Geomorphic assessment of changes in the Nisqually River, 2013-2015
Mount Rainier National Park, Washington, USA

ANDRY, Christina M.

Mount Rainier National Park, 55210 238th Ave E, Ashford, WA, 98304, christina_andry@partner.nps.gov

I. Abstract

Natural hazards associated with Mount Rainier extend beyond the potential for volcanic activity to include more imminent threats such as rockfalls, debris flows, glacial outburst floods, and seasonal flooding of the glacially-sourced braided rivers. Such events can occur nearly instantaneously but regular monitoring of the mountain's glaciers, climate, and river systems can facilitate hazard forecasting and early warning efforts. Several rivers are situated in close proximity to park infrastructure as well as within frequented hiking areas and have been chosen for studies such as discharge monitoring, cross-sectional surveys, and implementation of diversion or reinforcement structures.

Cross-sectional surveys of the Nisqually River were conducted in this study in order to identify locations of channel avulsion and rates of aggradation and incision since the last construction of cross sections in 2013. Areas surveyed are significant based on river size, proximity to park infrastructure, and historical mass wasting events.

The 2014-2015 winter snowpack within the park was at a record low, increasing hazard risk with more exposed unconsolidated sediment on steep slopes. All debris flows since 2006 have initiated in areas that have been recently deglaciated. Recent climate trends and continued rapid glacial retreat also contribute to an increase in hazard risk. These trends reflect the importance of future annual glacier and river surveys for park visitor and employee safety.

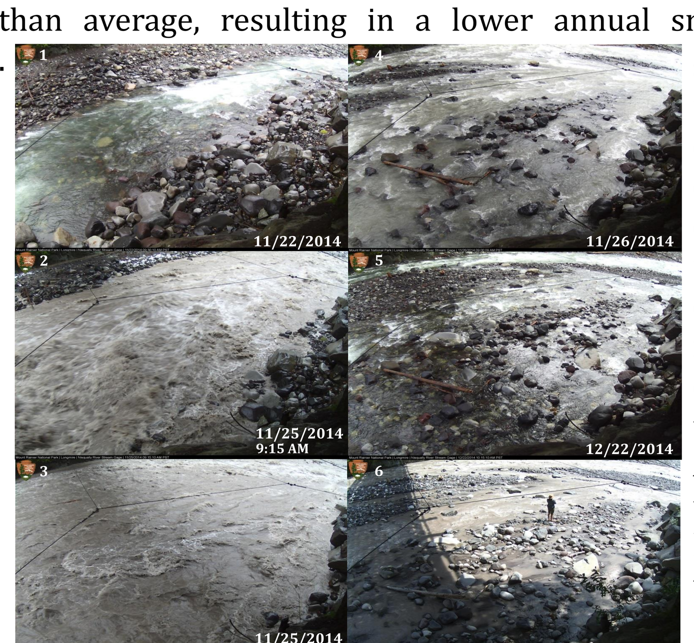
II. Background

Above: The Nisqually River is sourced from the Nisqually Glacier, carrying meltwater and sediment from the steep slopes of Mount Rainier.
Photo: Cathy Kamieniecki

The Nisqually River is a braided river sourced from the Nisqually Glacier on the southern slope of Mount Rainier. Large amounts of sediment are constantly supplied to the Nisqually River, resulting in overall aggradation, or deposition of more sediment than is removed. In addition to gradual aggradation, the river regularly experiences large-scale mass wasting and flooding events, causing more drastic changes to its path and configuration. Annual analysis of the river morphology is necessary to identify the rate and extent of these changes.

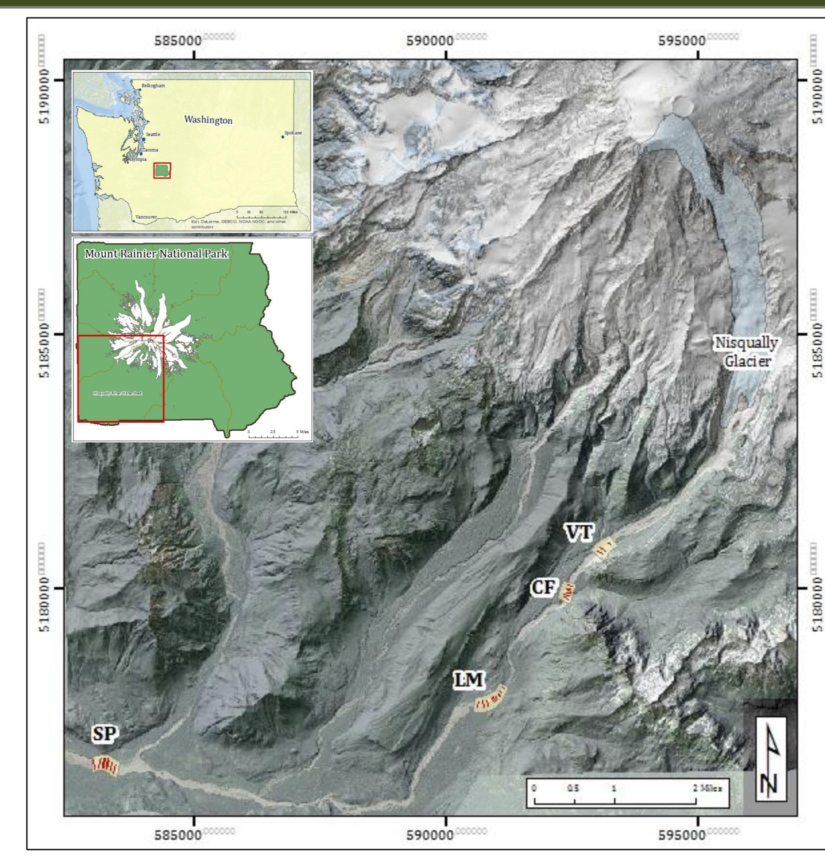
The area surrounding Mount Rainier experiences a distinct rainy season with 87% of annual peak flows occurring in autumn and winter (Beason et al., 2014). The Nisqually River sees annual flooding during these seasons, with the largest recorded flood in its history occurring in November 2006. This event coincided with an intense rainstorm atypical for the time of year and low snowpack on Mount Rainier.

The 2014-2015 winter in the Pacific Northwest region was much warmer than average, resulting in a lower annual snowpack and subsequent spring and summer melting occurring much earlier than usual. Effects of the drier winter may continue into the coming rainy season, possibly creating conditions favorable for flooding and debris flows similar to those of the 2006 event. Areas along and adjacent to the park's rivers are at a higher risk to such events when the steep, unconsolidated sediment slopes of Mount Rainier are exposed, particularly during and after intense rainstorms.



Above: 1) Photo showing main channel location before flooding event; 2-4) Time lapse photos of flooding event; 5) new position of main channel and side channels after event; 6) Channel position and river levels during 2015 cross section surveys.
Photo source: Nisqually River webcam beneath Longmire bridge

III. Study Areas



This study focuses on four areas along the Nisqually River on the southwest side of Mount Rainier. Each site has been chosen to represent delineated watersheds within the greater Nisqually watershed and is located at the downstream end. Selected sites have been assigned significance based on river size, proximity to park infrastructure, and historical mass wasting events (Beason et al., 2014).

1. **Lower Van Trump Hairpin (VT):** at the confluence of Van Trump Creek and the Nisqually; disappearing Van Trump glaciers left behind large areas of steep, loose material susceptible to mass wasting events; recent history of mass wasting events
2. **Carter Falls (CF):** area chosen because 1) located along a frequented hiking trail with a year-round maintained log bridge and 2) to track downstream migration of a 2005 debris flow deposit
3. **Longmire (LM):** river is adjacent to the primary year-round administration facilities and park housing; the elevation of the river is higher than most of the Longmire compound
4. **Sunshine Point (SP):** furthest downstream near park boundaries; location of major campsite destruction in 2006 flood

IV. Methods

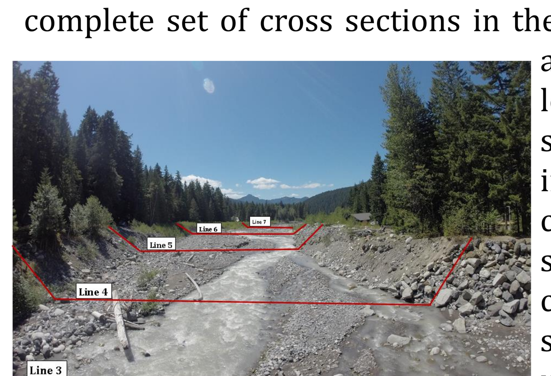
Cross section surveys

Above: Using a Topcon total station at the Longmire study site
Photo: Allison Madison

Cross-sectional profiles of the Nisqually River were surveyed in order to identify the locations of channel avulsion and rates of aggradation and incision. A Topcon GPT-3105W electronic total station was used to construct 27 total cross sections within the four study areas: VT (3), CF (6), LM (10), SP (8). Points along each line were assigned x, y, and z coordinates based on their relative positions to pre-existing control points with known coordinates and elevations. A handheld Topcon FC-250 data collector with Topcon TopSurv Basic software was used to store points of interest.

Analysis

Survey data was imported into the XSAnalysis-beta program, custom-written by Scott Beason. This program uses the surveyed data to calculate the net change and average yearly change along each cross section. Results from the 2015 surveys were compared to the most recent complete set of cross sections in the designated study areas from 2013 and were limited to the shared length of each line. Most cross sections surveyed in 2015 do not include the stretch of the main channel due to high flows during survey periods and inability to safely cross the river. Preliminary cross section graphs were constructed using Microsoft Excel and sample lines were chosen based on completeness.

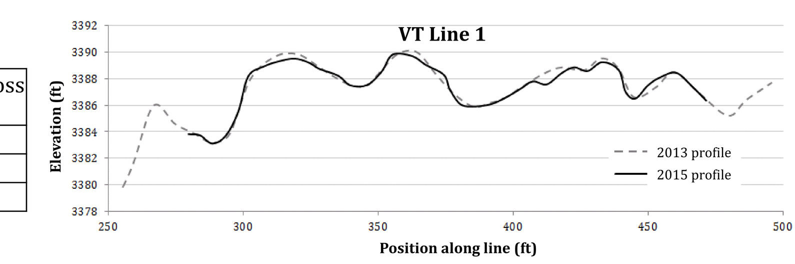


Above: Downstream view from the Longmire bridge with approximate locations of lines 3-7

V. Results and Discussion

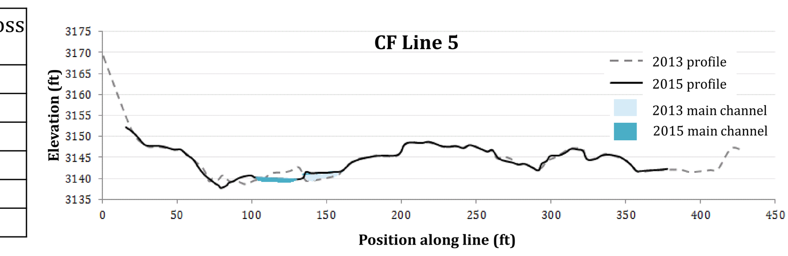
Lower Van Trump (VT)

Line	XS area total change (ft²)	Net change across channel (ft)
3	78.013	0.297
2	-19.537	-0.134
1	-11.721	-0.061



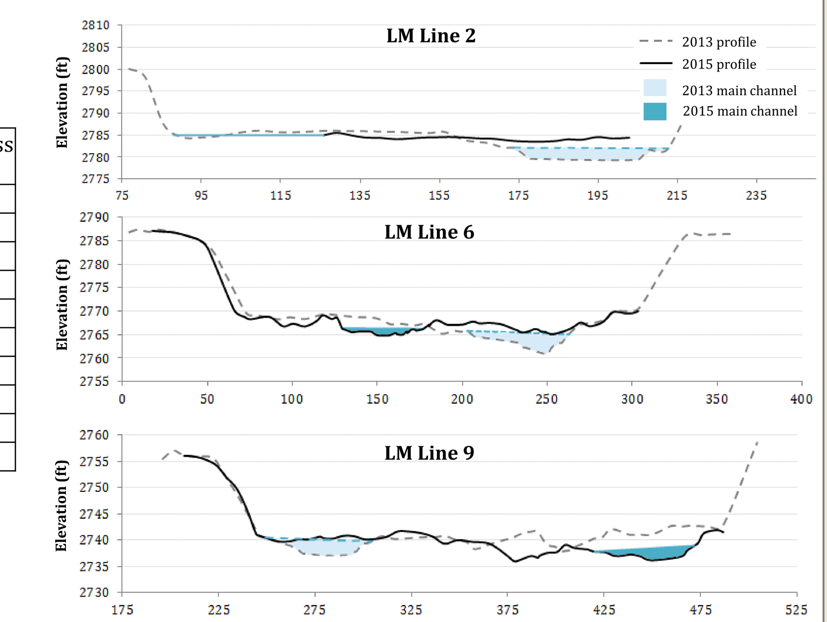
Carter Falls (CF)

Line	XS area total change (ft²)	Net change across channel (ft)
1	88.13	0.356
2	30.486	0.09
3	-93.435	-0.288
4	-63.979	-0.162
5	-29.658	-0.082
6	37.341	0.119



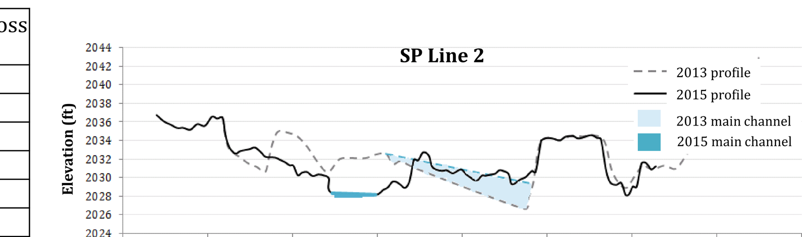
Longmire (LM)

Line	XS area total change (ft²)	Net change across channel (ft)
1	-197.39	-1.479
2	100.559	1.304
3	277.848	2.034
4	-9.522	-0.066
5	150.385	0.903
6	-15.713	-0.055
7	-64.682	-0.209
8	-1,036.34	-3.025
9	-244.226	-0.874
10	382.605	1.292



Sunshine Point (SP)

Line	XS area total change (ft²)	Net change across channel (ft)
3	417.338	0.79
1	-103.944	-0.219
8	-76.775	-0.164
2	-224.716	-0.44
4	55.259	0.098
5	109.553	0.201
6	-350.856	-0.515
7	138.205	0.299



Discussion

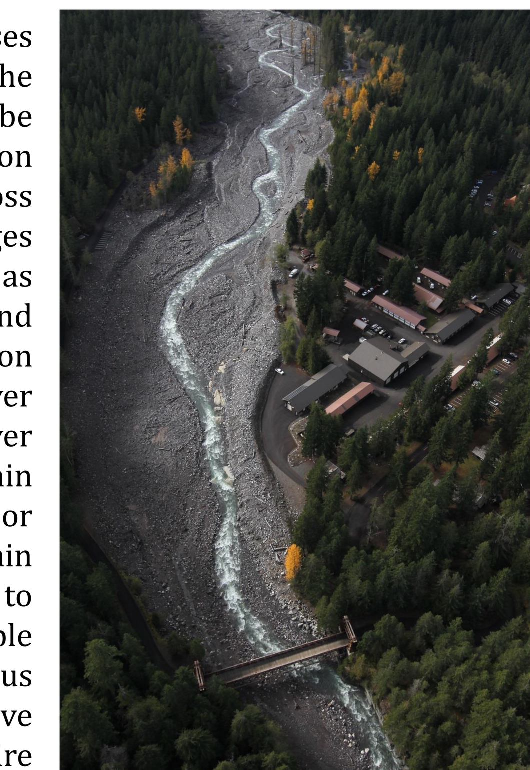
Tables for each study are list cross section area total change and net change across channel values for each line. Line order begins furthest upstream and ends furthest downstream. Cross section area total change was calculated by subtracting the cross-sectional area of the 2013 surveyed line from that of the 2015 surveyed line. Net change across channel was calculated by dividing the cross section area change by the length of the line. Positive values in green indicate overall aggradation for that line. Negative values in red indicate overall incision for that line.

Preliminary comparison of 2015 and 2013 cross section data indicate the following at each site:

1. **Lower Van Trump Hairpin (VT)**: The line upstream experiences net aggradation while the two lines downstream experience net incision. Cross section profiles do not show major changes in channel location.
2. **Carter Falls (CF):** Lines 3-5 show overall incision while the rest show overall aggradation. A slight shift in channel location can be seen on XS graph 5.
3. **Longmire (LM)**: Of all the study areas, the most significant changes in riverbed morphology are seen here. Since the flooding event of November 2014, the main stem of the Nisqually has migrated to the opposite side of the channel, as seen in the time lapse photos beneath the Longmire bridge. Differences in main channel position can be seen in cross section graphs 2, 6, and 9, all at varying positions in the study area. The upstream portions of the river in this area experience more aggradation and the downstream portions experience more incision.
4. **Sunshine Point (SP):** Cross section lines experience a mix of overall incision and aggradation. A change in main channel position can be seen in XS graph 2.

VI. Conclusion

Though the dominant processes within the study areas along the Nisqually River cannot be identified as strictly aggradation or incisional since 2013, the cross sections reveal significant changes in riverbed morphology as well as sediment transport and deposition. Main channel avulsion is common in braided river systems and the Nisqually River displays such behavior within several of the study areas. Major changes in the course of the main channel must be noted in order to predict flow paths and possible flooding areas. The most obvious changes in the last two years have occurred along the Longmire study area, adjacent to the primary park administration and housing facilities.



Above: 2010 Aerial view of the Nisqually River adjacent to the Longmire administrative and housing compound.
Photo credit: Dean Koepfler, Tacoma News Tribune

Future Studies

If warming trends continue throughout the Pacific Northwest in the coming years, the importance of monitoring channel migration and river aggradation will increase. Useful future studies and efforts may include higher precision cross section construction; stream gage installment and maintenance along major rivers such as the Nisqually River, White River, Carbon River, and Tahoma Creek; and sediment transport studies and monitoring.

Acknowledgements

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References

- Beason, S.R., 2007, The environmental implications of aggradation in major braided rivers at Mount Rainier National Park, Washington: M.S. Environmental Science Thesis, University of Northern Iowa, 165 p.
- Beason, S. R., L.C. Walkup and P.M. Kennard, 2014, Aggradation of glacially-sourced braided rivers at Mount Rainier National Park, Washington: Summary Report for 2007-2012: Natural Resources Technical Report NPS/MORA/NRTR-2014/910, National Park Service, Fort Collins, CO, 166 p.
- Beason, S.R., L.C. Walkup, and P.M. Kennard, 2014, Fluvial landscape response to aggradation, debris flows, and landslides: An example from the Nisqually River and Van Trump Creek, Mount Rainier, Washington, USA, GSA poster.
- MORA shared GIS data sets