GULLY CONTROL ON THE SUMTER NATIONAL FOREST IN S.C.

William F. Hansen [1] and Dennis L. Law[2]

AUTHORS: [1]Forest Hydrologist and [2]Forest Soil Scientist, Sumter and Francis Marion National Forest, 4931 Broad River Rd, Columbia, SC.

REFERENCE: *Proceedings of the 2008 South Carolina Water Resources Conference*, held October 14-15, 2008 at the Charleston Area Event Center

Abstract. This paper summarizes the gully control work on the Sumter National Forest during the last 3 decades. Gullies may affect hillslopes and associated ephemeral channels. The severity of gully development depends on a number of factors including soils, vegetation, rainfall, flow and disturbance by man.

Gullies develop in response to concentrated flow that exceed soil and channel tolerances. Unchecked, they erode and deliver sediment through a variety of processes that cause loss in soil productivity, channel entrenchment and expansion into the landscape. The processes increase the channel network, bank slope, bank height, and streambank instability resulting from the headward migration of nickpoints. Channel degradation in gullies may affect adjacent tributaries, sometimes expanding into ephemeral and undefined drainage pathways.

Alternative approaches to treatment may be considered dependent upon gully specifics and landowner desire for effectiveness, cost and reliability. The character of the gully and its potential for change should be considered. In terrain susceptible to gully formation, land use practices should recognize the causes and make adjustments before activities disturb the ground or alter drainage response. The information and examples provide information for varied circumstances.

INTRODUCTION

Gullies are entrenched channels extending into areas with weakly defined channel conditions (Schumm et. al., 1984; Hansen, 1995). They tend to follow ephemeral channel and fine topographic depressions that accumulate concentrated flow. Under extreme conditions, they can expand into hillslopes. Active gullies are recognized by headcuts (primary nickpoints) where there is an abrupt drop in elevation. The channel below the headcut is enlarged by cavitation, flow plunge, erosion, and sediment removal. Secondary nickpoints may be located downstream as additional adjustments to base level change. Nickpoints travel upstream as gully systems expand. Restrictive channel materials (e.g., bedrock or tree roots) can halt or slow nickpoint migration.

The processes responsible for headcut migration will vary somewhat with the position on the landscape and the conditions. Surface flow and plunge action exert pressure to undercut, widen, wear and collapse the nickpoint. Saturated soil also contributes to cavitation enlargement and slope failure, with seasonal winter frost heaving and slope raveling. Storm runoff causes plunge enlargement and material removal. Soil piping may contribute to gully development (Heede, 1976). As gullies expand, storm runoff becomes more dominant with declines in infiltration, groundwater, baseflow and evapotranspiration. The increased drainage density, soil exposure, erosion, and sediment delivery cause adjustments to both adjacent uplands and downstream bottomlands. In this process of channel entrenchment and densification, ground water may be tapped resulting in declining baseflows and conversion of perennial streams to intermittent or ephemeral flow. Adjacent lands have reduced moisture available for plant growth. Streams in downstream valleys aggrade, resulting in lost capacity with more frequent and extensive flooding. Gullies deplete the physical character and biological capability of the streams and affected landscape.

Gullies are sometimes confused with other erosion features gullies such as rills, entrenched channels, and landslides. Even though there continues to be some disagreement or overlap in definitions by individuals, it is important to make the distinction to properly address the causes and prescribe appropriate control measures.

<u>Rills</u> are characterized as relatively rapid developing linear erosional features from concentrated sheet flow on exposed, sloping terrain. One severe storm may be enough to develop severe rills in disturbed, erosive soils. Rills can be removed in tillage or left inactive with erosion control measures (Schumm et. al., 1984).

<u>Entrenched valley channels</u> have more permanent flow, but exhibit some of the same features and processes as ephemeral or hillslope gullies. Rosgen (1994) described gully type channels with low width to depth ratio, high entrenchment, moderate slope and low sinuosity. Channel degradation and the headward expansion of nickpoints occur, but are often less obvious than ephemeral gully headcuts on hillslopes.

<u>Landslides</u> are driven by slope processes dependent on subsurface soil saturation, loss of soil strength through exceeding liquid limits and/or slope shear strength forces often causing instantaneous mass failure. Steep slopes and subsurface flow along geologic contacts contribute to instantaneous failure when overloaded beyond some internal threshold. Once the internal pressures are released with mass delivery of sediments, continuing erosion/sediment but with little enlargement is common.

BACKGROUND

The Sumter National Forest (SNF) in SC was acquired under the Weeks Law of 1911 to sustain timber and water resources within navigable waters. Many of the lands had been deforested, farmed, abandoned and misused for decades (Trimble, 1974). Earliest gully treatments began in the 1930s with the Civilian Conservation Corps (CCC). Trial and error, successes and failures helped to define what was needed.

Since 1980, over 2,500 acres of severely eroding land including many gullied and galled barrens were treated in the piedmont of SC on the SNF, primarily within the Broad River basin. Most of the work accomplished since 1980 successfully controlled gully formation, and rehabilitated the land. Peak gully treatment activity on the SNF occurred in the mid-1980s. Declines in funding, other important issues and increased costs have reduced gully control activity substantially.

Gully formation and expansion of the drainage network were activated by altered land use, repeated deforestation, cultivation, abandonment, altered flow pattern, severe erosion and sedimentation (Trimble, 1974; Schumm et al, 1984, Yoho, 1980). Altering cover, soil and/or hydrologic function with no attention to erosion of sensitive soils, triggered gully formation and development. Many activities (e.g., roads, farming, mining, channelization, urbanization, development, and forest conversion) have the potential to alter surface and hydrologic conditions that contribute to gully formation.

Soil properties altered by years of cultivation in the SC piedmont reduced subsurface soil percolation and macropore space, and increased surface flow and gully formation on sloping terrain (Hoover, 1949). Conversion of forests lowers infiltration, evapotranspiration, root strength and increases runoff (Swank et. al., 1988). Although gully formation and enlargement are typically episodic, they are not instantaneous. Careful observation and treatment in the initial phases can slow or halt development (Schumm et. al., 1984).

Certain soil materials and landforms are especially susceptible to gully formation. Soil properties with weak cementation, consolidation and cohesion such as alluvium, colluvium, loess, ocean or lake deposits have more risk. Oxisols are susceptible to gully formation due to their degree of physical and chemical weathering. Soils that are altered by physically or those with chemical imbalances may also contribute (Heede, 1976, Singer et. al., 1978). Micaceous, granitic, and saprolite materials are susceptible to gully formation.

The abundance of resilient native grasses and other types of plant cover was also lost in the landscape erosion in the SC Piedmont. As a result, stabilization and restoration measures were more difficult to establish.

Hydrologic alterations or stream capture from an adjacent area generates more flow leading to severe erosion, gully formation and/or channel entrenchment. Severe tropical storms onto small gullied areas can deliver substantial sediment (Hansen and Law, 2004).

METHODS

Site Description. The conditions in the South Carolina piedmont include well distributed rainfall averaging about 114 cm per year, with water yield about 43 cm per year. The monthly average rainfall ranges between 7 and 13 cm of rainfall. Summer thunderstorms and tropical storms generated by moisture and temperature dynamics from both the Atlantic Ocean and Gulf of Mexico affect this area. Soils are derived primarily from mica schist, with deeply weathered saprolite subsoil in the C-horizon. Hillslope erosion that penetrates the more resistant B-horizon into the saprolite subsoil is likely to expand into gully networks if not treated. Saprolite materials are extremely erodible and nutrient deficient that limit revegetation recovery.

Treatments. Gully treatments consider physical site differences in soils, drainage size, slope, and other characteristics. The prescription for gully treatment needs to address the causes and severity of conditions, looking for effective ways to produce stability. Control of concentrated flow from impermeable surfaces and larger drainage areas. Treatments may help armor the surface, reduce flow, increase infiltration, provide root strength, and/or add structural integrity.

A variety of methods have been used to control gully erosion (Heede, 1976; Hansen, 1991, 1995; Hansen and Law, 1996, Law and Hansen, 2004). Treatments include:

1. <u>Reforestation/Revegetation</u> **-** Since the 1930s, establishment of pine forests and woodlands have been successful in reducing surface runoff and erosion associated with abandoned, cultivated, and other abused lands. Many active gully systems eventually healed themselves following the planting of loblolly pine by the CCC in the 1930s. Pine forests transpire about 80 cm of water, effectively reducing flow. This treatment was inexpensive, but the healing success was not immediate. Quick cover on the poor soils was sometimes difficult to achieve, but was established with brown top millet, winter wheat or other annual grains. Non-native grasses such as fescue, bahia, Bermuda and orchard along with legumes such as *Serecia lespedeza* and clover were used. Recent cooperative efforts have increased the use of native species for erosion control. In gullied terrain with poor soils, fertilization has been crucial for plant density and diversity (McKee and Law, 1985). Soil nutrient testing verifies nutrient needs. On the severely eroded Piedmont sites, nitrogen and phosphorus have been depleted and applications of 450 kg/ha (400 pounds per

acre) of pelletized (slow release) 35-17-0 increase the survival, growth and density of vegetation.

2. Gully Plugs and Dams - A gully plug is a small earthen dam constructed at one or more locations along the gully. They are generally located in ephemeral headwaters prior to perennial stream formation. More detailed dam design and construction methods should be used for intermittent and perennial channels. The design is similar to a well compacted road fill with clay core and drop inlet culvert. The goal of these structures is primarily to reduce grade, store or detain sediment and control runoff energy to stable downstream channel.

3. Log or woody debris dams were used on some of the early efforts to help stabilize SC gullies. Structures were often made of a variety of available materials such as small cedar trees piled between posts in the gully. Others consisted of chicken wire fences with cedar and other brush placed across small channels and barren lands. Debris structures provided some short-term stability by increasing roughness, slowing and/or dispersing concentrated water movement. However, in confined gully channels, diversion into banks, overtopping with plunge pool erosion and undermining the structure were issues. Commercial cois logs can provide short-term benefits until other treatments work.

4. Rock Check Dams help stabilize eroding channels or waterways and can provide permanent channel protection (grade control) and energy dissipation. Costs, proper sizing of materials, downstream splash and plunge pool control and frequency of structures are considered. The location and placement of structures with a 2-4 percent gradient will typically produce acceptable results for providing grade control. Dam stability is inversely proportional to its height, so low rise check dams are generally recommended unless specifically designed. Numerous publications exist on rock dam construction and use in the West on gullies and entrenched channels (Heede, 1976). Loose rock check dams should be very low in height (<1 m) and maintain a sufficient thalweg.

5. Coarse gravel or rock is occasionally used to stabilize ephemeral gully headcuts, rills, waterways, terraces, or diversion ditches to armor surface or control concentrated flow. Gravel or rock placement provides immediate benefits, but can be costly when materials and access are not readily available. Surgestone - ungraded aggregate about 4 inch minus placed in gully heads or at ephemeral nickpoints has produced effective surface armor and dissipated water energy to a more stable channel section downstream.

6. Water diversions, terraces and waterways can be used to control, capture and transmit storm water away from the gully. Diversions are especially appropriate when upslope activities have increased flow into the gully channel. A stable infiltration area such as a forested buffer zone is needed for the additional flow.

Terraces are constructed on a 1-2 percent grade to capture and remove stormwater from a treated slope. Hillslope terraces need periodic maintenance to function as water conveyances because then can clog and fail. Increasing terrace size to an effective depth of about a meter and compacting provide added insurance toward long-term function. Conversion to forest increases infiltration and transpiration to reduce surface flow.

Waterways are sometimes constructed in ephemeral gully treatment areas to move surface waters in channel systems when water and associated erosive forces cannot be diverted, defused or contained. Waterways can use natural channel design or structural measures to dissipate surface water energy in the channel. Natural channel design procedures apply dimension and profile of stable systems to unstable systems (Rosgen, 2007).

7. Land smoothing or reshaping has been a useful when treating active gully systems with complex headcuts with expanding channels into hillslopes. This method has provides the best long-term rehabilitation or restoration when all resources and benefits are considered, but costs more too. Land reshaping smooths the surface to less than 25 percent slope with dozers and other heavy equipment. Practices associated with land reshaping include other treatments described such as diversion ditches, waterways, terraces, soil ripping (at least 0.5 m deep), liming, fertilizing, mulching, seeding, and planting trees. Primary costs are for equipment use in the reshaping and water and erosion control measures. Land reshaping should not be attempted without aggressive erosion control and stormwater measures. Reshaping gullies can be a wasteful and ineffective experience if the measures are not maintained.

DISCUSSION

Hillslope gully control requires some science and some art. Triggering mechanisms generally involve disturbance of sensitive soil materials and increased concentrated flow from past actions. A variety of treatments are available, depending on the conditions, objectives and funding. Identifying gully impacts can help justify treatment and landowner options. Treatment may be simple as diverting flow or complex as reshaping and revegetating the land.

Mistakes, miscalculations or abnormal conditions during or following treatment need to be evaluated and corrected to avoid loosing investments. Regular checks after floods, droughts and during the first few years are critical. Pine reforestation of eroded landscapes helps to increase infiltration and transpiration losses, and reduce concentrated flow and sediment delivery downstream.

Cost sharing opportunities or partnerships can be explored to help facilitate treatment (Environmental Protection Agency, 1999). However, some of these programs take a substantial degree of documentation and analysis to prepare a proposal, with required reporting.

Because a gully system can affect substantial areas or may cross landowner or political boundaries, control considerations may need a broader cooperation and teamwork to implement effectively. Getting to consensus is sometimes not an easy task, so compromise may have to be fashioned to best fit the circumstance.

Acknowledgements. USDA agency personnel since the 1930s developed many of the initial control measures. Others have made technical contributions to gully analysis and control including those referenced.

There is inadequate room to recognize all of our co-workers who helped with the gully control work. Reliable technical field staff including Jimmy Shannon (retired), Horace Drew (retired), Keith Barnes, and Jay Swafford were critical in implementing the work on the ground. Special thanks to Luis Mundo for his surveying, Terramodel and AUTOCAD skills.

References

Environmental Protection Agency, 1999. Catalog of Federal Funding Sources for Watershed Protection (Second Edition). US EPA, 841-B-99-003.

Hansen, W.F., 1991. Land Rehabilitation on the Sumter National Forest. In Proceedings of the Fifth Federal Interagency Sedimentation Conference, Drs. S.S. Fan and Y.H. Kuo, Editors. Federal Energy Regulatory Commission, pages 3-110 to 3-117.

Hansen, W.F., 1995. Gully Treatments. In Proceedings of Watershed Assessment and Restoration, USDA Forest Service, National Advanced Resource Technology Center, Marana, AZ.

Hansen, W.F. and D.L. Law, 1996. Watershed Restoration after Calamity. In Symposium Proceedings on Watershed Restoration Management, Syracuse, NY. Am. Water Resources Assoc. Tech. Pub. Series TPS-96-1, Herndon, VA. pp. 187-198.

Hansen, W.F. and D.L. Law, 2002. Mitigation Partnership Opportunities with the Forest Service and Examples from South Carolina. In Proceedings of 5th National Mitigation Conference, Terene Institute, Washington, D.C.

Hansen, W.F. and D.L. Law, 2004. Sediment from a Small Ephemeral Gully in South Carolina. In Proceedings, 3rd International Symposium on Gully Erosion, University of Mississippi, Oxford MS.

Heede, B.H., 1976. Gully Development and Control - The Status of Our Knowledge. USDA Forest Service Research Paper RM-169. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. 42 pp.

Heede, B.H., 1982. Gully Control: Determining Treatment Priorities for Gullies in a Network. Environmental Management, Volume 6, Number 5. Published by Springer-Vertag NY Inc. pp. 441-451.

Hoover, M.D., 1949. Hydrological Characteristics of South Carolina Piedmont Forest Soils. Proceedings of the Soil Science Soc. pp 353-358.

Law, D.L. and W.F. Hansen, 2004. Native Plants and Fertilization Help to Improve Sites and Stabilize Gullies on the Sumter National Forest. In Proceedings, 3rd International Symposium on Gully Erosion, University of Mississippi, Oxford MS.

McKee, W.H. and D.L.Law, 1985. Response to Fertilization on the Francis Marion and Sumter Natl Forests. Report No. FS-SE-1103-157(2). Southern Research Station, Charleston, SC. 16 pp.

Norcross, T.W., 1936. *Handbook of Erosion Control Engineering on the National Forests.* US Govt Printing Office, Washington, DC. 90 pp.

Rosgen, D.L., 1992. A Stream Classification System. In Applied Geomorphology Workshop, Pagosa Springs, Colorado. pp. C1-C50.

Rosgen, D.L., 1994. A Classification of Natural Rivers. Elsevier Science, Catena 22. Pp 169-199.

Rosgen. D.L., 2007. Rosgen Geomorphic Channel Design. In Part 654 Stream Restoration Design, National Engineering Handbook, Chp 11, USDA-NRCS, Washington, DC. 80 p.

Rosgen, D.L. and L.B. Leopold, 1992, Applied Geomorphology Workshop, Pagosa Springs, Colorado. Lecture notes, notebook, field examples.

Schumm, S.A., M.D. Harvey and C.C. Watson, 1984. *Incised Channels, Morphology, Dynamics and Control.* Water Resources Publications, Littleton, Colorado. US Library of Congress Catalog Number 83-050243. 200 pp.

Singer, M.J., J. Blankard, E. Gillogley and K. Arulanandan, 1978. Engineering and Pedological Properties of Soils as They Affect Soil Erodibility. California Water Resources Center, Technical Completion Report Number 166, ISSN 0575-4941. 32 pp.

Swank, W.T., L.W. Swift, Jr and J.E. Douglas, 1988. Streamflow Changes Associated with Forest Cutting, Species Conversions and Natural Disturbances. In *Ecological Studies of Forest Hydrology and Ecology at Coweeta*. W.T. Swank and D.A. Crossley, Jr. (Eds). Springer-Verlag.

Trimble, S.W. 1974. Man-Induced Soil Erosion of the Southern Piedmont 1700-1970. Soil Conservation Society of America. Akeny, Iowa. USA. 180 pp.

Yoho, N.S. (1980). Forest Management and Sediment Production in the South - A Review. Southern Journal of Applied Forestry, Vol 4, No. 1 pp. 27-35.