USING STREAM CLASSIFICATION TO PRIORITIZE RIPARIAN REHABILITATION AFTER EXTREME EVENTS[1]

Sherman Swanson[2]

Abstract: Historic use of many stream riparian areas and associated watersheds has impaired the capacity of riparian vegetation and floodplains to reduce stream energy and trap sediments. As low-gradient streams with erodible banks increase in width and change their pattern, they approach a threshold of instability. Once a stream exceeds a threshold, it must proceed through a process of geomorphic gully evolution that includes degradation, widening, and aggradation phases. Opportunities for enhancing and maintaining favorable conditions of stream morphology and associated riparian values vary throughout this process. The highest priority stream reaches for watershed, riparian, and stream management are those approaching the threshold. After the degradation phase, the marginal reaction to management input increases as the gully widens. Riparian grazing can be managed in a variety of ways to avoid detrimental effects. A useful alternative to a riparian exclosure is a riparian pasture that can be managed for optimum riparian resource values.

The pattern of settlement and the history of use of the American West has left today's natural resource managers with many riparian problem areas and horror stories. Many stream environment zones that have degraded are now unraveling and have been doing so for decades Cottom and Stewart (1940). Some have not yet reached the threshold leading to collapse. Others are progressing through the process of geomorphic and ecological recovery. As years pass, additional stream reaches succumb to the convergence of a major runoff event and an approach to a threshold. This happened to many streams in the early 1980's when successive winters produced abnormally high runoff that each year prolonged the period of high flow.

Active stream-channel dimensions conform to the bank-full flow that typically represents the normal high water mark (Wolman and Miller 1960). This bank-full flow comes only once or a few times in most years. It is effective in forming the channel that conveys it because it represents the greatest cumulative energy level. Larger flood events last for too short a time to generate much effect even though their energy level is extreme for a short time. Low-flow events lack the energy even though their duration is substantial. However, when approaching a threshold (Van Havern and Jackson 1986), there can be substantial effect during a flood if either or both of two conditions occur: 1. The cohesiveness of stream channel materials weaken significantly; or 2. The forces impinging on the stream-channel materials increase because of some change in the cross-valley profile that confines the flood wave.

Historical land management has often created both of these conditions. Furthermore, inappropriate management of mining, road building, timbering, fire, or grazing has caused many watersheds to release water and sediment at substantially increased rates. Increased flows force the stream to adjust and they may exceed the capacity of the natural or stressed stream channel to convey them without significant alteration. Although streams approach and exceed thresholds of instability under natural conditions, it normally requires dramatic geologic or climatic change for a large number of streams to approach threshold within a time period as short as man's influence on the West. It seems inappropriate therefore, to attribute the inordinately devastating effects of rare but natural events to "acts of God".

This paper uses concepts developed from stream classification (Rosgen 1985) to describe the role of riparian vegetation and floodplains in maintaining stream channel morphology in low-gradient streams. From these concepts is drawn an approach for prioritization and management of such streams. Although many of the principles apply broadly, the management field of livestock grazing is emphasized.

Function of Riparian Vegetation in Stream Morphology

At the Sheldon Antelope Range in Northwestern Nevada, Nebraska sedge (*Carex nebraskensis*) dominated communities have an average of more than 2 meters of roots and rhizomes per cubic centimeter in the top 10 centimeters of the soil profile (Manning 1988). It is no wonder that it and other broad-leaved sedges have gained a reputation for stabilizing sediment and binding stream-bank soil (Youngblood and others 1986). Although other species of herbaceous plants may not have as great a root-length density, it is not uncommon to

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[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

[2] Extension Range Specialist and Research Scientist, University of Nevada, Department of Range Wildlife and Forestry, Reno, Nevada.

see stream banks that are stable because of the tough sod produced by plants that thrive in the moist conditions found with a high water table. Willows and other woody riparian species have also achieved a measure of notoriety for their role in stream-bank stability.

Besides providing cohesiveness to otherwise erodible alluvial materials, vegetation provides roughness that increases friction at the water-land interface. This decreases velocity and decreases the energy available for doing work including detachment of channel materials and transport of bedload or suspended sediment. The filtering effect of riparian vegetation is partly responsible for deposits of fine fertile soils on many floodplains such as mountain meadows. Within the active channel it is also instrumental in the process of narrowing streams that are recovering from bank erosion.

It is natural for streams on low (<1.5 percent) gradients with floodplains to meander (especially C6, C4, and C3 stream types (Rosgen 1988)). This involves a balance of erosion on the outside turns and deposition on the inside turns. In order for streams to remain stable, the rate of these two processes must remain in approximate equilibrium. If the outside erodes faster than the inside captures and stabilizes sediment, a narrow deep stream that could provide tremendous habitat for cold-water fish may become wide and shallow. As the stream widens, the stream pattern changes accordingly. Streams tend to form meanders that are approximately 7 to 10 times as long as the stream is wide (Leopold and others 1964). Characteristically, as a stream widens it breaks through meanders and the broad sweeping curves of the new channel lead to decreased stream length. Sinuosity is inversely related to channel gradient for a given reach of stream maintaining constant elevation at the top and bottom ends. Therefore, as the stream straightens, the gradient and velocity increase. The total energy is thus expended over a shorter length of channel. It can exceed critical shear and accelerate erosion.

Function of Floodplains in Stream Morphology and Gully Evolution

One of the characteristics of a narrow deep sinuous (C6) (Rosgen 1985) stream (fig. 1) is that the surface of the water is near the surface of a broad flat floodplain. The high water table provides abundant water to the vegetation that in turn provides the bank stability upon which stream morphology depends. The broad flat floodplain is necessary for dissipation of energy during flood events.

Figure 1–The broad floodplain of a narrow, deep sinuous channel dissipates flood energy allowing vegetation to build and stabilize stream banks.

Tractive force is directly related to depth of flow and slope. Therefore as a stream floods it has increased energy available to do work (erosion) on the stream channel largely in proportion to the increase in depth. A stream that can spread out over a broad floodplain increases depth only a small amount during a flood event therefore it can withstand floods of tremendous magnitude with little erosion. Such streams will generally deposit fine sediment on the floodplain and build stream banks during flood events.

As stream reaches with broad valleys capture sediment, they gradually steepen. Under natural conditions, the stream valley may become too steep for meander maintenance Patton and Schumm (1981). When meanders begin to cut and the stream straightens, the concentrated energy can downcut the channel by exporting channel materials. This can initiate a nick point that develops into a headcut (fig. 2) and proceeds upstream, assuming a life of its own.

Any net export of channel material causes the stream to lose some accessibility to its floodplain. As the floodplain loses its ability to dissipate flood energy, the energy of the confined and therefore deeper stream energy accelerates the process of downcutting until the stream reaches a gradient that is low enough, or the new channel materials are coarse enough, to stop downcutting. At this point the stream approaches local base level. A totally confined stream (gully or arroyo) on a low gradient (<1 percent) is labeled F by Rosgen (1988). Initially the stream width is the same as the gully-bottom width (fig. 3), the old floodplain is a terrace, and there is essentially no floodplain. Therefore energy is very concentrated and high water continues to do work by eroding the gully walls.

Figure 2–Headcuts concentrate the energy of flowing water, thereby accelerating erosion, downcutting, and confinement.

Figure 3–Initially downcut streams are as wide as the gully bottom and have no floodplain.

The water table that previously supported dense vegetation on the old floodplain is lowered as a result of downcutting. Riparian vegetation is then replaced by more xeric species such as sage brush (*Artemisia tridentata*) and cheatgrass (*Bromus tectorum*). The over-steepened gully walls typically remain unvegetated or lightly vegetated because of their natural instability and xeric soil conditions. Even as vegetation colonizes the water edge at the bottom of the gully wall, it is subject to extreme tractive force during high water because of the confinement of the stream. Therefore, the active channel in the bottom of a gully soon achieves a high width/depth ratio (10- 40). It stays wide and shallow until the gully walls erode apart far enough for there to develop a useful floodplain in the bottom of the gully. It then would be labeled a C type by Rosgen (1985).

The farther apart the gully walls become, the more the floodplain can dissipate energy and the more effect streambank vegetation can have in controlling the morphology of the active channel (fig. 4). As gully banks recede, there will eventually be aggradation on the expanding floodplain. Then floodplain widening can proceed under the dual influence of gully bank erosion and filling of the trapezoid-shaped gully. The gully banks define terraces that eventually may again become floodplain if the gully fills sufficiently.

At any point in the recovery, the aggrading sediments may again be cut by a new cycle of gully evolution. This cycle of aggradation and degradation has occurred repeatedly in some mountain meadows since the Pleistocene (Wood 1975). The time between cycles depends on a combination of factors including sediment supply from the headwaters, size and shape of the valley, climate, etc. Modern man has triggered the degradation phase of this cycle prematurely in thousands of locations by land use practices.

Roads and trails on floodplains are notorious for their effects on streams because of their tendency to help the stream cut through meanders. Some roads and trails have been captured by floodwaters to become stream channels. Their straight path allowed the tractive forces of floods to excavate a completely new channel, a gully. "Improved" roads may accomplish the same effect by covering part of the old floodplain area with road-fill material. This not only removes potential valley bottom for the stream to meander across but also confines floodwater and thereby increases its depth and energy.

Figure 4– The emerging floodplain of a widening gully dissipates energy and promotes vegetative stabilization of the active channel.

Other land-use activities may also produce gullies. Many stream valleys are used for transporting logs. In previous decades, the stream itself was sometimes the vehicle. The grazing effects of concentrated livestock in riparian areas is widespread where grazing management has not prevented distribution problems. Livestock grazing (or abrasion by logs) on stream banks can have the effect of caving in the overhanging banks (fish cover) that otherwise form on low-gradient meandering streams with erodible soil. As the stream banks erode from the physical effect of trampling or because of weakened root systems, the opposite bank must be able to capture and stabilize sediment in order to maintain the equilibrium and the narrow channel. If residual vegetation is not available during the period of high water, or if the grazing and trampling effects are too great, the net effect is first widening and then, if the gradient of the valley becomes too steep, downcutting. Many if not most streams located in wide valley bottoms have downcut to some extent in the last century and a half. The tremendous amount of sediment coming from these eroded stream banks and gully banks has in turn caused additional problems downstream.

Prioritizing Land Management Settings in Evolving Landscapes

Land managers must accept the history of land use that has preceded them. By understanding that history and the physical and ecological attributes of it, they can better appreciate the trend of their landscapes and the potential of those landscapes to respond to management. Effective land managers recognize the limits of their financial, physical, temporal, and managerial resources. They focus attention on land management practices that will most significantly improve resource values over some future period. In an evolving landscape, it is not useful to compare what could be with what is. One must instead compare what could be assuming option A, with what might be assuming option B. This must be done in individual settings to determine if the possible or proposed actions will be worthwhile. It also must be done in many settings simultaneously to determine where and how limited resources can do the most good. Economists term this the best marginal reaction.

Major problems or opportunities are commonly concentrated in small areas of a land unit, along certain roads, stream reaches, etc. Here is the place to begin prioritizing. However, care must be taken to avoid the approach of simply attacking that which is most ugly. Considering the evolution of stream valley degradation and aggradation discussed above, it is clear that land management input invested during certain phases of the cycle will yield far greater benefits over time than would comparable input invested during another phase.

Highest Priority Stream Reaches

The highest priority streams are the ones that still have and use their floodplain, especially if the use of it could be lost through downcutting (figs. 1 and 2). Streams that still rely on stream bank vegetation growing at the same or nearly the same level as the floodplain will be most likely to respond to appropriate riparian grazing strategies. This is in part because of the availability of water and the vegetative resilience that comes with water availability. It is also due to the energy dissipation influence of the floodplain. If the stream bank is composed of fine-grained erodible soil, especially sand, silt, loam, or fine gravel, and if the stream is or was highly sinuous (C6, C4, and C3), it is probably most dependent on bank vegetation.

If the stream has begun to downcut, it may be approaching a threshold of instability which, once exceeded, may require a long period of gully downcutting, widening, and filling to duplicate present riparian values. Proper management is especially critical in stream valleys that are long and deeply filled with erodible alluvium that has consistently depended upon streambank vegetation for streambank and meander integrity. Once headcuts form, they are very difficult to heal vegetatively. The time to act is before the threshold is exceeded and the nickpoint initiated.

Lowest Priority Stream Reaches

The lowest priority streams are the ones that are unlikely to respond to management even if they are the ugliest and even if they were once the prettiest (fig. 3) Where a stream has downcut and is totally confined in the bottom of a gully, stream energy is concentrated and management inputs are likely to be wasted. It is common for land managers to remember or presume how the meadow or streamside floodplain used to look and to want to refill the gully.

High check dams are a commonly used method for attempting to achieve this. Predictably these normally wash out. As it approaches local base level, a gully progresses through its natural evolution of widening. Behind dams, widening is accelerated because energy is redistributed against the bank at an elevated stage. Designers who recognize this often prolong the life of a dam by extending the keyways well into the banks. The concentrated energy dissipation at the dam is also a hazard if the dam is too steep on the downstream side, if the downstream banks are not adequately protected, or if the plunge pool is inadequately armored. If the dam is effective at redistributing flood waters over the old floodplain, some of the water must at some point reenter the gully. The concentrated energy dissipation at that point commonly initiates a headcut that can also bypass the dam. The hazard of this may increase as flood waters attain higher elevation behind a dam that is filling with vegetation-stabilized sediment.

It is possible to capture significant resource values, at least in the short run, with check dams in gullies (Swanson and others 1987). However, the financial cost can be high and the risk of failure increases with the quantity of water available to do work. The best application of check dam treatment is high in the watershed on small gullies that have reached local base level or where bedrock protects the lowest of a series of dams from an upstream migrating headcut. In general, low structures (1/10 to 1/4 of the active channel bankfull height) are preferred to high structures (1/4 to 2/3 gully bank height). For a discussion of how to choose the correct design for fish habitat improvement structures for particular stream types, refer to the work of Rosgen and Fittante (1986). They point out that many stream "improvement" structures, when placed in inappropriate stream types, cause more damage than benefit. Any of a variety of structures can produce benefit if properly used in the correct stream type.

Another common response to gully erosion, when it results from livestock grazing, is dramatically altered livestock management. Although protection of the riparian vegetation colonizing the gully bottom may provide some decrease in the width/depth ratio of the active channel in the bottom of the gully, and may slow the rate of gully widening, the effects are minimal. The opportunity for benefits to exceed costs are lowest in the early phases of the degradation/aggradation cycle discussed above. The marginal reaction of an investment in intensive livestock grazing management increases as the gully bottom widens.

Increasing Priority Stream Reaches

A dramatic shift in the potential of a gully bottom stream to produce a narrow stream channel conducive to cold-water fish appears to occur at about the time the gully bottom becomes wider than the active channel (fig. 4). At this time the floodplain inside the gully has begun forming and can begin to dissipate some flood energy. Riparian management and riparian vegetation then become significantly more important.

The marginal reaction of investments increases most with gully widening if the benefits are measured on site. These benefits include improved fish habitat, riparian vegetation, and aesthetics (fig. 5). To the degree that sediment is a concern downstream, the rate of gully widening (erosion) becomes more important. Sometimes the benefits of even a little riparian management and riparian vegetation along the bottom of a narrow gully prove worthwhile. However, if sediment is a big problem, the marginal reaction of investments to prevent the gully in the first place could have paid for some rather intense management. Also, such receiving streams will likely have suffered significant alteration from the sediment received after initial gully formation. Some stream types (such as flat gradient (<1 percent) gravel or sand bed streams with fine-soil banks, C3 and C4 (Rosgen 1985)) substantially increase bank erosion after an input of sediment. Sediments deposited in bars occupy channel capacity and force the stream to redistribute energy against its erodible banks. Sediment also fills reservoirs and may become trapped in coarser gravels that must be clean to provide adequate fish spawning habitat.

Other receiving streams can tolerate substantial input of sediment without significant alteration of channel morphology or resource values. The sediment is simply routed downstream to larger streams or rivers.

Figure 5– Gullies that are old, wide, and well managed become valued again for riparian vegetation, fish, and wildlife habitat, water and sediment storage, and aesthetics.

Grazing Management for Riparian Benefits

Livestock distribution is the number one grazing problem in the western United States. The heart of the problem is commonly over used riparian habitat. Controlling utilization is a central precept of grazing management. However, it must be recognized that this is not simply controlling the number of grazing animals or the length of time that they are in a pasture.

Typically cattle graze certain species and certain areas before they graze others. The species and areas are likely to change from season to season and the effect of grazing and trampling has a different effect on different species and areas at different times. This allows a careful observer to identify problem areas and practices that cause unacceptable damage. The manager can then use a variety of livestock management tools to avoid the problem. Grazing systems specify the season, the length of time, and the number of animals that can graze a pasture. Often grazing systems specify a rotation pattern so that periods of grazing that are in some way detrimental do not occur every year. Range improvements, such as water development and vegetation manipulation, that encourage livestock to increase use of previously under-utilized areas can also take pressure off riparian areas.

Perhaps the most direct means of control is a well maintained fence. Fences, however can serve diverse purposes. The design of a fence means a great deal to both the use of the area and the cost of the fence. Use of riparian exclosures has made it obvious that stopping bad grazing practices can produce tremendous benefits to streams and to fish and wildlife habitat (Platts and Rinne 1985). From riparian grazing research (Platts 1986) and accumulating experience (Elmore and Beschta 1987), it is also becoming apparent that improved grazing practices can produce improved riparian and stream conditions. Improved grazing management can do this without placing an exclosure fence in a recreation or wildlife use area.

A useful practice especially along streams with broad floodplains and expansive areas of abundant riparian vegetation is the riparian pasture (Platts and Nelson 1985). This avoids the problem of cattle concentrating in a small riparian part of very large pastures and allows grazing managers to efficiently tailor riparian grazing to optimize riparian values. Some riparian grazing management techniques such as grazing systems and seasons of use that are appropriate for particular settings are discussed by Elmore in this volume.

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