# Monitoring Bluff Erosion Rates Using Terrestrial Laser Scanning and Structure-from-Motion Photogrammetry on Minnesota's North Shore Streams

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## Abstract

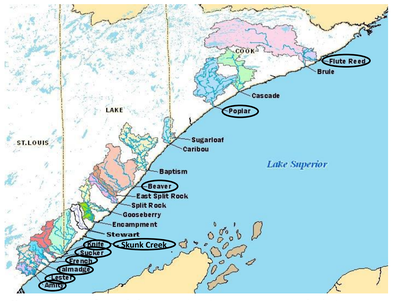
A common impairment to streams across the U.S. is turbidity. Excess turbidity via increased sedimentation can result in reduced water quality and can be harmful to fish and other aquatic life. Compared to the rest of the state of Minnesota, the North Shore of Lake Superior is largely undeveloped. Despite this, several turbidity impairments exist, often driven by erosion from stream bluffs. Quantification of rates of erosion on North Shore bluffs started in 2011, using terrestrial laser scanning (TLS). TLS is a method that allows for creation of high resolution digital elevation maps (DEMs) of topographic surfaces, which can then be compared over time. This method can be used to quantify geomorphic change over time on bluffs. This project adds to the earlier data, by providing bluff erosion rates on both natural and stabilized bluffs. We also use a new technique called Structure-from-Motion (SfM) to create DEMs from photographs collected with an unmanned aerial vehicle (UAV). This technique has been used with success in creating DEMs of glacial landforms, river topography, and landslide displacements, among others.

The data collected since 2013 has also demonstrated the importance of bluff stabilization projects in the North Shore. Bluff stabilization projects can cost hundreds of thousands of dollars, however, these projects often lack consistency in construction practices. A popular method of erosion control on these bluffs is the installation of a "bench", in which a flat structure installed at the base of a bluff is created for the purpose of trapping sediment that erodes off of the bluff above it. Benches have proven, when installed correctly, to be a good method of keeping excess sediment from bluffs out of streams. However, there are no guidelines informing the construction of the width of these benches, and as a result, their construction metrics remain highly variable.

In this research project, I continued TLS bluff monitoring work in order to monitor bluff erosion and bench deposition rates. I will apply the same geomorphic change detection analyses on both TLS and SfM data in order to determine in SfM photogrammetry is a good option for bluff project monitoring on North Shore streams. I am also conducting geotechnical analyses of bluff sediments to estimate the stable slope angle and thus calculate a bench width based on bluff height and material properties. The results from this work will assist in determining appropriate bench construction, and may better inform stream restoration activities along the North Shore.

## Background

The Knife River, pictured above, is one of 10 North Shore streams currently impaired for turbidity. Photo from Lake County SWCD.




Original map from lakesuperiorstreams.org; circled streams indicate those impaired for turbidity (2018).

Excess erosion on North Shore streams threatens property; excess turbidity from increased erosion threatens fish habitat

Steelhead trout makes its way up the turbid Knife River. Photo from Sam Cook, northlandoutdoors.com

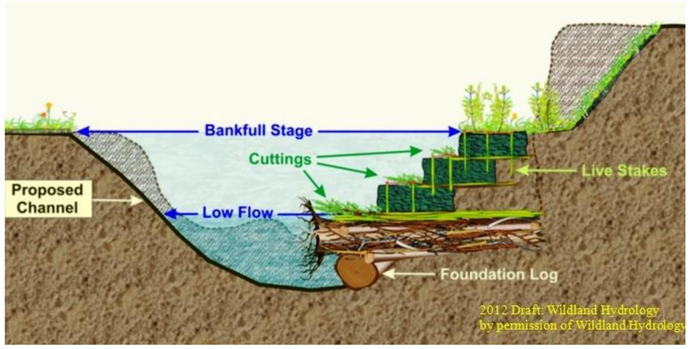
Much of this excess sediment comes from eroding stream bluffs

### Problems

- How can we limit excess sediment to North Shore streams?
- How do we know which areas/bluffs to fix?
- How effective are our fixes?

## Potential Solutions

Potential solutions include watershed scale hydrology management, water retention projects, or bankfull bench stabilization projects.




Toe wood structure design for bankfull bench style bank or bluff stabilization (Rosgen 2012)

Bankfull bench stabilization projects are becoming more and more common on North Shore streams, however, there are very little data on the effectiveness of bankfull bench stabilizations in North Shore streams with regards to reducing turbidity.

Stabilized vs. Unstabilized Bluffs

Bench with toe wood on Knife River, 2015. From L. Hall

Eroding bluff without bench or stabilization on Amity Creek, 2016

## Project Goals

**Goal 1**: Provide more data on the effectiveness of bankfull bench stabilizations in reducing turbidity in North Shore streams.

**Goal 2**: Compare methods of analyzing erosion rates, including terrestrial laser scanning and a drone technique which may be more cost effective and user friendly.

**Goal 3**: Provide more geotechnical guidance on the construction of bankfull bench stabilizations, with attention on finding appropriate bench widths given the slope, height, and material properties of bluff sediment.

## Methods

### Faro Focus 3D Terrestrial Laser Scanner

The Faro Focus 3D is a high-resolution, tripod-mounted, terrestrial laser scanner capable of measuring surface topography with mm-scale accuracy and a range of 0.5 – 130 m.

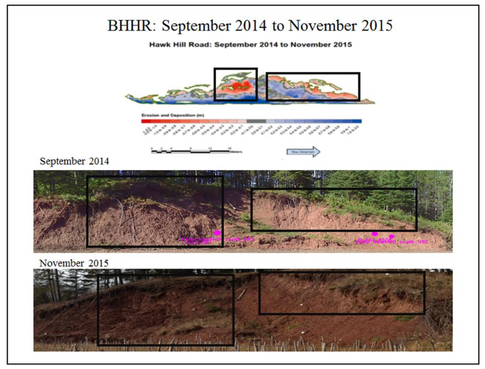
The Faro TLS system characterizes surface topography in the field and in the laboratory by the generation of point cloud data. Repeat surveys are used to determine how surfaces change over time, enabling measurements of erosion over time.

### Phantom 4 Quadcopter

The Phantom 4 quadcopter UAV is being used to acquire imagery for structure-from-motion analyses (SfM).

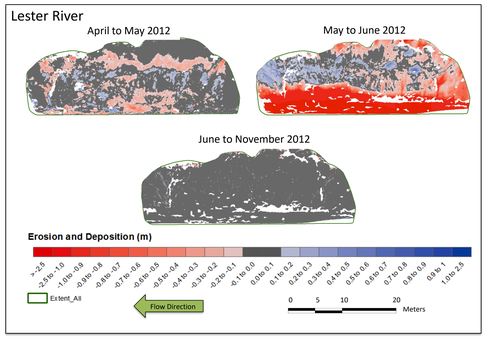
SfM allows for the creation of high-resolution topographic data from repeat photography or videography of a feature from multiple angles.

### Geomorphic Change Detection using TLS




Repeat scanning of river bluffs in the Knife River are being used to quantify erosional volumes over time. Leah Hall (M.S. 2016) was able to capture bluff erosion on sites in Amity Creek, Lester River, and the Knife River.

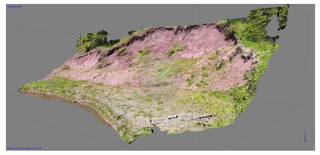
Red indicates erosion  Blue indicates deposition  Gray = no change



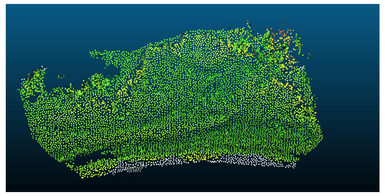

The upper left shows bluff erosion patterns, in one vector direction, in a typical spring flood while the upper right shows scour from the June 2012 flood. Following the flood, very little erosion occurred the rest of the year (lower scan). (Neitzel, 2013)

### Geomorphic Change Detection using SfM

Photos taken with drone



Photos are put into AgiSoft PhotoScan which stitches them together to create 3D point cloud



Resulting map is put in CloudCompare, which, like the GCD-TLS technique, compares repeat scans. It is more robust, allowing for more accurate volume calculations because instead of change calculated in one vector for the surface, change can be calculated in x, y, z directions for each sampled point. Sample results shown; results are forthcoming.

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