Sediment Transport in the North Fork Stillaguamish River

Report Prepared for

Seattle University
Center for Environmental Justice and Sustainability

Laboratory Report Prepared By
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Introduction

Our work on this project can be divided into several segments: Grainsize distributions, flow duration curves, modeling, and presentation of results. The data collection portion took place from September, 2015 to January, 2016. Our data analysis phase took place once we had finished data collection. From January to April we looked for trends in our grainsize distributions. During that time, we also created flow duration curves to investigate the impacts of climate change on the river's flow regime. Following our analysis, we performed hydraulic modelling in the program HEC-RAS. In May, we presented our research at Darrington High School in Darrington, Washington.

Grain Size Distributions

In October of 2015 Steven and I, with the help of Dr. Lauer, performed five pebble counts at five different reaches (Figure 1 through Figure show the grain size distributions). Pebble counts are performed by walking to the head of a riffle, and randomly selecting rocks several feet apart over 100-foot horizontal stretches until a minimum of 100 data points have been gathered. The grain size is determined through a gravelometer, which classes grain size based on the smallest hole a sample can fit through. The location of each site along the North Fork Stillaguamish is shown in Figure 6. Our ability to collect samples was limited by the accessibility of river riffles. Many riffles were impossible to actually get to without either trespassing on private property or wading across the river, the latter of which was frequently too dangerous to attempt due to high flows. Once it started raining we had to wait until

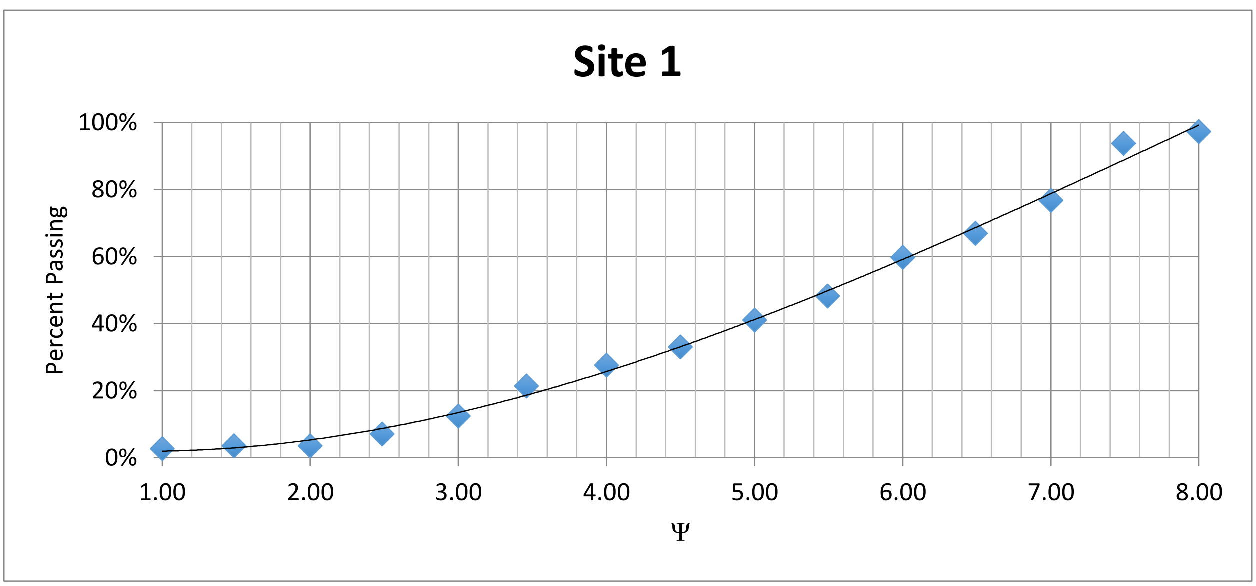

Figure 1, Grain size distribution at Site 1. Located upstream of the Oso Landslide at river mile 26.2.

January for winter low flows to collect additional data.

In developing the grainsize distributions, we used the Wentworth system of determining grainsize, thus the grainsize is represented as $\Psi = log_2(D)$ where D is the grain diameter in millimeters. As we move downstream (moving from site 1 to 5) the curves began to shift left, indicating that the larger rocks are being deposited while the finer sediments are still suspended in the river. This trend continues until Site 5, where the grainsize distribution suddenly shifts back to the right, indicating an influx of large sediments. Site 5 is located directly downstream of the Deer Creek confluence into the North Fork Stillaguamish, and the sudden influx of large sediments is consistent with a typical river confluence.

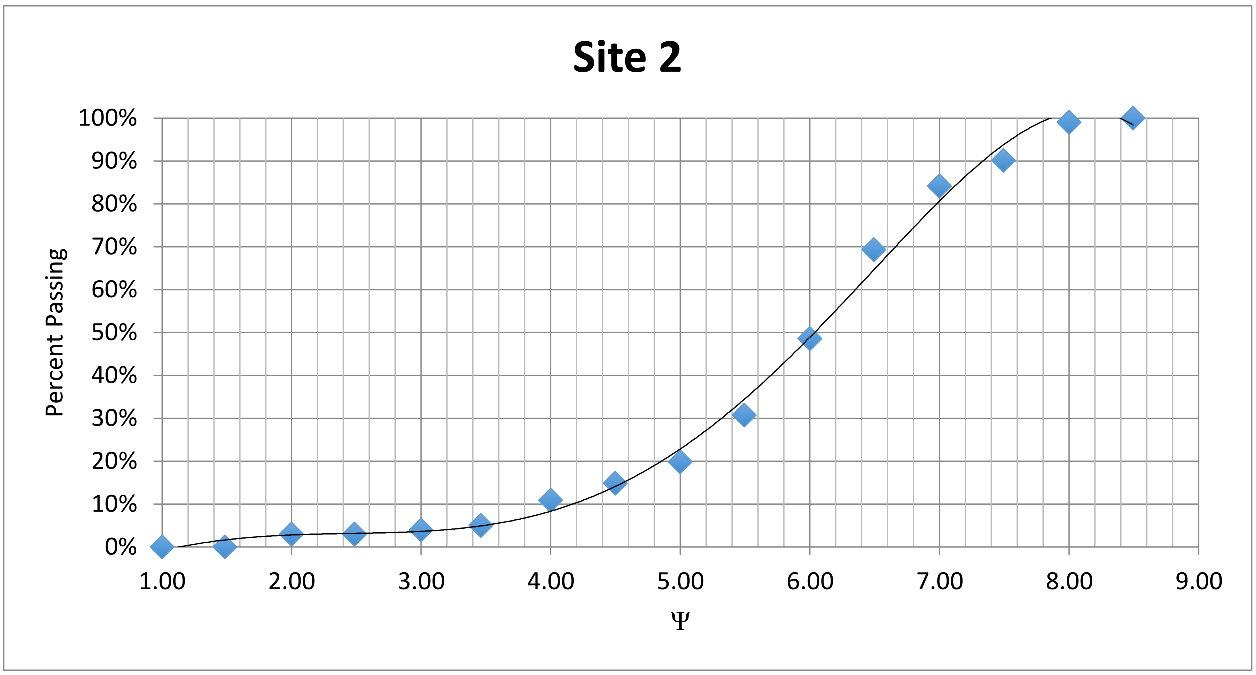

Figure 2, Grain size distribution at site 2. Located upstream of the Oso Landslide at river mile 25.8.

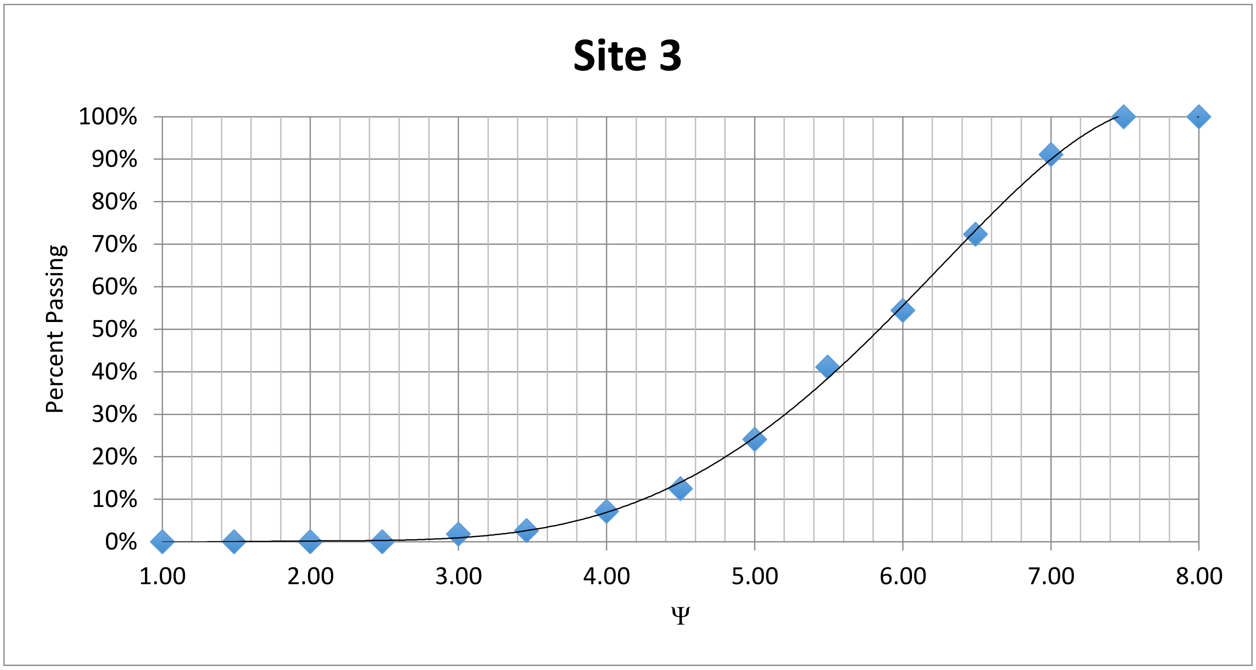

Figure 3, Grain size distribution at site 3. Located Downstream of the Oso Landslide at river mile 22.3.

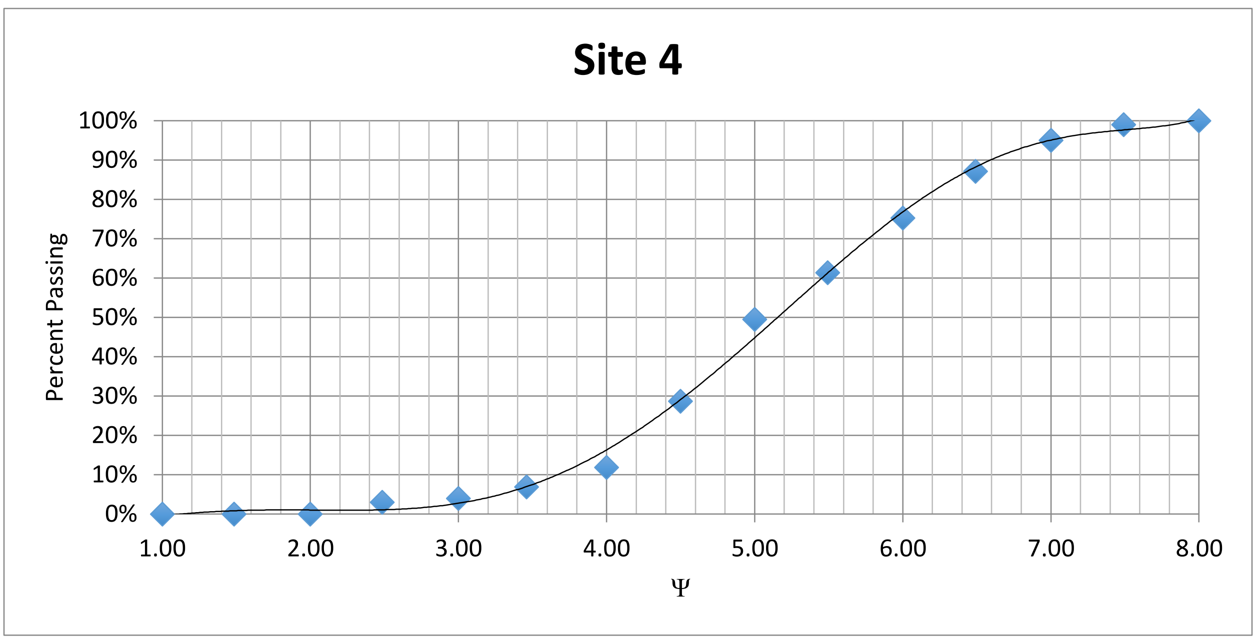

Figure 4, Grain size distribution at site 4. Located downstream of the Oso Landslide and upstream of Deer Creek at river mile 18.

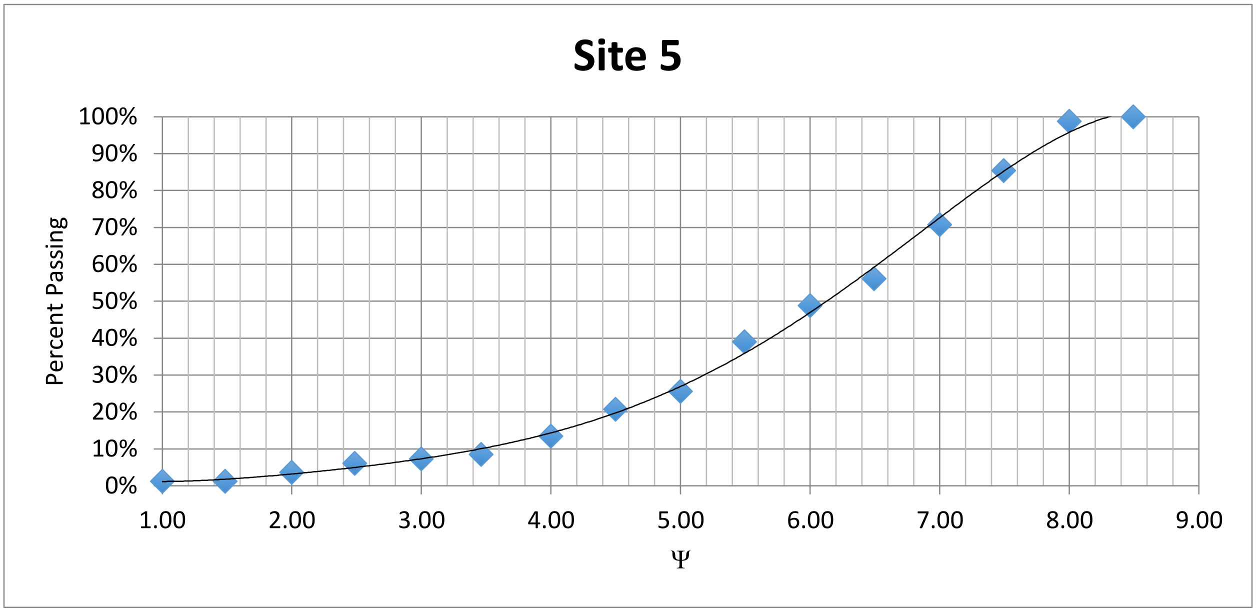

Figure 5, Grain size distribution at site 5. Located downstream of Deer Creek at river mile 14.5.

Figure 6, Location of each grain sample site.

Data Analysis

In addition to these grain size distributions, we also developed flow duration curves for the annual peak flow of each decade between 1928 and 2016 (Figure). It is important to note the trend that with each decade the peak flows in the river significantly increase; the smallest flood in between 2008 and 2016 is approximately 10,000 cubic feet per second (cfs) smaller than the largest flood between 1928 and 1938. This points to one of the hallmarks of climate change: places that experience high amounts of precipitation will experience more frequent and more intense rain events.

Merely looking at trends in a graph isn't a concrete way of measuring the impacts of climate change on a riverine system. However, we can measure the cumulative departure from the annual mean peak flow. The annual mean peak flow between 1928 and 2016 is 24,900 cfs, so anything below that is represented in Figure by a negative number, and anything above that is represented by a positive number. The first time we see a cumulative departure that is greater than the average flow is in 1972, and since then each decade has featured flows that are higher and higher above the annual average flow. Each decade is clearly distinct from the others and exhibits greater flow rates and deviations from the mean, which signifies that the increase in flows is a product of more than annual variability. We see that the 10 year flood from the 1928 to 1938 period closely resembles the 1.5 year flood from the 2008 to 2016 period, meaning that the frequency of large flood flows has increased dramatically.

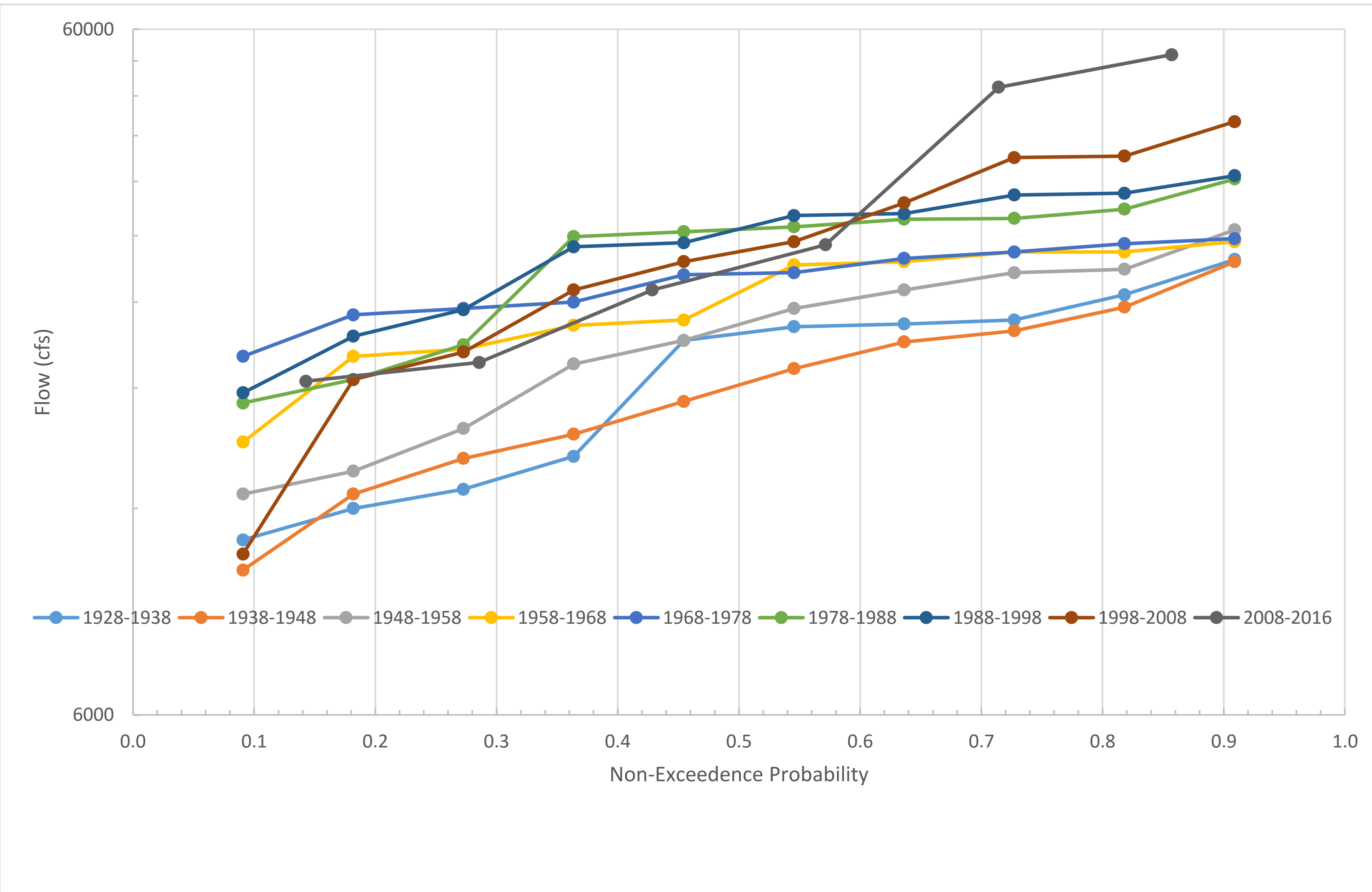

Figure 7, Flow duration curves for each decade from 1928 to 2016. The flows shown are the annual peak flow of each year.

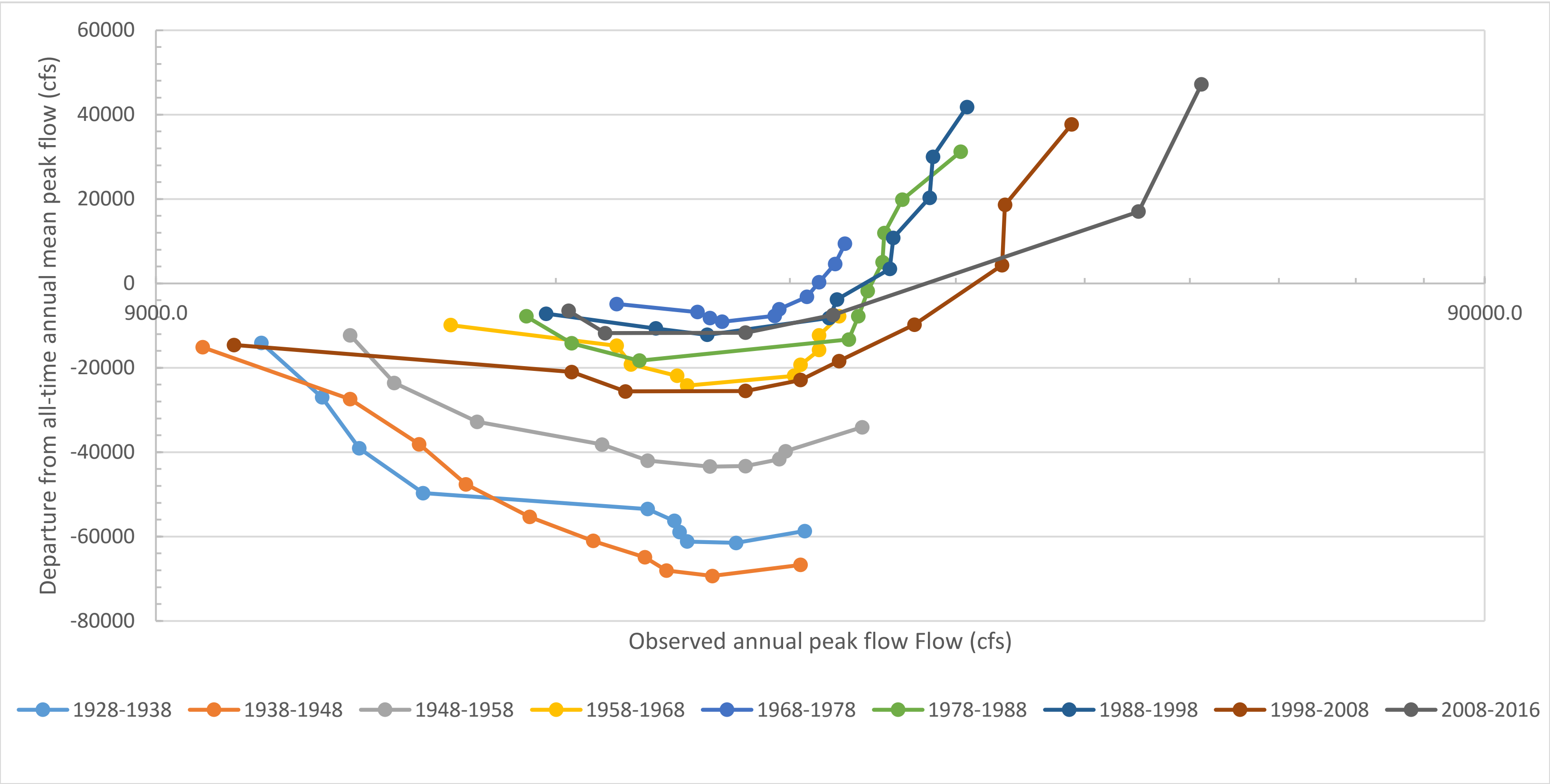

Figure 8, Cumulative departure from annual mean peak flow

Modeling

We received a Hydraulic Engineering Center River Analysis System (HEC-RAS) model from the United States Geologic Survey (USGS), which included surveyed channel cross-section every 500 meters and LiDAR floodplain data. From this topography data, we ran a HEC-RAS model to simulate the 1.5 year, 10 year, and 100 year floods in the river using the flow duration curve of monthly average flows for the entire period of flow data (Figure). The upstream boundary condition was set to the normal depth and the downstream boundary condition set to the water surface elevation (WSE) observed at the Arlington flow gage (3.44 feet, 4.91 feet, and 5.91 feet, with each WSE corresponding to the 1.5 year, 10 year, and 100 year flow, respectively). As mentioned earlier, the model was provided to us by USGS and had complete floodplain and in channel cross sections for the majority of the North Fork Stillaguamish River. Since the flow duration curve we used was developed for the flow gage at the Oso Landslide, the model will be most accurate in that reach of the river. Thus Figure through Figure focus on the Oso Landslide region.

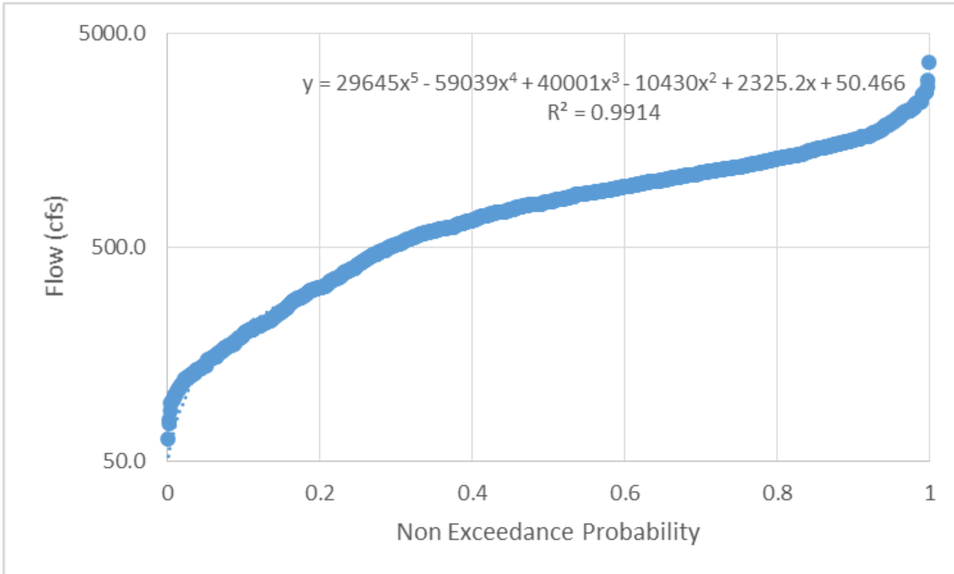

Figure 9, Flow duration curve for monthly average flows from 1928 to 2016 at the Oso Landslide flow gage

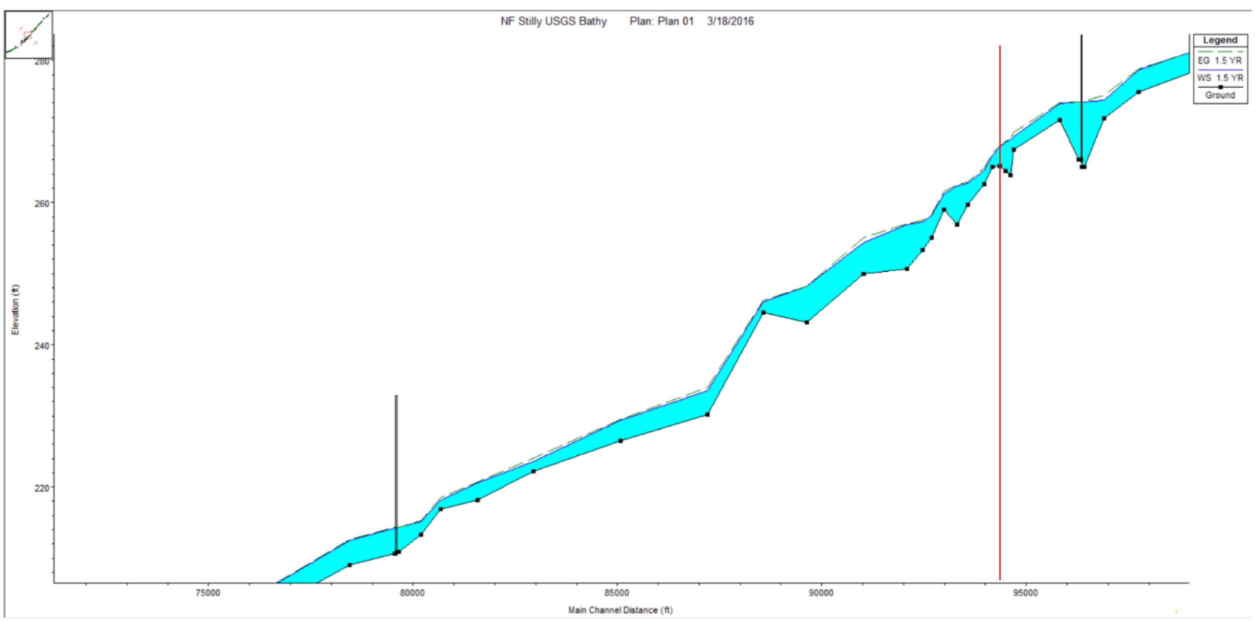

Figure 10, HEC-RAS output for 1.5 year flow near Oso landslide site.

Oso Landslide

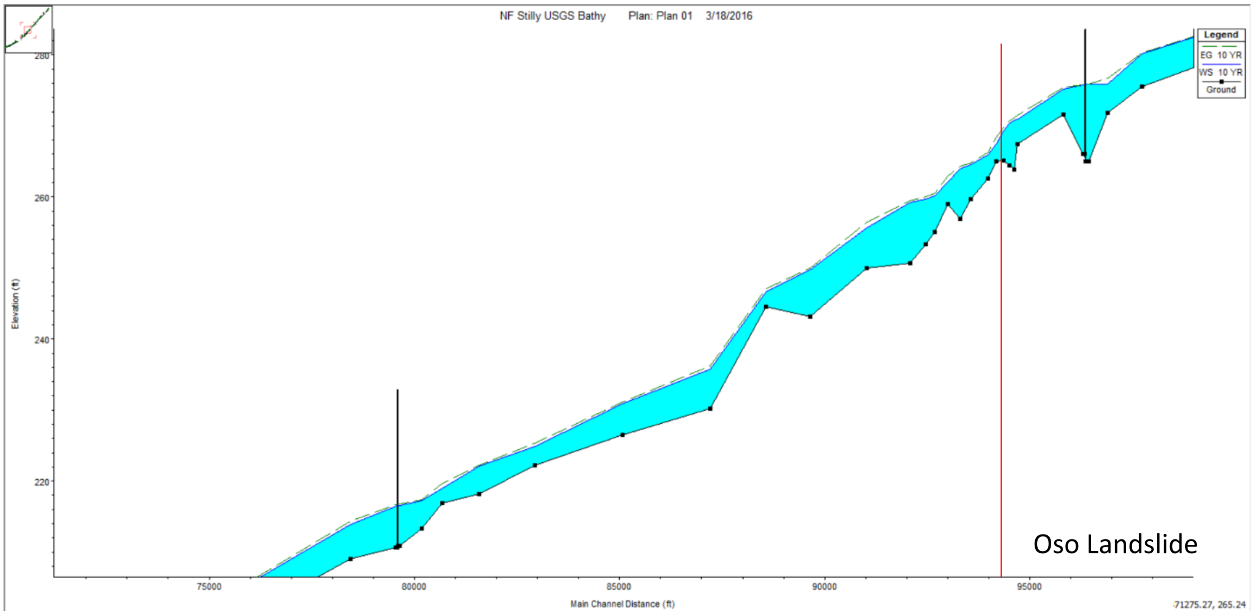

Figure 11, HEC-RAS output for 10 year flow near Oso landslide site.

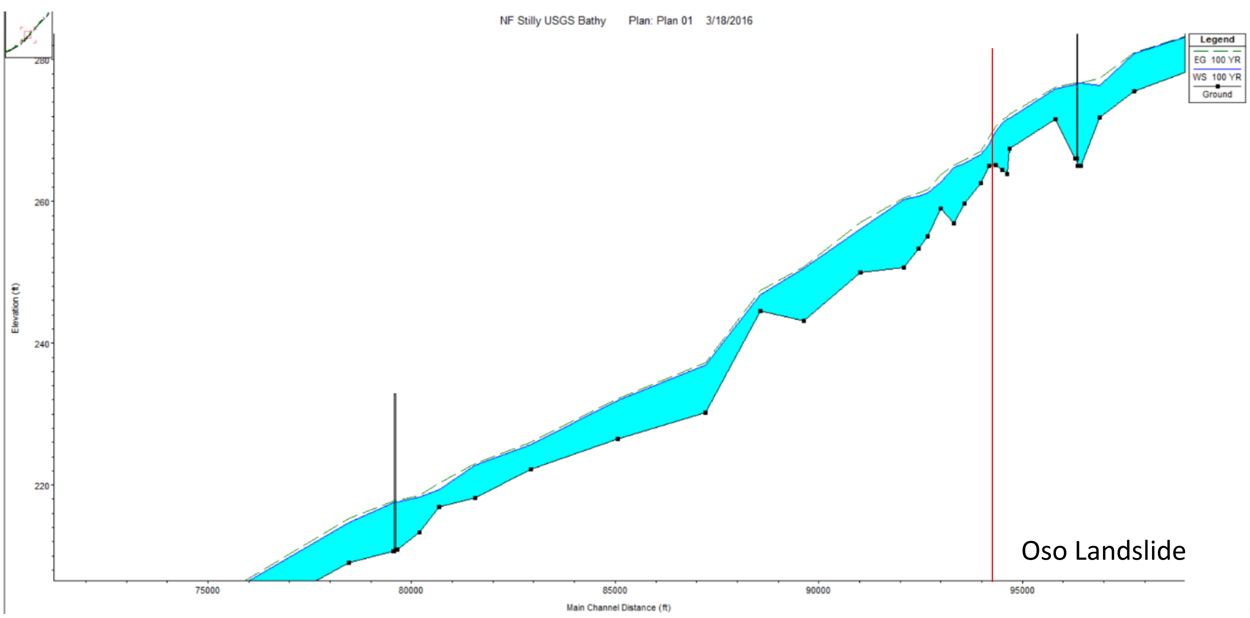

Figure 12, HEC-RAS output for 100 year flow near Oso landslide site.

Presentation of Results

Following our modeling, we presented our results at Darrington High School in Darrington, Washington. Our presentation focused on our research, but also had a strong emphasis on the fact that most of what we did, the high school students could do. We looked at the applications of geometry in the river bed and statistics with the grainsize distributions and flow durations curves, and we talked about how computer simulations make unrealistic assumptions and how one can address the error caused by those assumptions. We also discussed how the changing flow regime is consistent with some of the predictions of climate change science, namely that places that experience high precipitation will trend towards more frequent and severe storms. At the end of it, the kids had a few questions dealing with everything from climate change to student life at college.

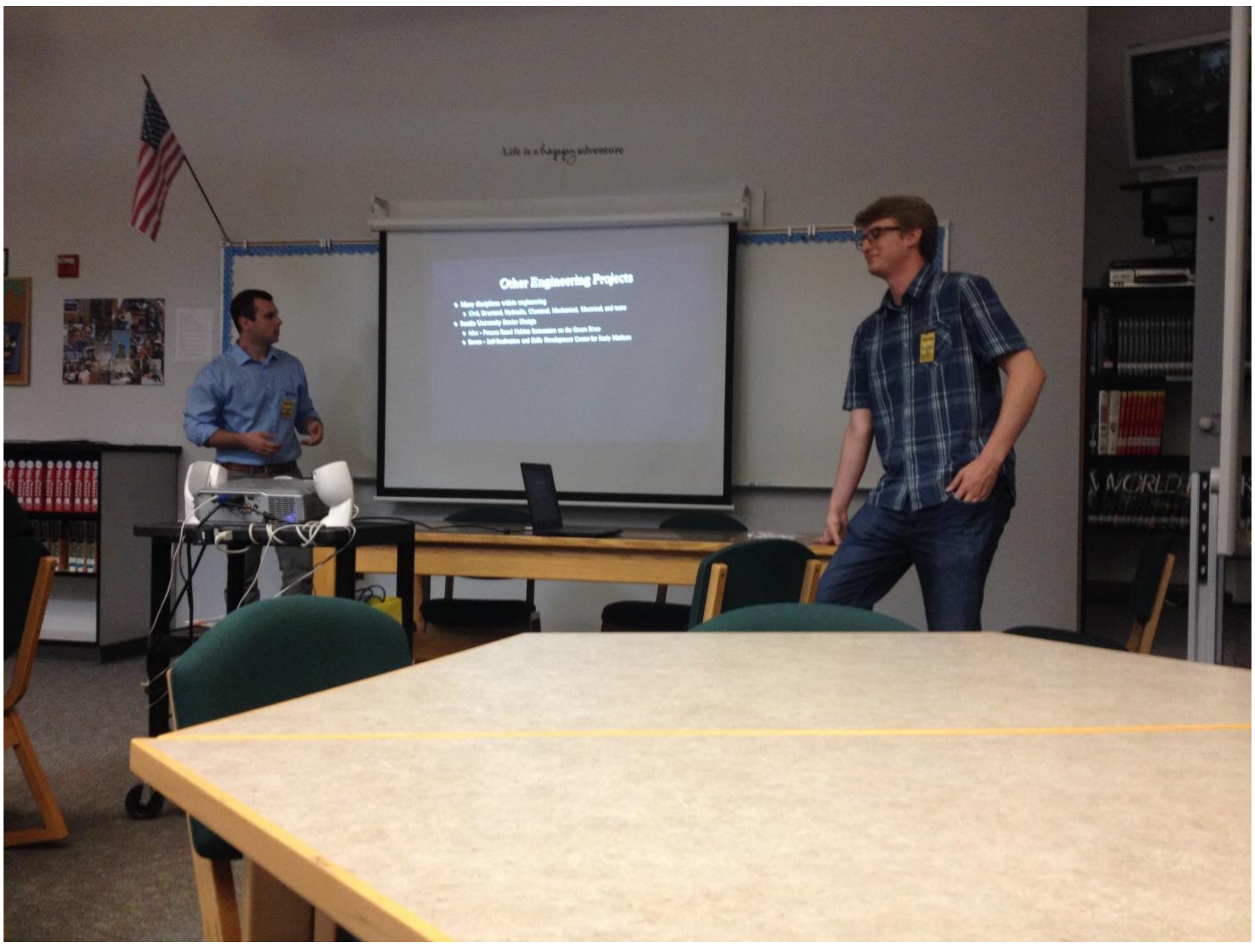

Figure 13, Alex (left) and Steven (right) in Darrington High School.