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Quantifying the Effects of Riparian Vegetation on Geotechnical Strength, and Resistance to Hydraulic Erosion: Alluvial Streambanks

Natasha Bankhead (1), Andrew Simon (1), and Robert Thomas (2)

(1) USDA-ARS, National Sedimentation Laboratory, Oxford, MS, USA , (2) Department of Civil and Environmental Engineering, University of Tennessee, Knoxville, TN, USA

Streambank erosion by mass failure is actually a combination of hydraulic processes operating with a tendency to steepen the bank, and geotechnical (slope stability) processes operating on the bank mass. Riparian vegetation has a number of effects on the mechanics of these processes through direct root reinforcement, modification of shear strength through effects on pore-water pressure, increased resistance of the bank surface to hydraulic shear and reduced effective, hydraulic stress through increases in roughness. These effects can be classified as those that affect geotechnical stability, and those that affect hydraulic processes acting at the bank face and toe. Both aspects were investigated using a combination of modeling, field work and laboratory studies.

Previous research has shown that the effect of mechanical root-reinforcement on geotechnical stability can be considerable, particularly on banks less than 3 m-high. Calculation and modeling of estimates of root-reinforcement were initially conducted using simple perpendicular root models, but recent work has made use of a fiber-bundle method so that progressive root breaking can be accounted for. Combining field and laboratory testing, the RipRoot fiber-bundle model was shown to provide more accurate estimates of root-reinforcement by allowing for progressive root breaking. Root-reinforcement is a function of a number of variables including root density, rooting depth and root orientations relative to the failure surface. For example, different distributions of root orientations relative to the failure plane can dramatically affect the shape and peak of the loading curves attained for a given bundle of roots; for 500 sycamore roots median reinforcement varied from 4.86 to 15.08 kPa on a slope and from 9.49 to 14.82 kPa when growing on the top of a streambank.

To test the effect of common North American riparian-plant species on pore-water pressure within a streambank, young riparian trees and grasses were grown in separate soil columns, each instrumented with tensiometers at 30 cm and 70 cm depths, and compared against bare, control columns. Results showed that the increased apparent cohesion as a result of enhanced matric suction from evapotranspiration, ranged from 1.0 to 3.1 kPa in spring when bank stability was most critical, to a maximum of 5.0 kPa in the summer. Experiments were also conducted using a jet-test device to examine the effect of plant roots on the erodibility of failed blocks of streambank material, permeated with varying densities of roots. These experiments showed approximately a ten-fold increase in resistance to hydraulic erosion over the range of root densities tested.

The combination of methods used here to quantify the individual effects of vegetation on geotechnical and hydraulic processes allow us to compare their relative importance for various flow conditions, bank stratigraphies, and vegetation assemblages. For example, a sensitivity analysis conducted using BSTEM 5.1 to compare the above three affects on a 3-m tall silt streambank with a 60 degree bank face, over a 6-hour storm event, showed that the change in soil matric suction from evapotranspiration provided the greatest potential benefit to Fs but only during the summer months. During the winter and spring months, root-reinforcement remained the most important contributor to Fs . In this example the sensitivity analysis showed that although roots are capable of reducing the volume of hydraulic scour, the resulting effect on streambank geometry did not increase Fs as much as changes in soil matric suction and/or mechanical root-reinforcement. Sensitivity analyses for different bank materials or flow conditions may, however, change the relative effect of vegetation on the geotechnical and hydraulic processes reported here.