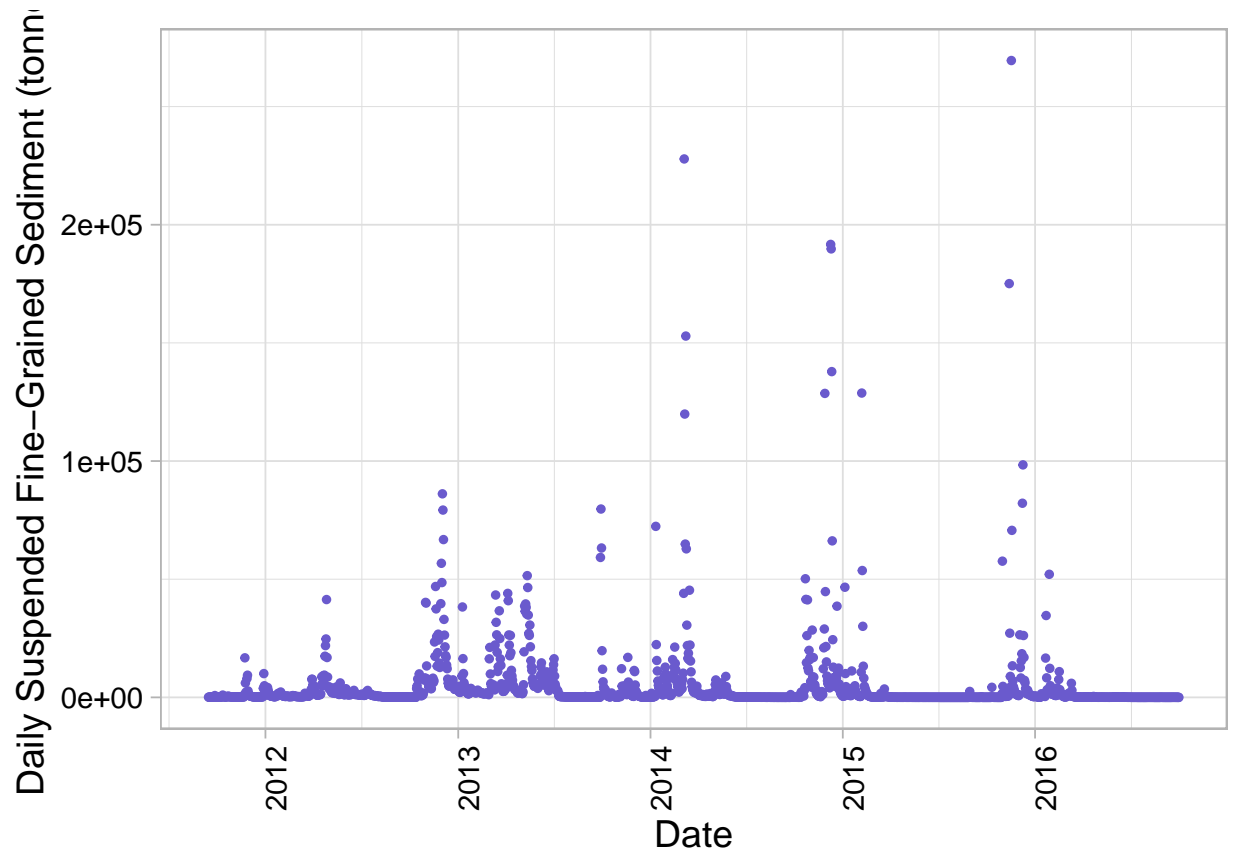


Figure 3: Daily suspended sediment of fine-grained particles in the Elwha River, WA, from September 15, 2011 to September 30, 2016.

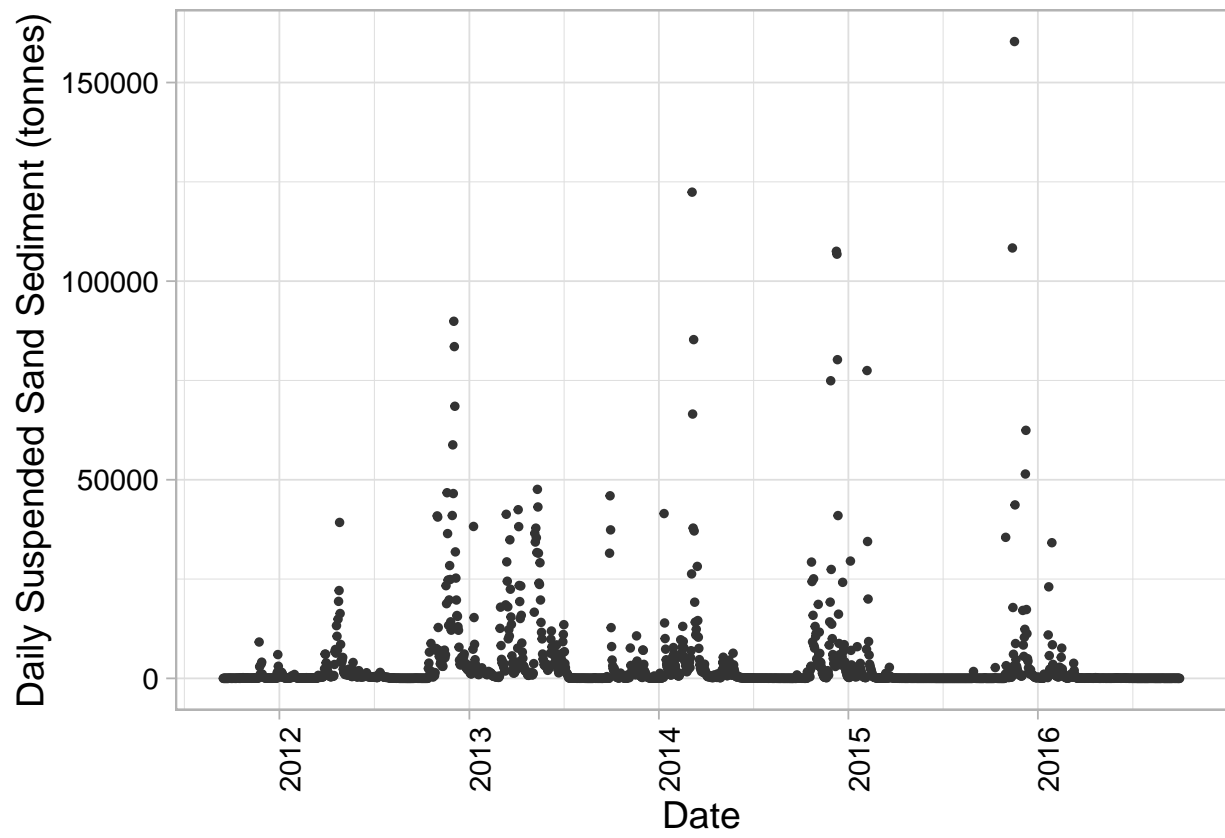


Figure 4: Daily suspended sediment of sand particles in the Elwha River, WA, from September 15, 2011 to September 30, 2016.

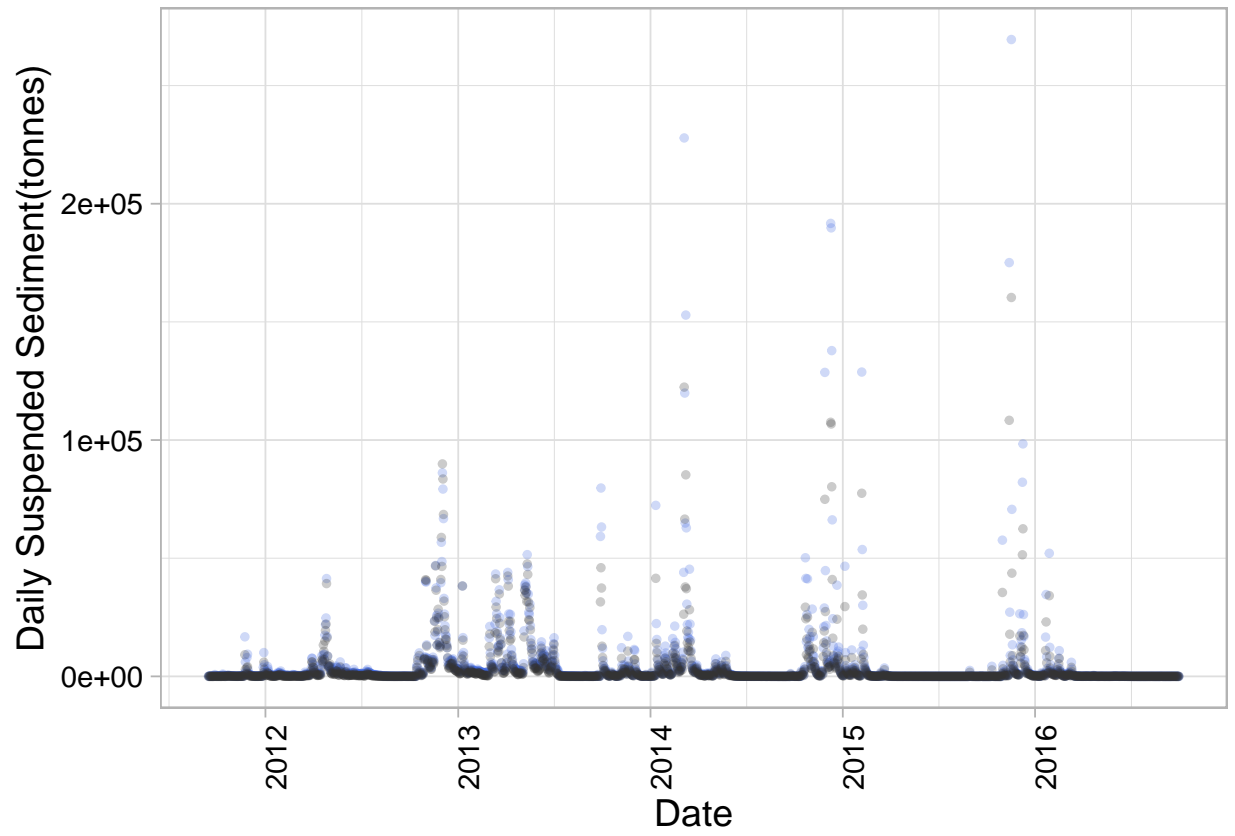


Figure 5: Daily suspended sediment of fine-grained particles (blue) and sand particles (gray) in the Elwha River, WA, from September 15, 2011 to September 30, 2016.

recordings of suspended sediment later on through the project years. However, these might have to do with the high water discharge. Further analysis will compare the relationship between daily suspended sediment and water discharge over time. The dataset also has daily suspended sediment of fine-grained particles, and sand particles. Their general point plots are shown individually, *Figures 3 and 4* and together in one plot, *Figure 5*, where we see there doesn't appear to be much difference between the makeup of the suspended sediment, although a further test can prove this.

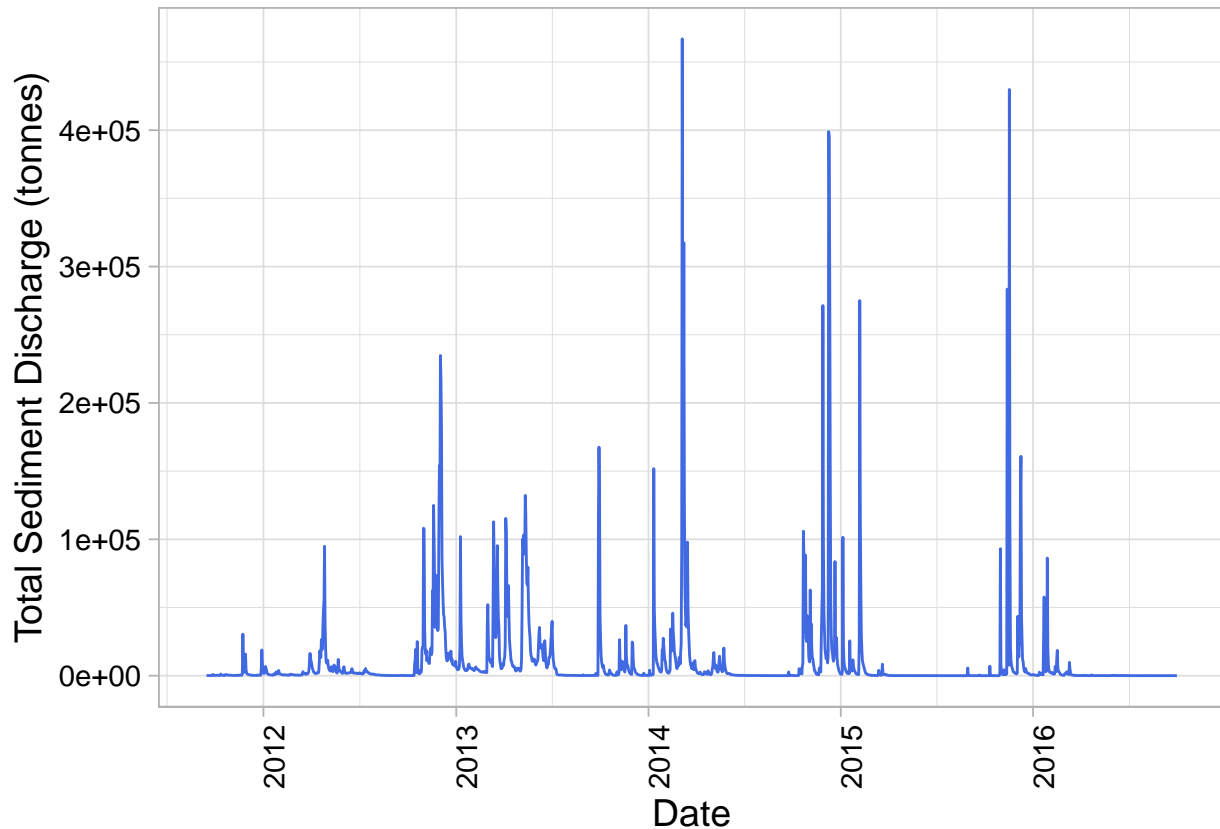


Figure 6: Daily total sediment discharge from the Elwha River, WA, from September 15, 2011 to September 30, 2016.

While there are multiple parameters highlighting the sediment traveling downstream, daily sediment discharge is a straight forward parameter of moving sediment in the Elwha River during and after the dam removal processes. From a general line plot of total sediment discharge over time, *Figure 6*, shows a peak discharge in 2013 and multiple large peaks as well as what appears like a larger average sediment discharge happening after 2014. These seem to make sense with the time stamps of the dam removal process, but combining the time stamps and this relationship in one graph will help better visualize the relationship with dam removal over time. Calculations of yearly averages of total sediment discharge will also be useful to determine if they are increasing from 2012 to 2016 like they appear to be in this figure.

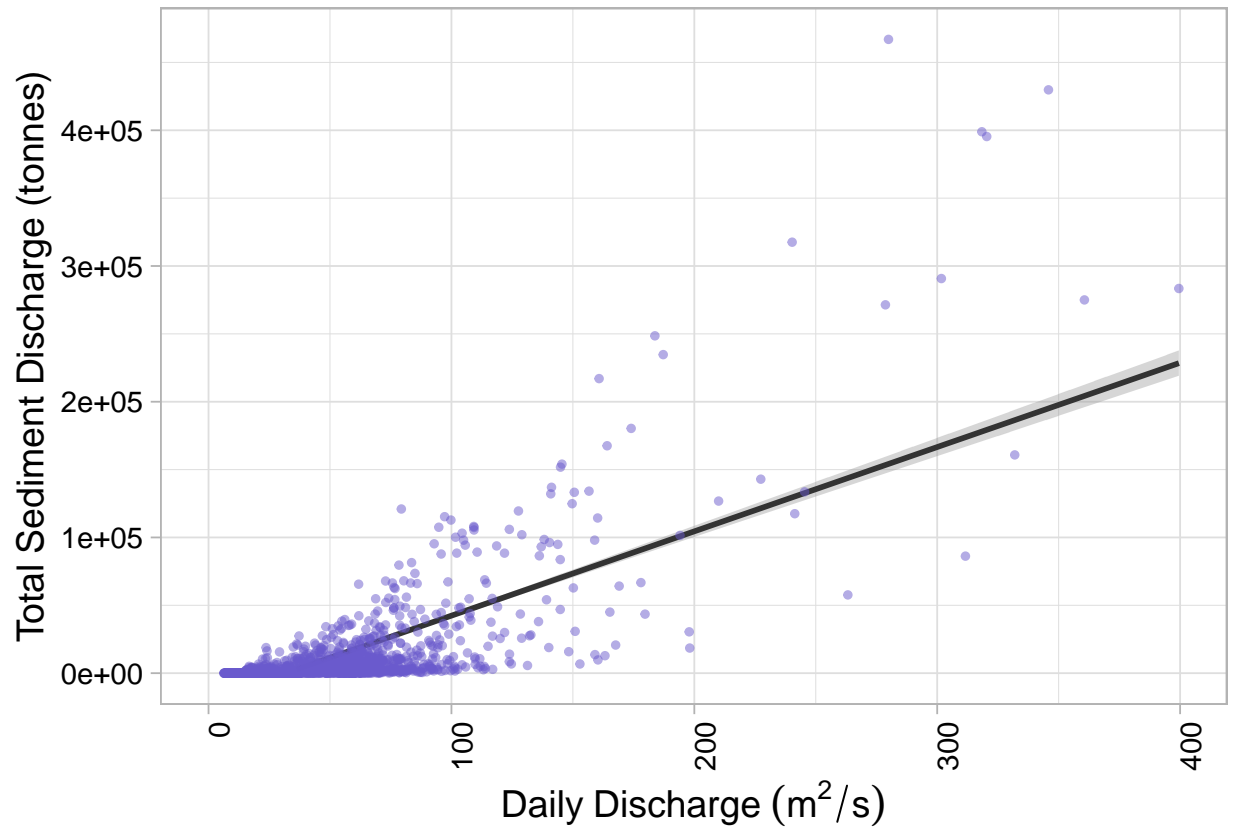


Figure 7: Daily total sediment discharge and water discharge on the Elwha River, with a linear model, from September 15, 2011 to September 30, 2016.

With daily water discharge and total sediment discharge being important parameters for showing changes in the Elwha River following dam removal, the relationship between them was graphed with a linear model to show a relationship. It makes sense that increased flow would generate increased sediment discharge, which we see from the positive linear relationship. It would be interesting to see this relationship graphed out for each individual year and see how this relationship might change.

4 Analysis

4.1 Question 1: How does water and sediment discharge in the Elwha River differ during and after the two part dam removal process?

A closer look into total sediment discharge and daily discharge of water from the Elwha River with attention on the time stamps of when the dam removal project begins, and when it is completed, *Figures 8 and 9*, prompted an in depth analysis of trends. Data was separated into during the dam removal process and after its completion, September 26, 2014. Part one of this analysis hoped to determine whether the means of daily water discharge were equivalent during and after the dam removal process. similarly, part two hoped to determine whether the means of daily total sediment discharge were equivalent during and after the dam removal process.

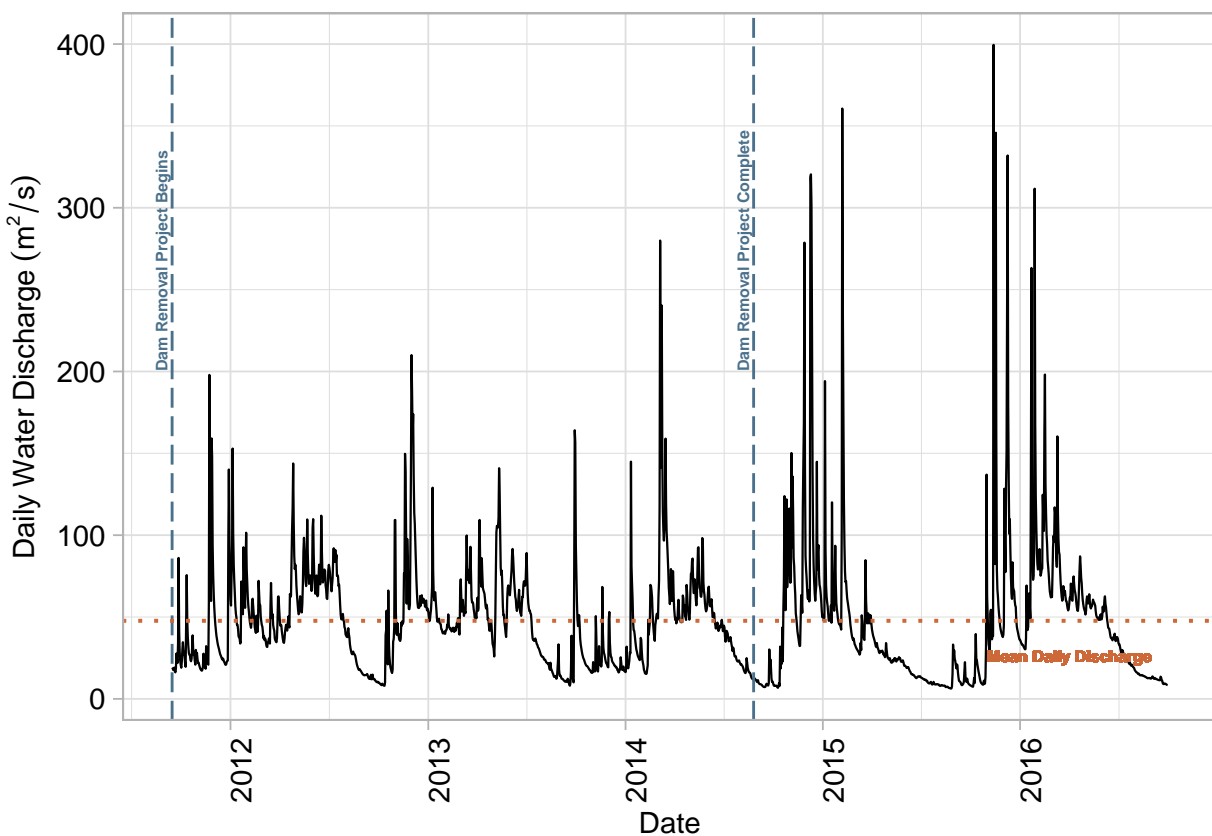


Figure 8: Daily water discharge from the Elwha River from September 15, 2011 to September 30, 2016 measured at the U.S. Geological Survey gaging station 12046260 at the diversion near Port Angeles, Washington. A project to remove the Elwha and Glines Canyon Dam began on September 15, 2011, and was completed on August 26, 2014. Mean Daily discharge across the whole time range was 47.7.

Daily water discharge data, *Figure 8*, was classified as during or after the dam removal process

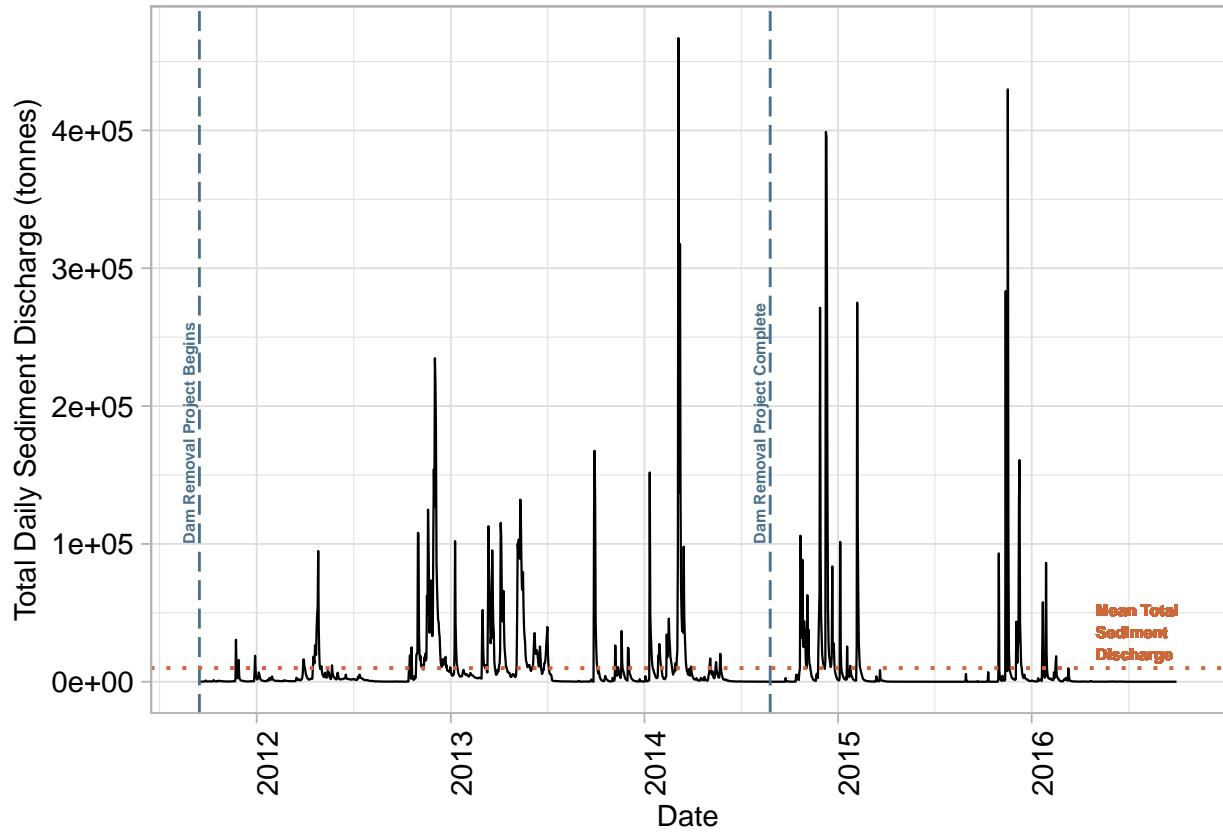


Figure 9: Daily total sediment discharge from the Elwha River from September 15, 2011 to September 30, 2016 measured at the U.S. Geological Survey gaging station 12046260 at the diversion near Port Angeles, Washington. A project to remove the Elwha and Glines Canyon Dam began on September 15, 2011, and was completed on August 26, 2014. Mean Daily sediment discharge across the whole time range was 9886.876 tonnes.

based on dates. September 26, 2014 was the dividing date. A two-sample t-test was run to determine if means are equivalent during and after dam removal. This test assumes equal variance, however, results showed there is not an equal variance, meaning the assumption of normality is not met ($p\text{-value} < 0.05$; Shapiro-Wilk normality test). Similarly, Daily total sediment discharge data, *Figure 9*, was classified as during or after the dam removal process based on dates, and a two-sample t-test was also run. Daily total sediment discharge over time does not have equal variance as well ($p\text{-value} < 0.05$; Shapiro-Wilk normality test).

To avoid the assumption of normality, a non-parametric method, Wilcoxon rank sum, is used to determine if means are equivalent during and after dam removal for both water and sediment discharge. The mean daily discharge during the dam removal process is 48.31 m²/s, and 46.9 m²/s after the completion of the project. There is a significant difference between the means of daily water discharge during and after dam removal (*Figure 10*, $W = 349134$, $p\text{-value} < 0.0001$, Wilcoxon rank sum test). The mean daily total sediment discharge during the dam removal process is 11,319.0 tonnes, and 7,888.0 tonnes for after completion of dam removal. There is a significant difference between the means of daily total sediment discharge during and after dam removal (*Figure 11*, $W = 209858$, $p\text{-value} < 0.0001$, Wilcoxon rank sum test).

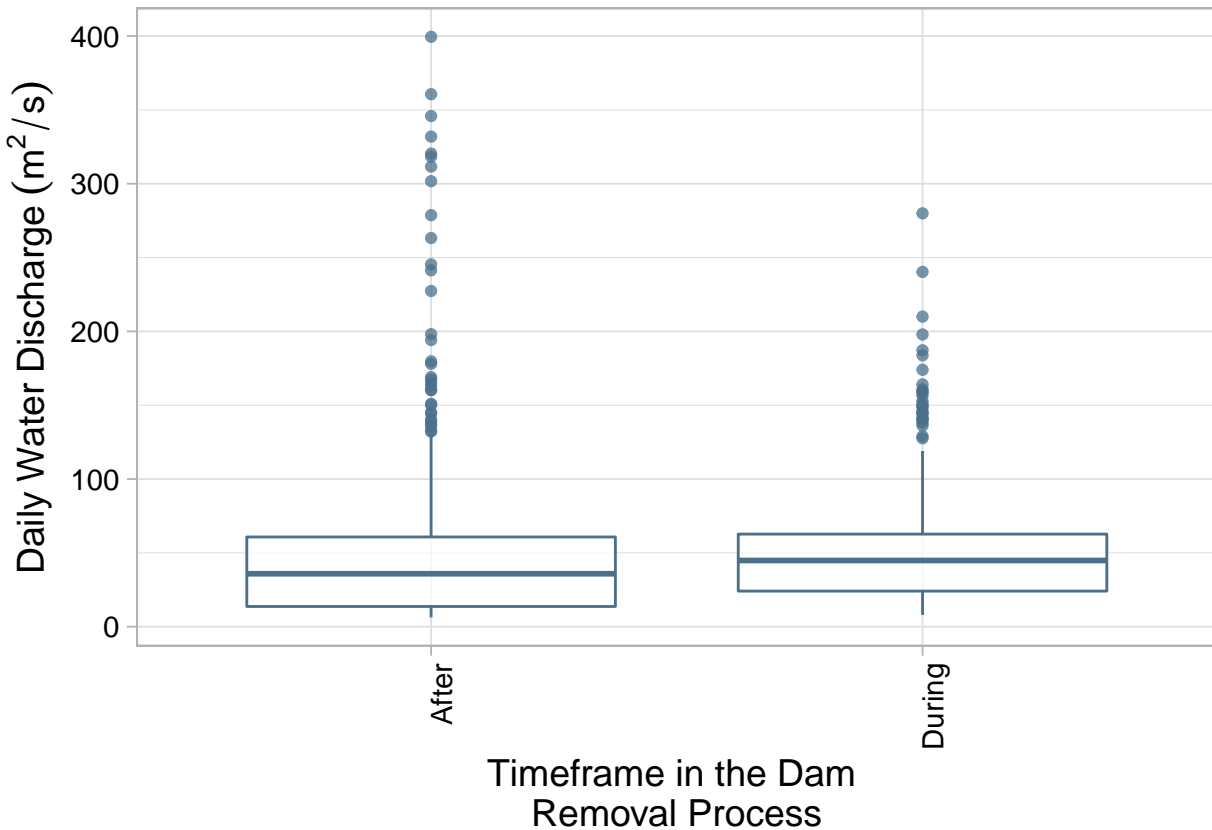


Figure 10: Daily water discharge distribution during and after the Elwha River two dam removal process. During the dam removal is classified by dates from September 15, 2011 to August 26, 2014, and after is from then until September 30, 2016.

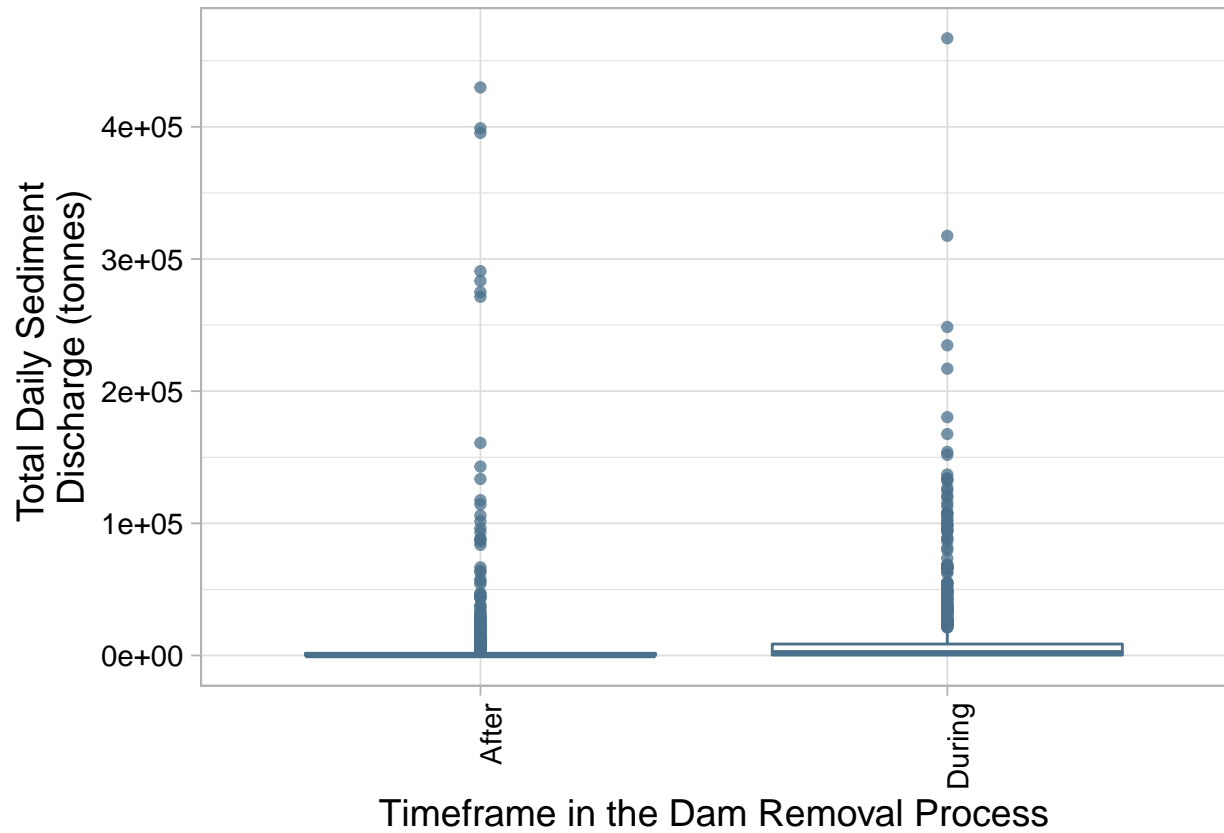


Figure 11: Daily total sediment discharge distribution during and after the Elwha River two dam removal process. During the dam removal is classified by dates from September 15, 2011 to August 26, 2014, and after is from then until September 30, 2016.

4.2 Question 2: Can we predict sediment discharge from water flow on the Elwha River?

Increased water flow on a river should carry more sediment, producing more overall sediment discharge. An analysis of water discharge and sediment discharge is performed over the entirety of the sampling period to find a general trend of the relationship of these two parameters over time on the Elwha.

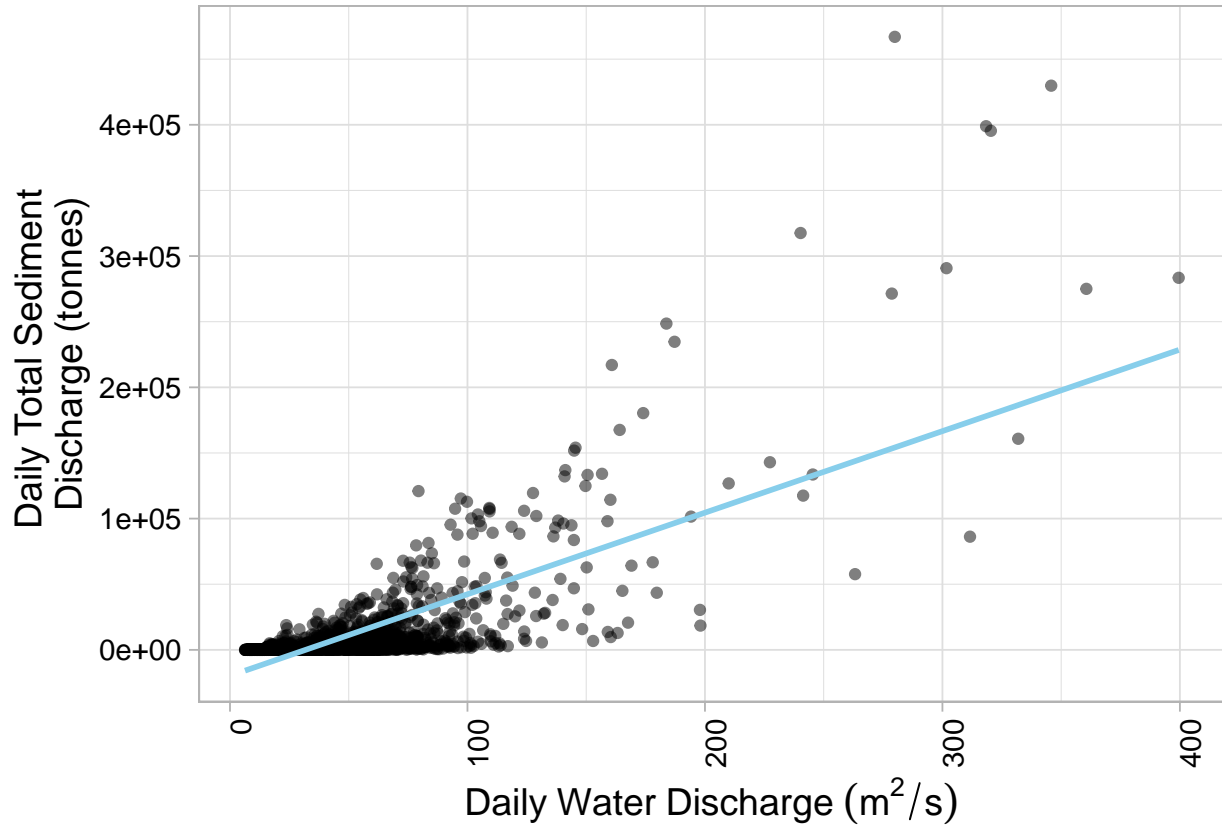


Figure 12: Daily water discharge as an indicator for daily total sediment discharge on the Elwha River, with a linear regression.

A linear regression model determines a line of best fit between two continuous variables, in this case, daily water discharge and total sediment discharge. There is a strong, significant positive correlation between water and sediment discharge during the entirety of the sampling period ($\text{cor} = 0.73$, $\text{p-value} < 0.0001$, pearson's correlation test). Therefore, water discharge is an effective predictor for sediment discharge (*Figure 12*, $\text{p-value} < 0.0001$, $R^2 = 0.54$, linear regression). Each square meter per second of water discharge accounted for 0.0008 tonnes of sediment discharge.

4.3 Question 3: Does daily water discharge predict total sediment discharge during and after the two part dam removal process?

Data recorded during the dam removal process, and data recorded after were separated. Separate linear regressions were run on each to determine if water discharge is an effective predictor of sediment discharge, and to what extent.

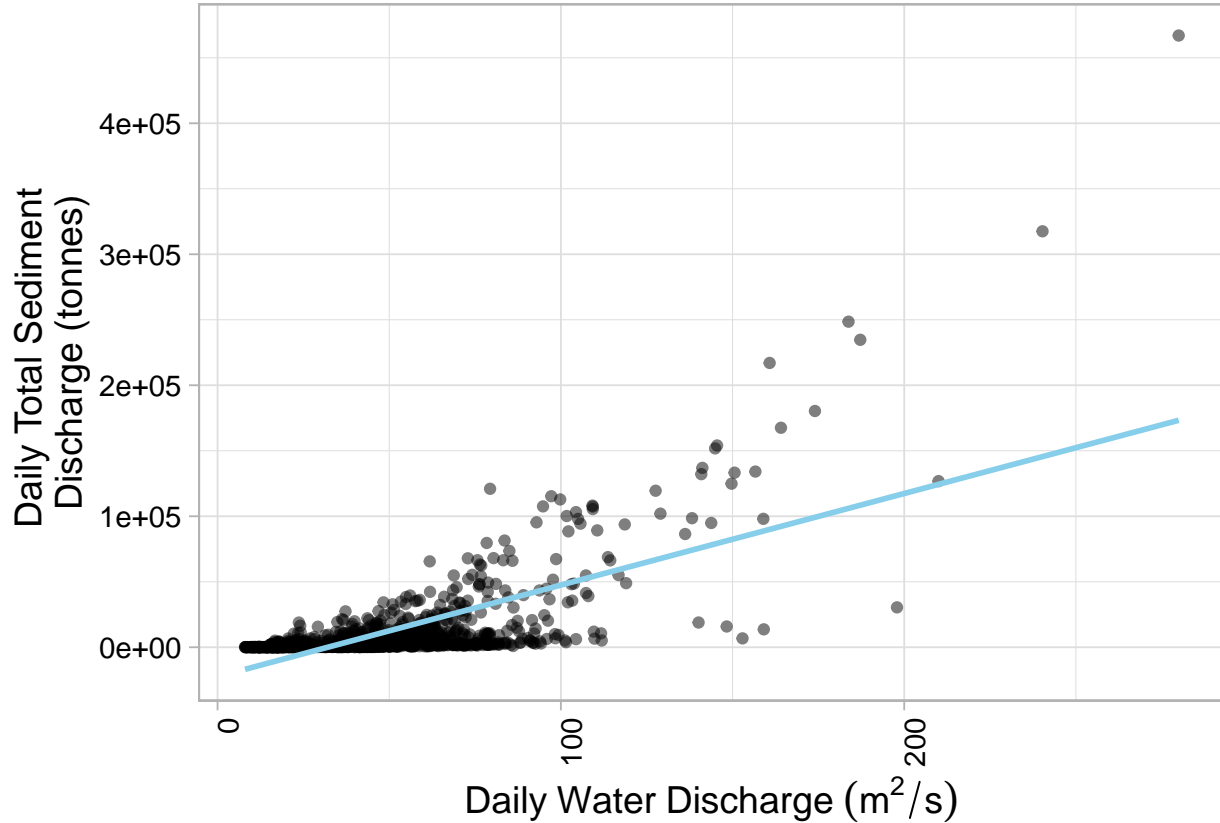


Figure 13: Daily water discharge as an indicator for daily total sediment discharge on the Elwha River during the two part dam removal process, with a linear regression.

There is a strong, significant positive correlation between water and sediment discharge during the dam removal process ($\text{cor} = 0.70$, $\text{p-value} < 0.0001$, pearson's correlation test). During dam removal, water discharge is an effective predictor for sediment discharge (*Figure 13*, $\text{p-value} < 0.0001$, $R^2 = 0.50$, linear regression). Each square meter per second of water discharge accounted for 0.0007 tonnes of sediment discharge.

After the completion of dam removal, there is still a strong, significant positive correlation between water and discharge ($\text{cor} = 0.77$, $\text{p-value} < 0.0001$, pearson's correlation test). Water discharge serves as an effective predictor for sediment discharge (*Figure 14*, $\text{p-value} < 0.0001$, $R^2 = 0.59$, linear regression). Each square meter per second of water discharge accounted for 0.0017 tonnes of sediment discharge.

There is a stronger correlation after dam removal completion, making water discharge a

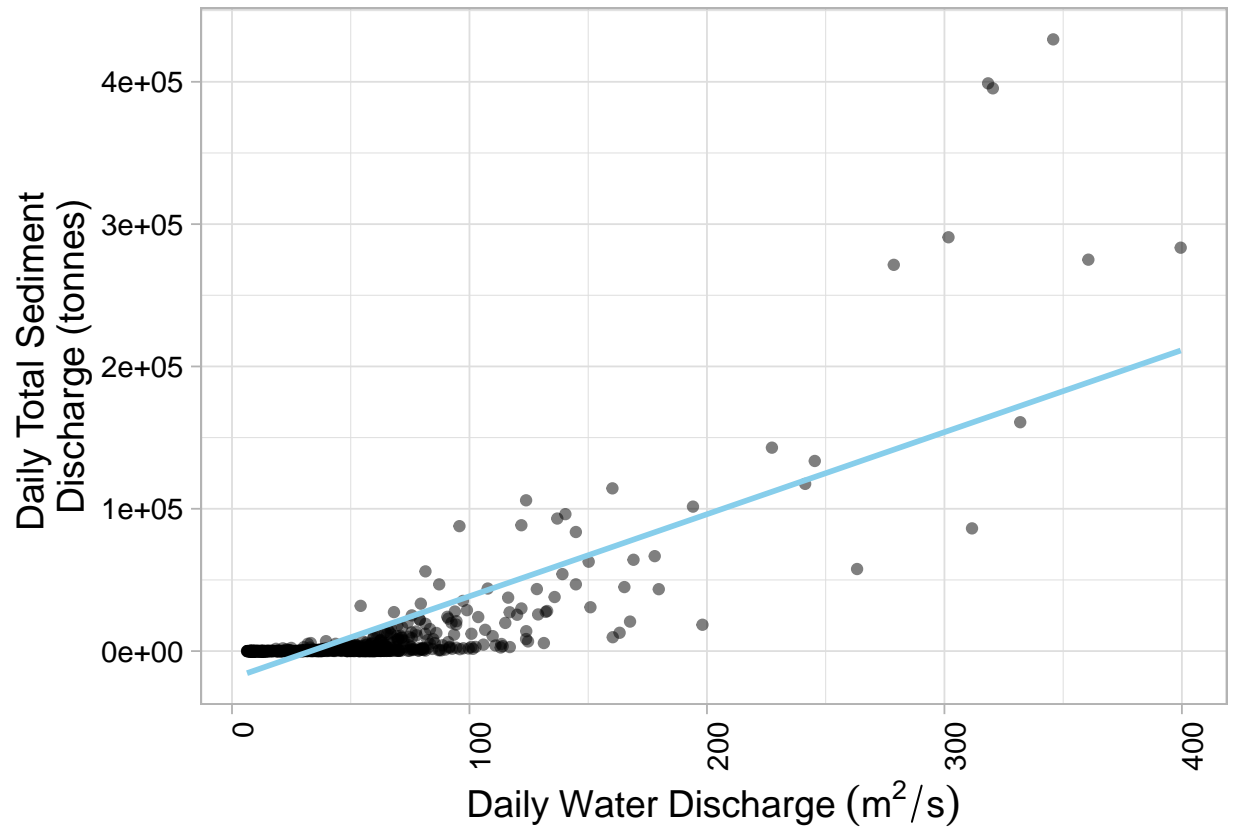


Figure 14: Daily water discharge as an indicator for daily total sediment discharge on the Elwha River after completion of the two part dam removal process, with a linear regression.

better predictor of sediment discharge after dam removal compared to during the process. The model explains accounts for a larger percentage of variance by the explanatory variable of water discharge.

5 Summary and Conclusions

Summarize your major findings from your analyses in a few paragraphs. What conclusions do you draw from your findings? Relate your findings back to the original research questions and rationale.

6 References

Ritchie, A.C., Curran, C.A., Magirl, C.S., Bountry, J.A., Hildale, R.C., Randle, T.J., and Duda, J.J., 2018, Data in support of 5-year sediment budget and morphodynamic analysis of Elwha River following dam removals: U.S. Geological Survey data release, <https://doi.org/10.5066/F7PG1QWC>.

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