The potential influence of coal seams and tree roots on slope stability in response to timber harvest and road construction

Clay, Owsley, and Knox Counties on the Red Bird Ranger District on the Daniel Boone National Forest respectively have 17, 17 and 18 named coal seams mapped. These seams are of lower to middle Pennsylvania geologic age. They range in thickness from 14 to over 56 inches. A substantial number of slope failures have been previously documented as being associated with some coal seams, in particular the Fire Clay Rider, and the Fire Clay, with timber harvest and road construction. The Fire Clay Rider is predominately between 14 and 28 inches thick with some exceeding 56 inches, while the Fire Clay ranges between 14 and 42 inches thick with some reserves approaching 56 inches thick.

Hydraulic Characteristics

The hydraulic conductivity of bedrock and coal is a fundamental parameter for the quantitative measure of their capacity to transmit and store water. *Hydraulic conductivity and transmissivities associated with coal seams are commonly one to two orders of magnitude greater than those of other rock types or their lithologic contacts.* Transmissivity is related to hydraulic conductivity in that it is used to describe the capacity of a particular water-bearing zone of a given thickness, such as an aquifer, to transmit water, which decreases with depth. Conductivity commonly ranges from less than 0.001 gal/day/ft^2 to 60 gal/dayft^2 in **coal seams**, from less than 0.001 to greater than 50 gal/day/f^{t2} in fine to coarse grained sandstone, from less than 0.001 to greater than 170 gal/dayft^2 in **siltstone and shale**, for limestone about 20 gal/day/ft^2, and from less than 0.001 to greater than 20 gal/day/ft^2 at lithologic contacts . **Coal seams** in contrast usually have a median transmissivity of **<u>0 .15 gal/day/ft^2</u>, whereas other rock types and lithologic contacts have median transmissivities less than or equal to <u>0.001 gal/day/ft^2</u>**. All rock types usually are permeable to a depth of approximately 100 ft; *however, at depths greater than 200 ft only coal seams consistently had measurable permeability* (transmissivity greater than 0 .001 gal/day/ft^2).

Coal seams function as an aquifer. Water inflow within a coal seam increases logarithmically with seam thickness, and the volume of flow through the seam remains constant with static or constant head and increases linearly with the coal seam burial depth and head pressure. The top or roof and floor strata provide a natural barrier for water occupying fissures/fractures, and natural cleats/joints in the coal seam, resulting in a relatively closed storage space of confined water.

Lateral ground-water flow is associated with the coal seams more so than associated overburden sedimentary rock types (e.g. sandstone, shale, siltstone). Some of the coal seams could be partly saturated, confined, or semiconfined and, in some instances, water could be perched above these coal seams in places where the elevation of a seam rolls up and down.

Structural features such as the regional strike and dip of coal seams and overburden Thickness/head, and bedding plane partings, jointing and fracturing will influence conductivity and transmissivity of groundwater and landslide risks.

Another factor to consider is the interbasin connectivity of groundwater. Where a coal seal outcrops in an adjacent watershed, but due to a hydrologic gradient dipping opposite of the surface gradient of the slope at the outcrop on the up dip position, groundwater will move down gradient to increase the flow to the adjacent watershed. The longer this interval the more water will be available to boost groundwater supplies in soils near and below the down gradient outcropping. So, coal seams outcropping higher on a slope and nearest the ridge top are of less risk to pose a risk to a slope failure connected with timber harvest and road construction.

Soil Properties

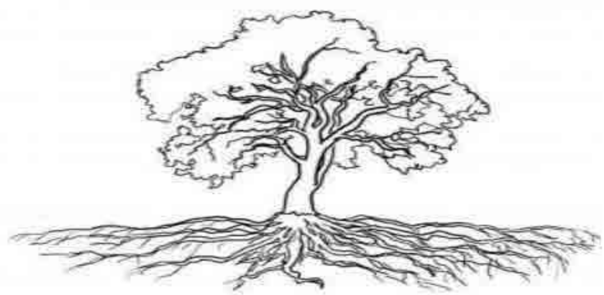
Soil shear strength can be described as the resistance to failure, a function of stress on the potential failure surface, cohesion, and internal angle of friction. Normal stress is influenced by the unit weight or density of the soil at field moisture content, soil depth, and slope gradient. Pore water pressure at the failure surface will decrease the normal stress by acting as a buoyant force. Additional infiltrating water can generate an unstable condition by increasing the weight of the soil and pore water pressures

Cohesion is related to the amount of clay in the soil profile. The higher the clay content the higher cohesion. Cohesive soils are characteristic of deep-seated soil creep and slope failures. Cohesion of these fine-grained soils is a function of moisture content. With saturation cohesion in clayey and silty clay textured soils will drop dramatically. *Cohesion though is supplemented by the contribution of rooting strength provided by vegetative cover.*

Internal angle of friction represents the degree of interlocking by individual soil aggregates and is influenced by the shape, shape, size and packing arrangement of soil particles. Angular shaped particles have a larger angle of friction than rounded particles. Therefore, sandy textured soils have greater shear strength dependent on intergranular friction and grain interlocking than cohesion associated with clayey and fine-loamy textured soils.

The role of forest in slope stability

A live root network of a healthy timber stand increases soil strength substantially. *The shear strength at saturation is more dependent on the root system than the cohesive and frictional resistance within the soil to failure.* After a timber harvest soil moisture levels increase.



Slope stability problems often develop after timber harvest on steeper slopes where much of the soil strength is provided by tree roots. As roots decay after harvest, in particular clear cutting, their value diminishes rapidly. Research has disclosed that it is likely that over 50 percent of the tensile strength provided by the root system will be lost within 2 years after harvest and much more within 5 years. As much as 90 percent within 5 to 9 years. This rate of decline in tensile strength will vary according to species, root size, and the activity of decay organisms. The first to go are the small roots while the larger roots are more decay resistant.

The most sensitive slopes to harvest are ones located at the head of ephemeral and intermittent streams as these are very hydrologically sensitive areas. This is even more so if a coal seam is present which has a regional dip in the direction of surface and groundwater flow (hydraulic gradient). Removal of trees here will upset the hydrologic balance that has been achieved over a long period of time. As the root system decays pore water pressure within the soil profile in response to flow from a coal seam, groundwater, subsurface and surface runoff along a failure surface will likely exceed the inherent soil strength available with cohesion and internal friction. A rapid rise in groundwater will generate a buoyancy force sufficient to exacerbate inherent risks of slope failure.

Road Construction

Locating, designing and construction of roads as a transportation system supporting forest management on slopes possessing potential stability issues should recognize the influence coal seams may play. Excavation of a road prism in proximity below or downdip of a hidden outcrop of a coal seam or through a seam itself of a thickness comparable to the Fire Clay and Fire Clay Rider itself can potentially release a substantial flow of water previously confined within the seam. Where a seam dips to the roadway this is of highest risk for immediate problems.

From: George Chalfant
Sent: Thu, 12 Nov 2020 14:05:13 +0000 (UTC)
To: Cotton, Claudia A -FS
Subject: Coal seams and tree roots
Attachments: Coal seams influence on slope stability.docx

Hi Claudia, I'm late with my input for you. My laptop decided to take a break yesterday until around 2 p.m. yesterday. Frustrating.
I enjoyed doing this. It brought back a lot of good memories working with two of my early mentors Dr. Byron Thomas and Ed Burroughs. Byron retired from the Bureau of Land Management after working for the F.S. for some years and Ed was the head of a F.S. research station in Montana prior to his death. I last saw Ed in Greenville S.C. where both of us spoke at a meeting on slope stability. Both of these guys worked and published material on root strength follwoing timber harvests. It took a lot of digging and root sampling (different sizes) and then conducting tensile strength tests (roots of different ages).
Ed was being given an award for his work at a meeting and when he got up and was walking down to get is award he had a massive heart attack and died. Really traumatic for all in attendance. Both of these fellows are just outstanding to work with. Byron is now pushing 90 and lives across the bay from Seattle.
I hope what I've put together makes some sense. I had to pull stuff deep from within my aging brain. ha
Please let me know of any comments, suggestions, or requests that you may have.
I recall inventorying over 20 slides in clear cuts on the Red Bird and all but about 3 or so were associated with a coal seam. Most of these occured around 5 years after harvest. The Fire Clay seams I recall were involved with most. I did write something up on that but I dont have a clue if it's still around.
If I think of anything more I'll be in touch.
I have an appt. with my heart Doc. at 10:40 this morning. It never ends. ha
Say, how are your parents doing? Hopefully really well.
Also, how are you holding up under these stressful times? I'm confident you're dealing with this really well.
George
p.s. I would love to take a trip down to the Red Bird with you and revisit some of the old slide areas and see how they've healed.