A LiDAR Analysis of Changes in the Stream Morphology of the Oregon Sandy River from 2008 to 2011

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Table of Contents

Summary of Scope

This project aims to examine the impacts resulting from the removal of the Marmot Dam, which was once located in the upper regions of the Oregon Sandy River. Having stood for over a century, the Marmot Dam was removed in 2007 by the Army Corp of Engineers and the Bonneville Power Administration. The dam was removed to give the Sandy River the ability to flow freely and allow easier upstream accessibility for fish that travel from the ocean to freshwater streams. The removal of the dam changed the stream drastically. Sediment that was once confined behind the dam was washed downstream, while the upstream channel naturally reclaimed the territory that was once submerged by the trapped reservoir.

This project will use aerially collected elevation LiDAR data that will visualize the extent of the changes in the stream morphology in the Sandy River. This analysis will compare the differences in elevation from a dataset collected in 2008 to a dataset collected in 2011. The outcome of this project will illustrate the alterations in the channel configuration four years after the removal of the Marmot Dam. For a brief visualization of the changes this study is analyzing, see Figure 1.

Figure 1: This image provides a representative illustration of the changes in the riverbed structure of the Sandy River that will be analyzed in this study. On the left, before the removal of Marmot Dam, the water was shallow, even, and had a "simpler" appearance. On the right, we can observe that after the dam was removed, the river underwent significant changes, resulting in a more complex topography with different flow dynamics.

Project Area

The study area for this project is located in the upper region of the Sandy River. The specific location can be found just north of Mt Hood Hwy (U.S. Hwy 26) and roughly five miles east of Sandy, Oregon. Refer to Figure 2 for a map of the project area in reference to Hwy 26 and the city of Sandy. This figure also has a rectangle that estimates the outline of the project area. See Figure 3 for a closer look at the terrain of the project area.

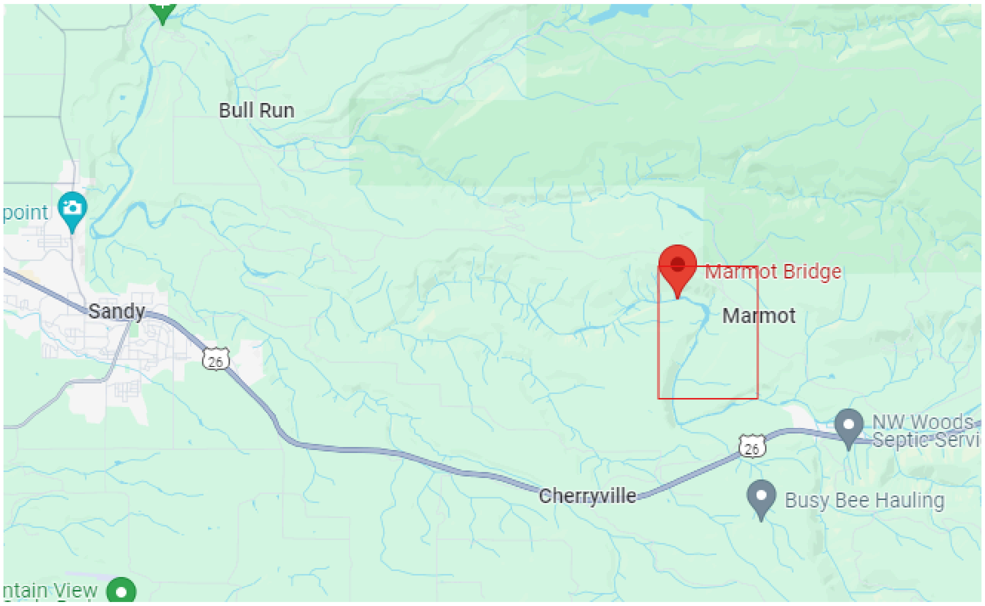

Figure 2: An image of the project area captured by Google Maps. The project area is outlined in a red rectangle with a pin on the Marmot Bridge. The Marmot Dam was once located underneath the Marmot Bridge. The Sandy River can be seen stretching from the northwest corner of the rectangle in a curve to the southwest corner. The project area is located above Mt Hood Hwy and is approximately five miles east of Sandy, Oregon.

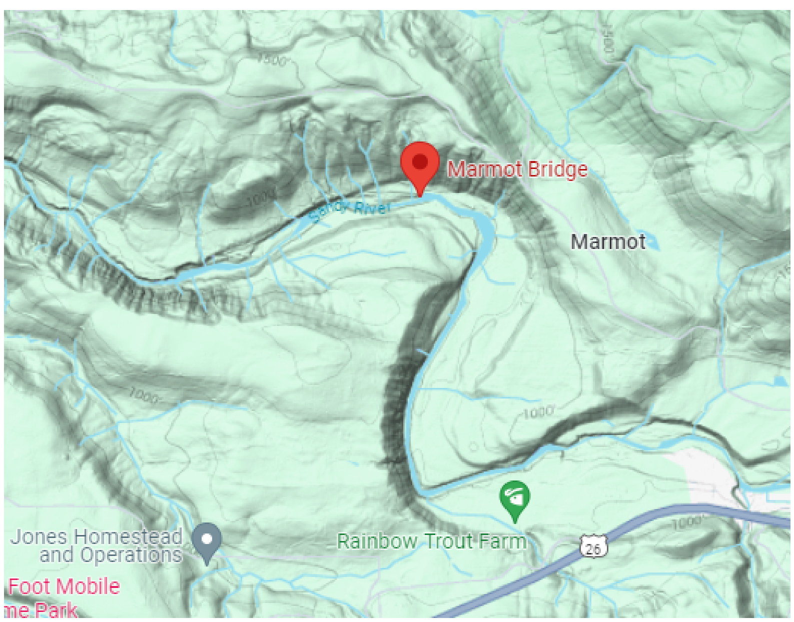

Figure 3: A closeup image of the project area captured by Google Maps. This image focuses on the terrain of the Sandy River project area. A key characteristic of the zone is that the river is located in a mountainous area. The specific segment of the Sandy River under analysis in this project lies within a valley.

Research Questions

The research question for this study is "What modifications have occurred between 2008 and 2011 in the Sandy River due to the removal of the Marmot Dam four years prior?". This question will be answered with respect to elevation changes. By analyzing the elevation changes in the riverbed between 2008 and 2011, we can see how the dam removal may have caused changes in the stream morphology. The answer to this inquiry will provide useful information about the changed morphology of the Sandy River. The alterations resulting from enabling unrestricted river flow offer potential ecological advantages, including improved habits for aquatic species, natural erosion of sediment, and enhanced accessibility to spawning grounds for anadromous fish.

Methods

As previously mentioned, two LiDAR datasets were used to compare elevation differences between 2008 and 2011. Both LiDAR datasets were collected aerially by plane. The 2008 LiDAR data area of interest contained approximately 34,021 acres. However, the total area flown encompasses around 35,873 acres. The total area flown is greater than the area of interest to account for flight planning optimization and buffering. LiDAR intensity values were collected, which proved to be extremely important in the elevation analysis that will be discussed later. The 2008 LiDAR data was originally collected using UTM Zone 10 NAD83 (CORS96) projection and NAVD88 (Geoid03) vertical datum. This projection was later converted to reference NAVD88 and GEOID18 in meters. The flight lines for the mission allowed for at least 50% sidelap, there were no gaps between flight lines, and there are consistent elevation values. The final dataset was then compressed to a LAZ format file containing LiDAR point cloud data. A limitation of this dataset is that the elevation values for open water surfaces must be open to variation due to difficulty in returning LiDAR points from water surfaces. This is important to consider since our research question is analyzing the morphological changes of a river.

The 2011 data was collected in a survey that stretched from August 30th to September 3rd, 2011. This examination was conducted using a Leica ALS60 laser system mounted to a Cessna Caravan 208B. Low nadir scan angles were employed to enhance the penetration of vegetation to ground surfaces. Ground-level GPS and aircraft IMU data were gathered during flight. The horizontal resolution was 0.35m and the vertical position accuracy is 0.04m with 193 GCPs. Each flight line during the mission had at least 50% sidelap in the LiDAR data collected with no gaps and consistent elevation values between overlapping flightlines. The data was collected in a NAD83 projection and EPSG:4152 as the Coordinate Reference System. This survey had a much larger area of interest, however only a small portion was used in this project. See Figure 4 for a map of the study area in the 2011 survey.

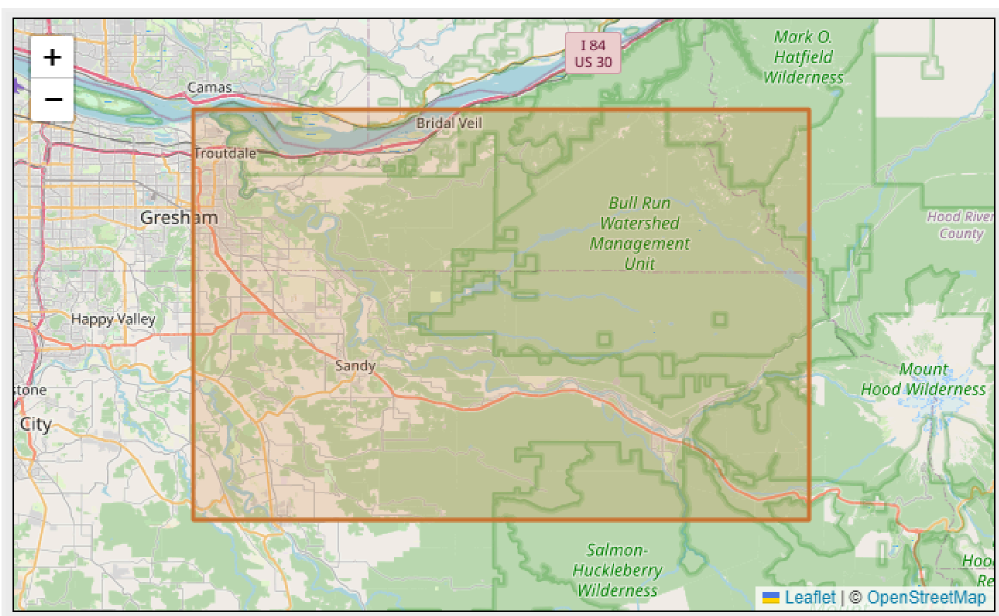

Figure 4: A closeup image of the extent of the 2011 flight mission dataset. This project area stretches from the east side of Gresham to the east edges of the Bull Run Watershed Management Unit. The flight mission extent is much larger than the data used in this project.

The 2008 and 2011 datasets previously described were then processed in CloudCompare. The two datasets were first set to “Export Coordinate(s) to SF” as Z coordinates. The scalar field was set to “Intensity”. Since the two datasets were in different projections and Coordinate Reference Systems, they were aligned using the “Align Two Cloud Points by Picking” tool. The error for this process reached a maximum of 0.9% error. In the SF Display Parameters, the color ramp was adjusted to show an elevation increase or decrease of roughly 5 meters. The final product was then sliced to show the elevation decrease in the area that changed the most in the Sandy River. After testing different slice widths, it was found that a 10m width was the best representation of the elevation. Excessive slice width would have complicated the determination of the length of the section with elevation change if its width had been increased. Both the sectioned slice and the whole image were exported as products of this project.

Results

The results of this project include a map of the project area showing the elevation change between 2008 and 2011. This project also consists of a closer view of a slice taken from the part of the Sandy River with the most change. See Figure 5 for a view of the full map with a scale bar. Figure 6 has a closer visualization of the map and Figure 7 has the imagery from the sliced section of the Sandy River.

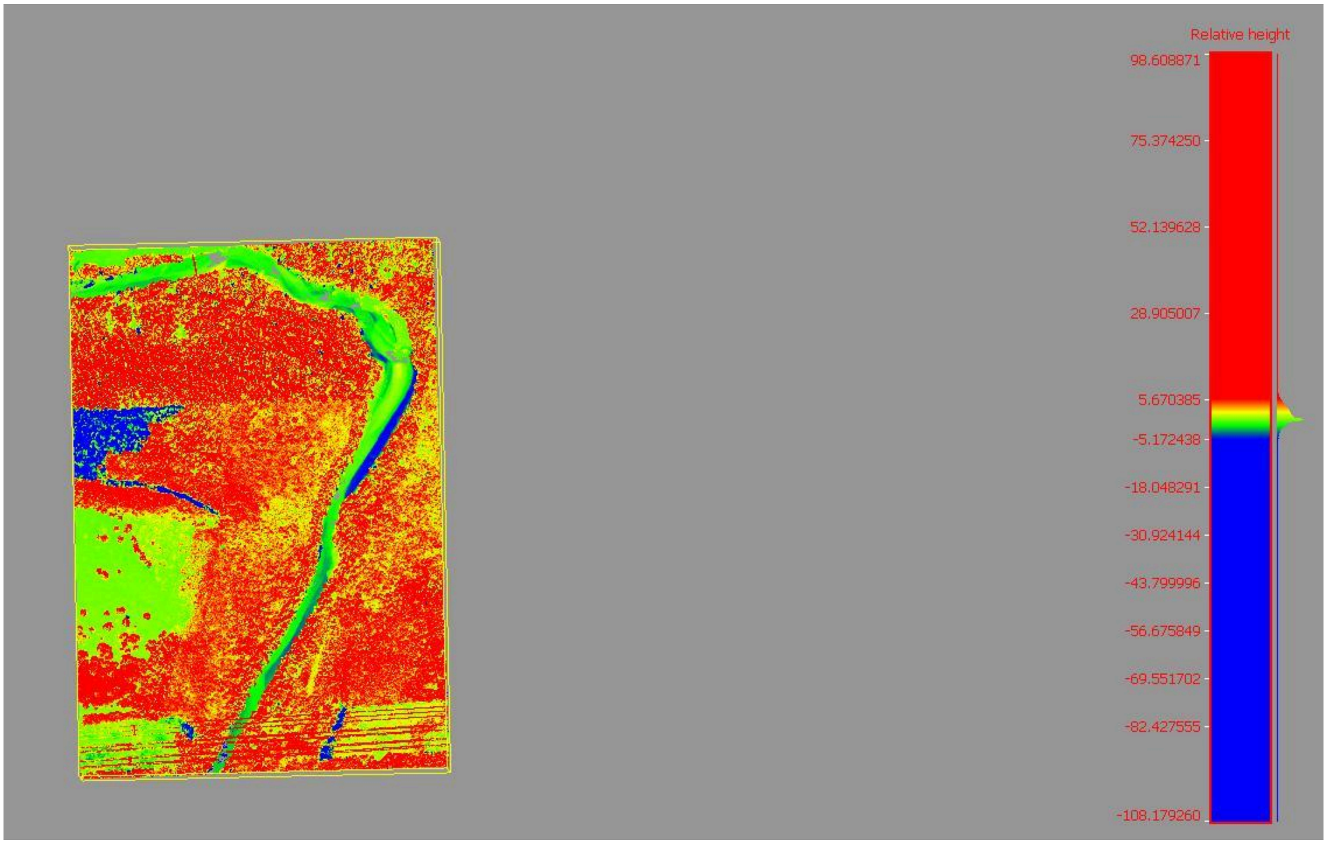

Figure 5: Imagery showing the change in elevation between 2008 and 2011 of the project area. Areas of the color red show an increase in elevation over the three-year interval of at least 5.67 meters. Areas in blue show a decrease in elevation of at least 5.17 meters. Yellow areas slightly increased in elevation while green areas slightly decreased. Notice in the image that the Sandy River has slightly decreased in elevation overall with a large decrease along the east shore. A section of trees has also significantly decreased in elevation on the west side of the image.

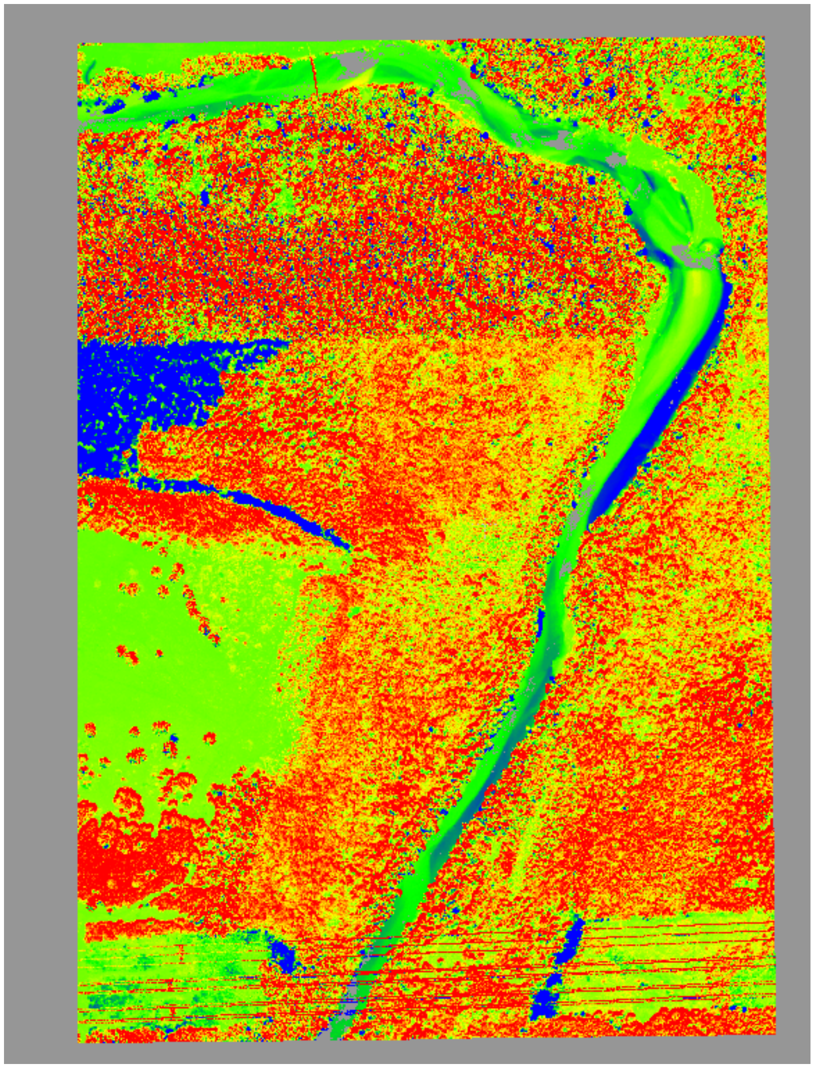

Figure 6: This imagery shows a closeup version of the same map from Figure 5 for closer visual analysis.

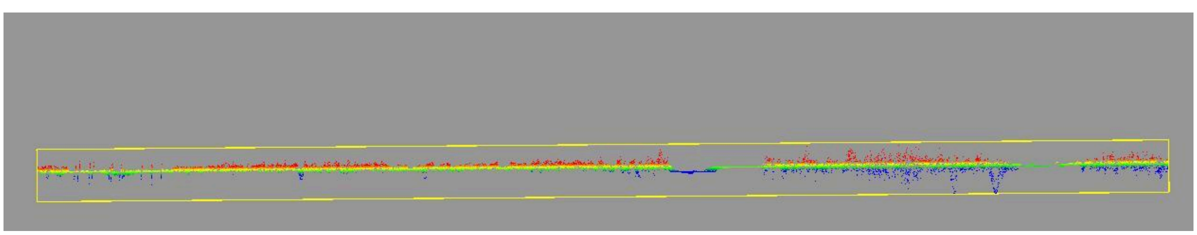

Figure 7: Imagery from a sliced section of the full map. This slice was taken along the east side of the Sandy River where there is the most elevation change (shown in blue). The section runs from North to South, with the North side located on the right of the image in this figure and the South side located on the left. The removal of the scale bar enabled a closer examination of the slice. The scale bar used in Figure 5 remains the same in this image.

Analysis

The results of this project effectively examined the fluxations in the elevation of the project area between 2008 and 2011. When analyzing the elevation change map, we can see obvious elevation changes that we would expect to happen over time, such as tree growth or clearings made. The red throughout the whole forest displays natural tree growth that had occurred over the three-year period. As expected, we can see that clearings have generally remained with a consistent elevation by their green color. We can also see that a few new clearings have been made and are displayed in blue. The largest of these new clearings would be the large blue area on the west side of the site where trees were likely cut or harvested. Two other areas on the south edge of the zone display a significant decrease in elevation as well. These are a few details discovered in this research project in the area surrounding the Sandy River.

Regarding the research question "What modifications have occurred between 2008 and 2011 in the Sandy River due to the removal of the Marmot Dam four years prior?", we can see that there are a few significant changes to notice. The main conclusion is that there are stretches along the Sandy River that have significantly decreased in elevation by at least 5.17 meters. The largest of this stretch is located on the eastern side of the river where there seems to be an abruptly sectioned elevation decline. Downstream of this area along the shore, we can see that elevation decline "flows" down the river. This elevation decline is likely due to an increase in channel erosion that will often occur downstream as a stream adjusts to an increased sediment load upstream. This increase in channel erosion would be why there are significant marks of elevation decline downstream in the Sandy River. From these results, we can conclude that after the Marmot Dam removal, the large increase in released sediment that was once trapped behind the dam considerably changed the river morphology upstream. This change upstream led to a substantial increase in channel erosion downstream.

Conclusion

This research project has proved to be insightful in revealing the impacts on stream morphology of the Marmot Dam removal on the Sandy River between 2008 and 2011. By looking at the results of this investigation into stream morphology four years after the dam removal, significant channel erosion downstream is revealed likely due to the suddenly unleashed sediment. While the Marmot Dam was ecologically beneficial in creating healthier fish habitats, an increase in channel erosion can make a stream unstable. This project demonstrates the importance of recognizing the potential cascading effects of environmental interventions. It is evident that the use of LiDAR data is exceptionally beneficial in examining geomorphic changes in riverbeds. Further research is needed to examine the long-term effects of the Marmot Dam removal on channel erosion and the stability of the Sandy River.