

# The Quantification of Added Cohesion Due to Vegetation in the Mad River Valley



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## Introduction

Over the past fifty years, Vermont's climate has changed significantly. Vermont is expected to face larger amounts of precipitation and more intense rainfalls. One of the biggest concerns is the increase in sediment entering our river systems, and eventually being deposited in Lake Champlain. Due to the presence of nitrogen, phosphorus, and other chemicals in the soil, this increased sediment loading is contributing to higher levels of eutrophication and algal blooms occurring in Lake Champlain, and consequently affecting the animals and communities which call it home.

Stream bank erosion, including scour and mass failures account for approximately 30 to 80% of sediment loading into our lakes and streams.<sup>1</sup> In order to better understand erosion caused by increased rainfall and stream flows, there has been a push to create quantitative computer models of watersheds in Vermont. This will allow for more accurate predictions of sediment loadings connected with storms of certain sizes and intensities. Before we can create these computer models, we must first quantify the strengths of the soils in stream banks along the major rivers in the area.

One of the main characteristics of soil that contributes to erosion is the shear strength and cohesion. These variables are very important to stream bank failure and therefore directly affect the magnitude of sediment eroding into our lakes and streams. The purpose of this project was to quantify these soil characteristics by collecting field data to identify a significant correlation between the strength of soils and the vegetation at various locations in the watershed. We also aimed to develop an understanding of the connection between slope failure, stream and ground water levels, and land use type.

## Materials

**Borehole Shear Tests (BST)**- Borehole Shear Tests are effective ways to measure a soil's shear strength, frictional angle, and cohesion in-situ.

**Tensiometer**- Tensiometers are used to measure the matric water pressure within soil.

**Accelerometers**- Accelerometers are small devices which measure acceleration and angle trajectory.

**Pressure Transducers**- Pressure transducers can be used to measure water levels over given time intervals. In this case they were used to measure stream and ground water levels.

**Monitoring Well**- monitoring wells enabled us to keep track of ground water levels at each site.



(Left) A pressure transducer is secured to the stream bed in a section of PVC pipe to safely monitor the stream height.

(Right) The BST machine sits level a top a tarp while it conducts tests.



## Methods

**Monitoring Soil Strength & Cohesion:** Our primary method for collecting data on soil strength and cohesion was conducting automated in-situ bore hole shear tests. This allowed us to measure soil properties on site and prevented many hours of additional laboratory work. At each test location we conducted two BSTs, the first at approximately one foot deep and the other at about three feet deep. This was done with the notion that the majority of plant roots extend to a depth of two feet, leaving soil at the three foot depth to be generally undisturbed<sup>2</sup>. Test location was based on proximity to the Mad River, vegetation, and land use type. To simplify the selection, we labeled each test site one of four land use types: forest, field, pasture, and Japanese Knotweed. At the site of each test, we also took three tensiometer readings in order to quantify pore pressure.



(Above) Pictured is the automated in situ BST machine mid test. The whole system includes the electronics case (orange), a portable battery, the BST machine (center), and the mechanics case (right). In the background you can see a dying grove of Japanese knotweed.

**Tracking Stream Bank Failures:** In order to track stream bank failures related to vegetation/land use type we used a system of accelerometers, monitoring wells, and pressure transducers planted in the stream. The aim of the set up was to compare the levels of water in the streams and the stream banks in order to correlate them to the times at which stream bank failures occurred.

(Left) Here I am installing accelerometers on a stream bank that was displaying weakening conditions.

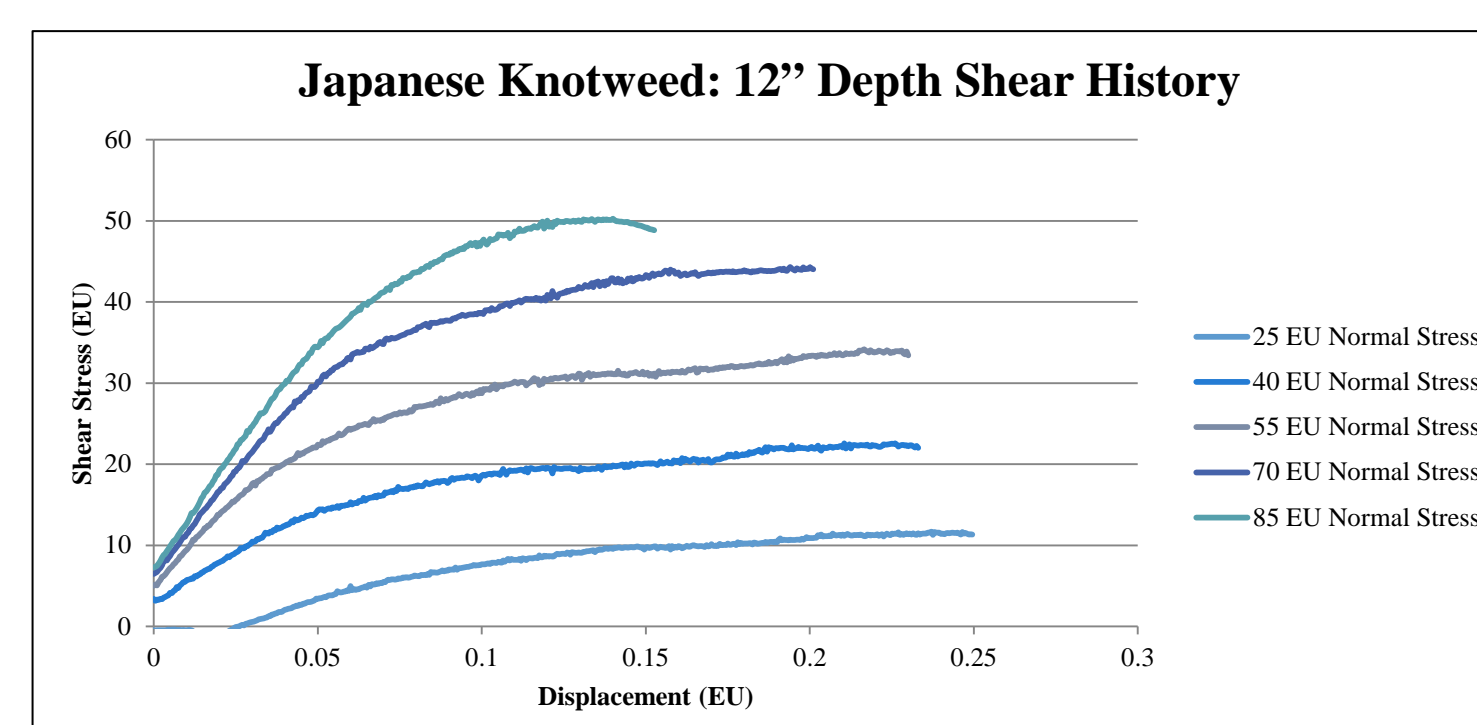
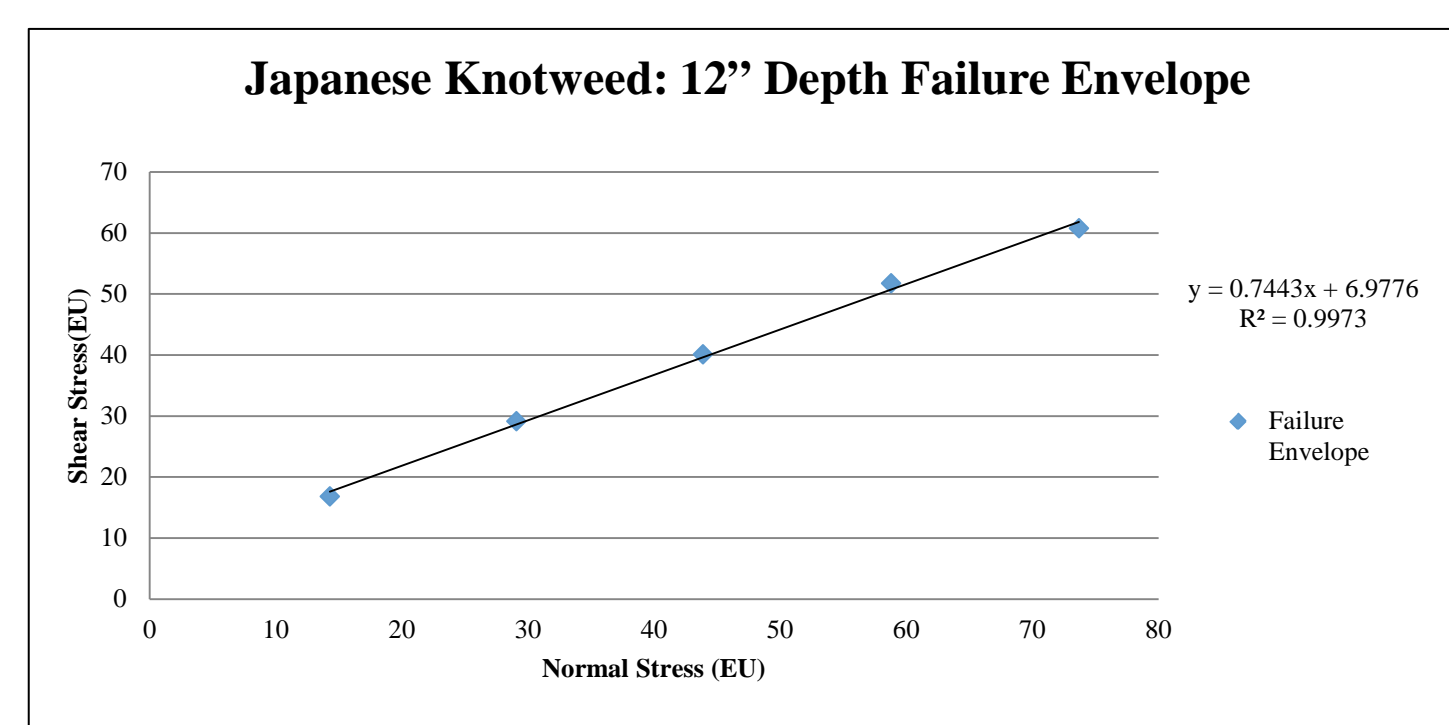


(Right) A closer detail of an installed accelerometer before it is again covered with soil.

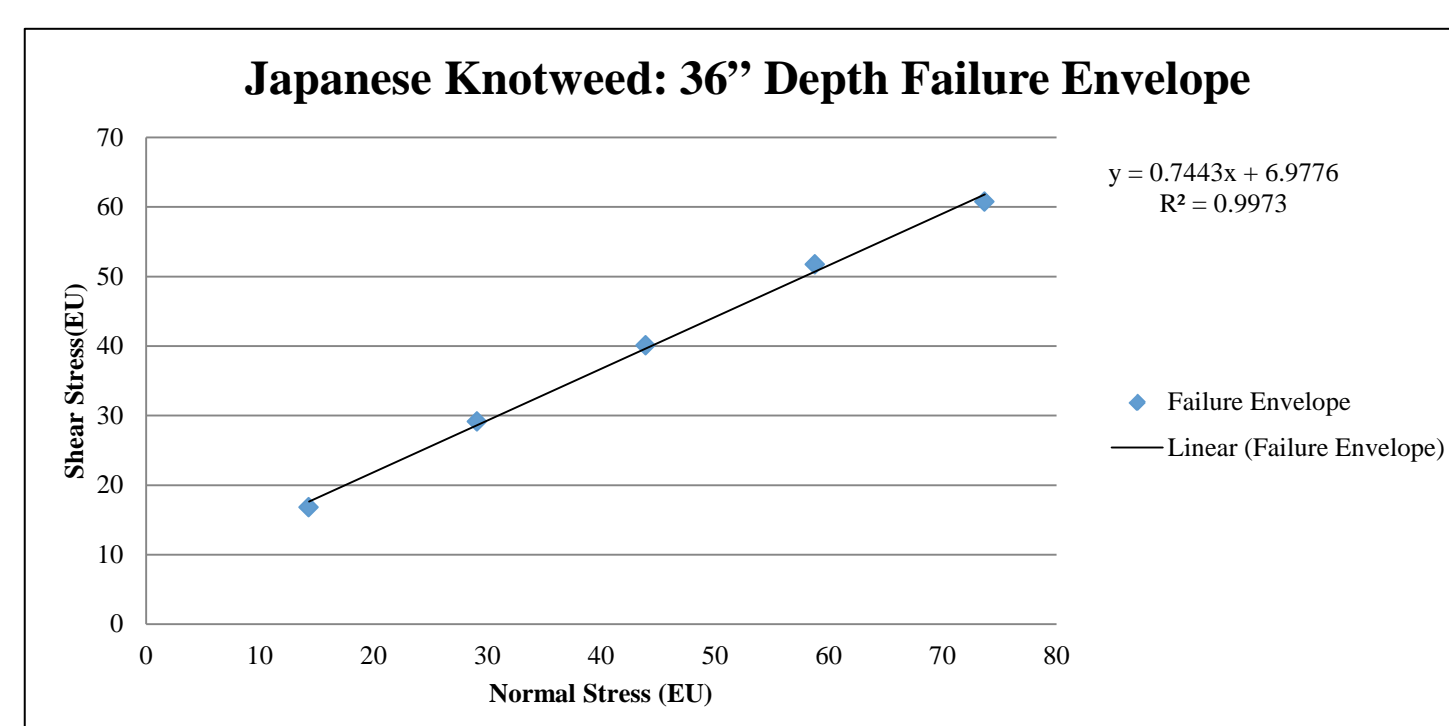


## Results

Although we conducted over 25 BST tests, only a select number of the tests were successful. During the first two thirds of the research period the BST machine was not fully functioning as there were problems with the automated portion of the set up and mechanical aspects of the machine. After many days and hours spent trouble shooting we finally sent it back to its manufacturer, who repaired the device free of charge. Once the device was again operational, we continued to run into problems due to the heavy presence of gravel in the soils found along the Mad River. The BST machine works best with soils that contain less than 10% gravel and therefore it became extremely challenging to collect data and many of our designated test sites. However, we were able to run a total of six successful tests with the fully functioning machine and their results were quite interesting.



**Sample Test Results:** Pictured left are typical results produced by a successful BST test. The graph on the far left demonstrates the soil shear strength when subjected to varying normal stress levels produced by the device. The shear history graph shows the shear stress being absorbed by the soil during the five applied normal stresses. The final applied stress (85 kPa) produces a clear indication of the soil's maximum shear stress, 50 kPa. This particular test also concluded that this particular soil has a friction angle of 33.6° and a cohesion factor of 2.545.



(Above) The graph above is the result of a second BST test conducted in the same borehole as the previously pictured test but at a depth of 36" instead of 12". It produced a cohesion factor of 6.99 and a friction angle of 36.5°.

As mentioned earlier, we also planted accelerometer set ups in four stream banks along the Mad River. Unfortunately, due in part to low levels or rain this past summer we only caught one failure. Thanks to our monitoring well and in-stream pressure transducer, we concluded that the failure was not due to a rise in stream level, but more likely due to the increased weight of soil after a small rain event, which was accompanied by a slight rise in ground water levels in the bank. However, because this was our only failure we were unable to relate its probability to the local vegetation of land use type.



(Right) Pictured here is the sole stream bank failure we captured during the project's field season. It is located on the edge of a pasture (Reynold's Farm in Waitsfeild, VT).

## Conclusions

Unfortunately, after a long summer and fall of conducting BST tests and monitoring many aspects of stream bank stability, we were unable to collect enough valid data to make any significant conclusions that related to soil properties to vegetation types. However, even though our efforts were thwarted by mechanical mishaps, natural obstacles, and low levels of rain, some tentative conclusions can be made.

Based on BST results, I believe that Japanese Knotweed is having a grave affect on soil strength and thereby slope stability. I found that in areas where knotweed growth was rampant, the first twelve inches of soil had a noticeably lower maximum shear strength, friction angle, and cohesion factor than soil found in the same spot, only 24" lower. This is because Japanese Knotweed roots are shallow and bulky causing the soil to become less dense in the top layers. I was unable to make such conclusions for other land use types.



(Left) High levels of rock and gravel consistently prevented accurate strength tests to be conducted in areas of interest.

Although this project currently does not have any conclusive results I believe it to be a success. The targeted data is valuable and if used correctly has the ability to greatly increase our understanding of sediment loading in the Mad River Valley and possibly other local rivers that are affecting the ecological health of Lake Champlain. If this endeavor is again funded I would recommend the following suggestions:

1. The use of Direct Shear Tests (DSTs): These can be performed with smaller amounts of soil sample as to avoid the excess gravel present when in situ tests are performed.
2. Better placement of accelerometers: During this study I focused solely on larger failures, it maybe more beneficial to have more set ups focused on smaller more probably slope failures.
3. The use of LIDAR data which compares the erosion between different land use types. LIDAR technology already being utilized by the EPSCoR program may be useful in determining the different erosion rates in areas with varying vegetation types.

## Additional Information

For Additional information feel free to contact me at sbrenna1@uvm.edu

## Acknowledgments

I'd like to thank my mentors Jody Stryker and Arne Bomblies, my research partner Sarah Liedger, Vermont EpscoR, CWDD, and the National Science Foundation for a great summer full of interesting research. Funding provided by NSF Grant EPS-1101317.

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