Evaluating riparian grazing guidelines on the Long Creek Allotment, Beaverhead National Forest
by Burk Jay Rhodes

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Range Science
Montana State University

Abstract:
Riparian grazing standards (RG) are being used on the Beaverhead National Forest for grazing management of riparian areas. A study was conducted to determine if RG were good predictors of stream channel morphology on the Long Creek Allotment Before and after grazing data from stream channel cross-sections and RG measurements were collected from 3 streams within the allotment over a two year period. Regression and correlation analyses were used to determine the relationships of RG parameters to measurable changes in stream channel form in response to livestock grazing. Streambank alteration, stubble height, woody plant and forage utilization were correlated with stream channel cross-sectional indices. Correlation analyses indicated that changes in stream channel form did not correlate strongly with RG parameters. Further work will be needed before RG can be used effectively for grazing management of riparian areas. We conclude that the RG parameters do not appear to be strong predictors of stream channel morphology.

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MONTANA STATE UNIVERSITY
Bozeman, Montana

May 1996

APPROVAL

of a thesis submitted by

Burk Jay Rhodes

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

17 Apr 1996
Date

Chairperson, Graduate Committee

Approved for the Major Department

April 17, 1996
Date

Head, Major Department

Approved for the College of Graduate Studies

5/6/96
Date

Graduate Dean

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Dedicated to my son, Abija Jay Rhodes.

ACKNOWLEDGMENTS

I would like to thank the Beaverhead Forest Service, Matador Cattle Co., and Montana Agriculture Experiment Station for their commitment to and funding of this research project. I would also like to thank Dr. Clayton Marlow for giving me the opportunity to pursue a masters degree at Montana State University. I would like to thank Dr. Bok Sowell for taking an active role in my research.

I would like to thank Dr. Frank Hinds for his advice, guidance, and support during my undergraduate training at the University of Wyoming. His teachings gave me an appreciation for science and a devotion toward seeking perfection.

I would like to thank my mother and father for instilling in me a sense of pride, workmanship, and honesty. Their support in my endeavors has proven to be invaluable. Most importantly, I would like to thank my wife, Cathy, and son, Abija for their support and faith in me. A more understanding, caring, and lovable wife and son I could not have.

Finally, I would like to thank all those I have failed to mention who have aided and supported me in my education. Most know who they are, and their contributions are held with highest regards.

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ABSTRACT

Riparian grazing standards (RG) are being used on the Beaverhead National Forest for grazing management of riparian areas. A study was conducted to determine if RG were good predictors of stream channel morphology on the Long Creek Allotment. Before and after grazing data from stream channel cross-sections and RG measurements were collected from 3 streams within the allotment over a two year period. Regression and correlation analyses were used to determine the relationships of RG parameters to measurable changes in stream channel form in response to livestock grazing. Streambank alteration, stubble height, woody plant and forage utilization were correlated with stream channel cross-sectional indices. Correlation analyses indicated that changes in stream channel form did not correlate strongly with RG parameters. Further work will be needed before RG can be used effectively for grazing management of riparian areas. We conclude that the RG parameters do not appear to be strong predictors of stream channel morphology.

CHAPTER 1

INTRODUCTION

Stream channel form and bank stability are important both for stream function and the biotic community structure of riparian ecosystems (Olson-Rutz and Marlow 1992; Prichard et al. 1993). Stream morphology not only dictates habitat for fish and other aquatic organisms (Bauer and Burton 1993; Platts 1979), but also regulates erosion, flow regime, and groundwater recharge (Skinner 1994; Heede 1980). Consequently, stream channel stability has become a fundamental component of the Forest Service- Bureau of Land Management (BLM) preferred management alternative described in the *RANGELAND REFORM '94 FINAL ENVIRONMENTAL IMPACT STATEMENT* (USDI-BLM 1994).

Public land management agencies intend to promulgate national guidelines and standards to achieve a 27% improvement in riparian function on BLM lands, and a 7% improvement on Forest Service lands (USDI-BLM 1994). It is intended that these guidelines would become the framework for state and local standards (USDI-BLM 1994). However, one recent Federal riparian management manual (Chaney et al. 1993), and an earlier scientific journal article (Myers and Swanson 1991) both arrived at the same general conclusion, "that each watershed, stream, stream reach, and riparian area has unique characteristics that must be accounted for in developing a grazing strategy." This poses a significant challenge to the development of national standards, because land managers must assume that all rangeland and riparian sites within the same region and forest will respond in a similar manner. If streams, or even stream reaches react differently to grazing, then the application of national standards and guidelines may prolong the controversy over livestock use of riparian areas.

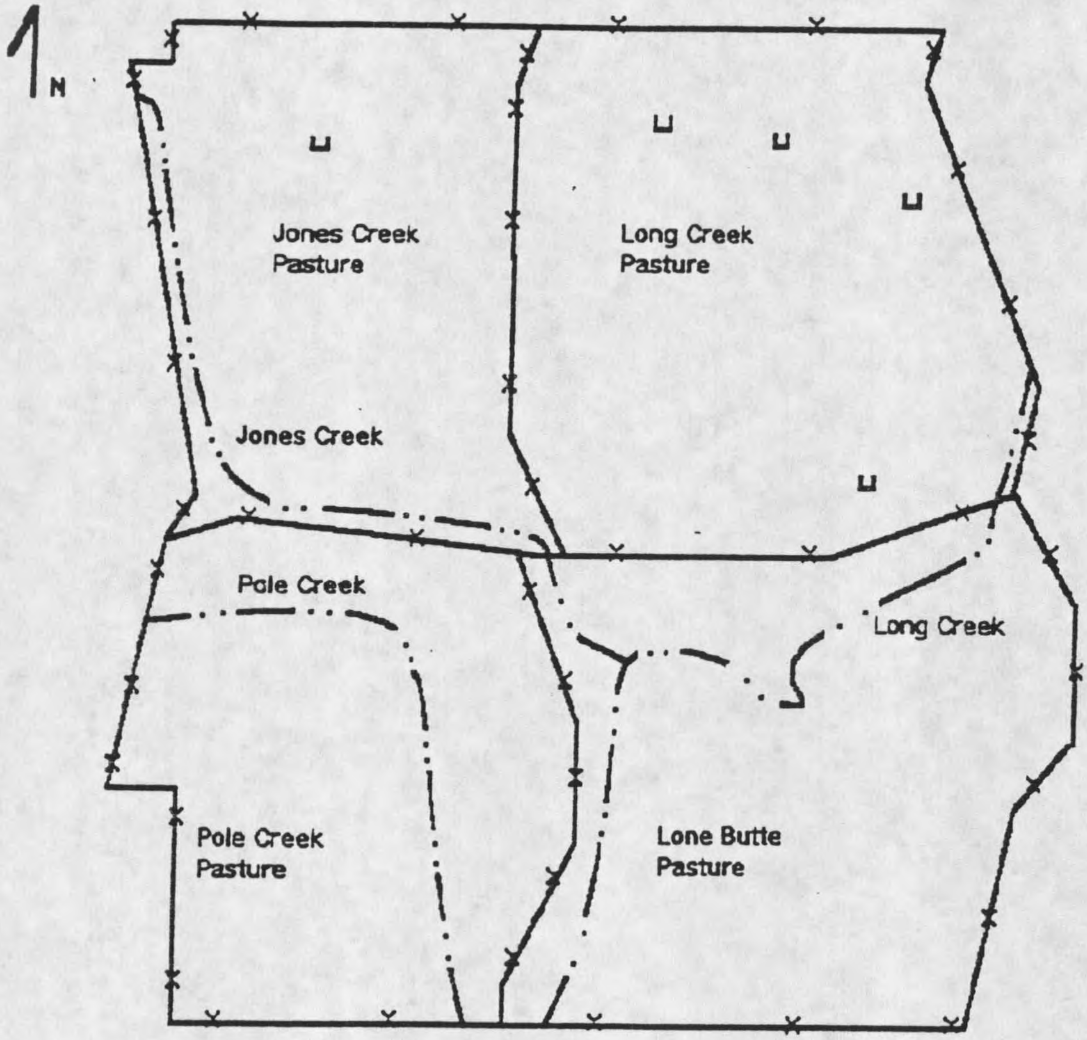
In 1991, heightened concern for riparian areas in the Long Creek Allotment, Beaverhead National Forest, and conflicts surrounding management guidelines led to the development of a memorandum of understanding (MOU) among the Beaverhead National Forest, Matador Cattle Company, and the Montana Agricultural Experiment Station (Memorandum of Understanding, USDA 1991). Objectives stated in the MOU were to evaluate the effects of the grazing management strategy developed by Resource Concepts Inc. on streambank stability, willow regeneration, upland utilization patterns, and cattle performance as compared to total herd performance (Memorandum of Understanding, USDA 1991).

Grazing History

Unrestricted livestock grazing in the upper Long Creek drainage was curtailed in 1935 when the US Forest Service established the present Long Creek Allotment boundary. From 1935 to 1962, class and number of livestock varied from 535 cows and

75 horses to as many as 1238 cows and 115 horses or 1351 sheep and 120 horses. Season of use was 1 June to 31 October for horses and 1 August to 31 October for cattle and sheep. The allotment was not grazed by livestock 1963 and 1964 when the Forest Service aerially applied 2,4-dichlorophenoxyacetic acid (2,4-D) to control sagebrush. In 1965, the allotment was fenced into four pastures, Pole, Jones, Long Creek, and Lone Butte (Fig. 1), and a four pasture rest-rotation management system was implemented. Season of use was set at 90 days, from 16 July to 15 October, for 800 cow/calf pairs. In 1986 concerns over increasing sagebrush caused Matador Cattle Company to voluntarily reduce the permit by 200 cow/calf pairs (Manoukian 1994). Further reductions in livestock grazing were discussed in 1989 due to concerns over riparian condition. This prompted the development of a double rest-rotation grazing system which would be administered under a Memorandum of Understanding between the Matador Cattle Company, the Beaverhead Forest Service, and the Montana Agricultural Experiment Station (MOU 1991).

In 1994, after a thorough evaluation of the willows (Manoukian 1994), the need for a more direct assessment of the streambank monitoring protocol was recognized. Therefore, this study was designed to compare the proposed riparian use guidelines to measurable changes in stream channel form at a constant level of livestock use, and evaluate their ability to predict stream channel change in response to livestock grazing impacts.



Legend:

Stream	—— · · ——
Fence	—X——X—
Water Trough	⊔
Scale	├──────┤ ≅ 1 km

Figure 1. Location of pastures and main streams within Long Creek Allotment.

CHAPTER 2

LITERATURE REVIEW

One of the major problems facing riparian ecosystem management today is the inability of managers to objectively monitor user impacts on stream channel systems in a measurable and repeatable way (Olson-Rutz and Marlow 1992; Platts et al. 1987). Marlow et al. (1991) noted that rising public concern necessitates monitoring of stream channel and riparian systems. However, Platts et al. (1987) indicated that resource managers had inadequate guidelines for determining existing and potential impacts on riparian systems because methods that document and monitor riparian ecosystems had not been adequately developed. They also stated that resource managers regularly made decisions based on measurements that were assumed to correctly describe stream habitat. Yet, time optimization rather than accuracy is often the most influential factor used to design stream monitoring systems, and as a result, resource management decisions can be made with inadequate information (Rinne and LaFayette 1991).

Monitoring is used to measure responses to land management practices and determine whether management objectives are being met (Meyers 1989; Platts et al.

1987). Platts et al. (1987) outlined seven steps of a monitoring program that would give meaningful results. Myers (1989) and Cagney (1993) recommended similar approaches.

Step one: Platts et al. (1987), stated that documentation of existing baseline condition, site potential, and factors preventing the system from reaching potential were necessary to begin a riparian monitoring program. Otherwise, it is impossible to determine if conditions are improving or not (Cagney 1993). A word of caution is given with this step, for if site or stream potential is evaluated too high then a failure to meet management objectives will occur. Further, management objectives must be compatible with site potential, an idea that has been stressed by others (Skinner 1994; Meyers 1989).

Step two: The development of realistic, quantifiable, and measurable goals, as Platts et al. (1987) noted, "...is of paramount importance". Cagney (1993) stated, "...if objectives are not established, success cannot be measured and direction is lost." Platts et al. (1987) further stressed that riparian habitat objectives must be compatible with the overall multiple-use plan (Platts and Rinne 1985).

Step three: Design site-specific management plans. This requires multiple-use planning and conflict resolution.

Step four: Designing the monitoring program should take into account several key considerations:

A) Measurement of response to management and determination through hypothesis testing if objectives have been met. The variable of choice must be responsive to the management that will be applied, and the measurement of that response with a given level of precision and accuracy must be obtainable.

B) Control areas not receiving management treatments should be included. These areas need to have the same characteristics and same potential for response to management.

C) Monitoring needs to be conducted over a long enough period for management responses to occur (Rinne and LaFayette 1991).

D) Management must remain consistent over time. Platts et al. (1987) noted this is one of the major factors inhibiting most studies (Rinne and LaFayette 1991).

E) Confounding factors must be controlled or accounted for.

F) Proper statistical tests need to be designated when the monitoring program is designed, and the underlying assumptions of those tests must be met (Hurlbert 1984; Eberhardt and Thomas 1991).

Step five: Conduct a pilot study. This is to help insure that meaningful statistical tests are feasible. Once this has occurred, management can be applied and monitoring can proceed (step 6). Care must be exercised to insure the quality and properties of the data collected so that bias is prevented from influencing results (Hurlbert 1984).

The final step outlined by Platts et al. (1987), is the employment of statistical tests, with predetermined confidence levels, to determine whether objectives have been met. The authors further emphasized that pass/fail conclusions should be avoided.

As Kauffman and Krueger (1984) noted, much of the riparian grazing literature contains opinions rather than good science. and indicates that little effort has been put into testing riparian area measurements or management guidelines.

Beaverhead Riparian Guidelines

The Beaverhead Riparian Guidelines (RG) is a method used to determine when livestock should be removed from riparian areas. The sensitivity level of an area, as determined by an interdisciplinary team, and its inherent stability, determined from the potential community type, are combined to produce a rating for determining the amount of allowable alteration by livestock in each of four parameters (Table 6). The four parameters are: 1) bank alteration; 2) stubble height; 3) woody plant or browse utilization; and, 4) forage utilization. Bank alteration is determined by measuring the amount of streambank that has been altered by livestock on each side of a 30 m transect. Stubble height is measured along the soil-water interface and in "key areas" where palatable species exist. Browse utilization is measured by determining the length of the current years growth that has been removed, and forage utilization is also measured in "key areas". Forage utilization is determined as percentage weight removal of forage species.

The RG are used to determine when livestock should be moved from an area. When any one of the RG parameters have been met by livestock use, the livestock should be moved from that area. Secondly, records of RG variables can be kept as part of a grazing record and monitoring effort. However, it is unclear whether a trend could be established with just this data.

Although many measurement techniques have been proposed for stream channel systems, little work has been done to test these methods for their ability to assess “user” impacts on stream channel form and function (Platts et al. 1987; Platts et al. 1983). In one of the earlier attempts, Platts et al. (1983) found that natural variability in time and space inhibited consistent results for most measurement techniques. They found that subjective measurements determined from narrative descriptions lowered the precision ratings of those measurements and limited inferential ability. For example, streambank soil alteration ratings could, at best, detect a change of ± 16% in the true mean. The authors further noted difficulty in training individuals to visualize the same optimal bank condition.

Evidence supporting the use of riparian grazing guidelines is scarce. Another paper (Clary and Webster 1990), recommended streamside vegetation utilization levels for different seasons of the year. They suggested that the primary concerns with grazing riparian areas should be the herbaceous plant community, the woody plant community, and streambank morphology. No evidence was provided to support their recommendations.

Hockett and Roscoe (1994) provided guidelines which define resource threshold levels for livestock-caused damage to streambanks, herbaceous, and woody components of riparian systems in southwest Montana. They did not discuss statistical design or monitoring strategies, and no study, reference, or other evidence was provided to support their recommendations.

Streambank Stability

Principal factors affecting streambank stability are streamflow characteristics, physical properties of the bed and bank material, geometry and stratigraphy of the banks, seepage forces, climatic conditions, and vegetative protection (Alonso and Combs 1990). The two most common causes of bank instability are channel bed degradation and lateral erosion (Osman et al. 1988; Alonso and Combs 1990). Little et al. (1982) noted that banks retreat primarily by mass failures due to overheightened and oversteepened banks.

Lateral erosion occurs when the critical shear stress acting on the streambank exceeds the critical shear stress of the bank. Similarly, lateral erosion increases the channel width, and causes instability by oversteepening the streambanks (Osman et al. 1988). Hydraulic scour of the bed and bank toe increases the bank's height and slope angle, decreasing its stability with respect to gravity induced mass failure (Alonso and Combs 1990; Osman et al. 1988). The amount of erosion is a function of bank material properties, bank geometry, type of bed material, and flow characteristics (Osman et al. 1988; Hooke 1979).

Sloughing or sliding of streambanks is usually caused by a reduction of the bank's internal strength which can be caused by saturation, foundation deterioration caused by seepage, piping, or undermining of the toe of the channel bank, or any combination of these factors (Alonso and Combs 1990; Little et al. 1980). The susceptibility of cohesive banks to erosion is dependent on their moisture content and degree of weathering, as well as bank slope angle and height (Alonso and Combs 1990). Hard, dry banks are very resistant to erosion, while wet banks are easily eroded.

Riparian Vegetation

Riparian vegetation is often implicated as one of the key factors controlling streambank stability. However, little information is available on the subject and it suggests that our knowledge of stream vegetation and channel stability is lacking. Most research on effects of grazing on riparian vegetation focuses on plant responses, not impacts on streams. For example, in a grazing simulation study, Clary (1995) concluded that "many of the land management agency riparian guidelines would maintain biomass productivity in these sedge-dominated communities." Similarly, Allen and Marlow (1994) concluded that beaked sedge (*Carex rostrata* ex With.) was tolerant of light to moderate grazing, given adequate regrowth between spring and fall grazing.

Vegetation is apparently successful at controlling channel erosion only when the scouring forces causing channel degradation are eliminated (Shields et al. 1995; Bowie 1982). Shields et al. (1995) determined that vegetation is useful for protecting banks against some types of erosion, but it cannot stabilize banks against the effects of mass gravity failure. However, several authors suggest that riparian vegetation plays an important role influencing channel stability (Gregory and Gurnell 1988; Beeson and Doyle 1995).

Ree and Palmer (1949), as cited in Temple (1985), indicated that maintaining a channel in a regularly mown condition results in very dense and uniform cover, which provides protection from erosion at the soil boundary. Similarly, Abt et al. (1995) determined that vegetation stubble heights of 7.6 cm or less tended to enhance sediment deposition, and those greater than 7.6 cm tended to retain sediment that has been deposited. In contrast, Frasier et al. (1994) could find no relationship between riparian vegetation height and sediment deposition from runoff water.

The importance of riparian vegetation is unclear from the literature. However, riparian vegetation alone does not control streambank stability (Trimble 1994). Three of four RG criteria involve vegetation, while the fourth is largely an index of bank trampling. Use of the RG assumes that vegetation and impacts of grazing on vegetation are important to stream form. In addition, the RG assume that the field measurements used to index grazing pressure are useful for predicting stream channel changes. Further testing and study of the use of riparian grazing guidelines is needed before they can be recommended for stream protection under livestock use. Specifically, relationships between riparian guideline parameters and stream channel stability need a more in depth analysis.

CHAPTER 3

MATERIALS AND METHODS

Study Site Description

The study site lies within the Long Creek Forest Service allotment, Beaverhead National Forest, approximately 71 km southeast of Dillon, Montana. The Long Creek allotment occupies the southern face of the Ruby Valley-Centennial Valley divide and ranges in elevation from 2133 m to 2426 m. Upland vegetation is dominated by the mountain big sagebrush (*Artemisia tridentata* Nutt.)/Idaho fescue (*Festuca idahoensis* Elmer.) habitat type (Mueggler and Stewart 1980). Riparian habitat types consist of the Geyer willow (*Salix geyeriana* Anderss.)/beaked sedge (Carex rostrata Stokes), and shrubby cinquefoil (*Potentilla fruticosa* L.)/tufted hairgrass (*Deschampsia cespitosa* (L.) Beauv.) habitat type (Hanson et al. 1995), but is dominated by Kentucky bluegrass (*Poa pratensis* L.) and Booth willow (*Salix boothii* Dorn). Annual precipitation ranges from 35.5 cm to 76.2 cm with most occurring during winter and spring (USDA SCS 1973).

The allotment is located on an ancient erosional surface that has been preserved along the crest of the adjacent Gravelly Range. The surface is gently rolling with underlying rocks, deeply weathered, and prone to landslides; while ridges are underlain by more resistant sandstone. The ancient surface is overlain in places by gravels, which in turn are overlain by a thick pre-glacial soil that is preserved in only a few small areas (Rupple 1993). Drainage is strongly rectilinear, and controlled by fractures in the bedrock. Streams are fed primarily by groundwater, which is also fracture controlled (Rupple 1993).

The current grazing plan was developed by Resource Concepts Inc. (1991), and initiated during the 1991 grazing season (Table 1). Under the grazing plan cattle

Table 1. 1991-1995 grazing schedule for the Long Creek Allotment, Beaverhead National Forest.

	Grazing Schedule			
Year	**Pole Creek**	**Lone Butte**	**Long Creek**	**Jones Creek**
1991	Grazed	Rested	Grazed (late)	Grazed (mid)
1992	Grazed	Rested	Grazed (mid)	Grazed (late)
1993	Rested	Grazed	Grazed (late)	Grazed (mid)
1994	Rested	Grazed	Grazed (mid)	Grazed (late)
1995	Grazed	Rested	Grazed (late)	Grazed (early)

numbers were to be increased to approximately 800 cow-calf pairs. This produced a stocking rate of 1-1.5 ha/AUM from mid July to mid October. Grazing in the Jones Creek and Long Creek pastures rotated yearly between mid and late season use (deferred). The Pole Creek and Lone Butte pastures were grazed for two years, followed by two years of rest (double rest-rotation). Livestock grazed each pasture for approximately 3-4 weeks, and were moved when the stubble height of riparian grasses had been reduced to approximately 3-4 inches as mandated in the Beaverhead Forest Plan (USDA-FS 1986).

Twelve sample stations, consisting of 3 cross-sectional transects per station, were systematically located on streams throughout the Long Creek Allotment, and were divided evenly among the four pastures. Sample sites were located in areas of high, moderate, and low levels of livestock use within each pasture (Manoukian personnel comm. 1994). In an effort to account for natural variation in stream morphology two exclosures were used. An exclosure was located in both the Pole Creek and Lone Butte pastures, to exclude all large animal herbivory. One sample station was established within each of these exclosures. The Lone Butte and Pole Creek game exclosures (LB0 and PC0) had not been grazed since 1990.

Permanent transects were marked at 15 m intervals and placed across the channel perpendicular to water flow, consistent with the methods of Olson-Rutz and Marlow (1992). Stakes were placed with the endpoints, 0.1 - 0.2 m inland from high water edge, and driven to a depth sufficient to insure permanency. A line level was used to set the horizontal line from which depth was measured, and reset to these measurements each time the transects were measured. The distance from the transect tape to the channel bottom was measured with a stadia rod every 10 cm along the tape, always beginning on the right side of the channel while facing downstream.

Stream channel cross-sections and Beaverhead Riparian Guideline measurements were collected from each sample site over a two year period. Stream channel transects were measured before the cattle entered the allotment (July), and after the cattle left each pasture of each year. This produced 30 before and after channel cross-sectional observations for each grazed station in 1994 and 1995. Training and calibration in the use of the Beaverhead Riparian Guidelines was provided by a Forest Service Range Conservationist, to assure proper usage of the standards. Forage utilization was determined from ocular estimates during the study period.

Stream channel cross-sectional measurements were analyzed according to the methods of Olson-Rutz and Marlow (1992), and Rhodes and Marlow (1996). This methodology uses four indices to evaluate change in channel morphology over time. The indices are net percent change in area (AREA), absolute percent change in area (ABS), width/depth change (W/D_{change}), and the Gini coefficient change (G_{change}). These four indices can be used to identify morphologic changes occurring on any stream system.

The net percent change in area under a transect is used to quantify either degradation or aggradation of a stream channel. AREA values quantify the net change in cross-sectional area under the stream channel transect, and are calculated in the following manner[1]:

$$AREA = \frac{\sum_{i=1}^{n} Y_{iafter} - Y_{ibefore}}{\sum_{i=1}^{n} = Y_{iafter}} \quad X\,100$$

Y_i is the distance from the transect line to the streambank, or streambed at the ith point along the transect line, while n is the total number of points measured along the transect.

[1] Corrected formula (Pers. Comm. C.B. Marlow 1995).

The absolute percent change in area under a transect is used to quantify cumulative streambed or bank material movement. Degradation at one point under a transect can be balanced by an equal amount of aggradation at another point (Olson-Rutz and Marlow 1992). This can be dealt with by calculating the absolute percent change in area under the transect, as follows[2]:

$$ABS = \frac{\sum_{i=1}^{n} \left| Y_{iafter} - Y_{ibefore} \right|}{\sum_{i=1}^{n} Y_{iafter}} \quad X\ 100$$

Channel W/D is a relative index of channel shape, and is used to relate channel morphology to water and sediment discharge (Heede 1980). Width measurements are fixed by the width of the channel cross section, while depth is the mean depth across the channel bottom (Heede 1980), and can vary through time. The W/D value is expressed as a difference ($W/D_{diff} = W/D_{post} - W/D_{pre}$) or a percent ($W/Dchange = (W/D_{post} - W/D_{pre} / W/D_{post})*100$). Negative values for W/D indicate the channel has become deeper.

The Gini coefficient is used to describe the cross-sectional profile of the stream channel. The Gini coefficient is calculated from pre and post treatment data to quantify change in channel form. Gini coefficients can range in value from 0 to 1. A horizontal line would be depicted by 0, while 1 would represent a vertical line. The coefficient is derived from this equation:

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[2] Corrected formula (Pers. Comm. C.B. Marlow 1995).

$$G = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}|Y_i - Y_j|}{2n^2\overline{Y}}$$

which is the arithmetic average of the absolute values of differences between all pairs of depth measurements.

The difference describes the change in channel shape over time, and can be expressed as a difference ($G_{diff} = G_{post} - G_{pre}$), or as a percent ($G_{change} = [(G_{post} - G_{pre}) / G_{post}]*100$). Positive values for G_{change} indicate that the channel is becoming deeper and narrower, while negative values indicate that the channel is becoming wider and shallower.

Regression and correlation analyses were used to evaluate the relationships among riparian guideline measurements and changes in stream channel morphology in response to livestock use. Missing RG data prior to 1994 prohibited the use of long term data. Stubble height measurements were used in two different ways to determine their predictive ability. First the raw values for stubble height were considered for all analyses, which is prescribed by the RG. Secondly, percentage change in stubble height was calculated and used in the analyses in an effort to represent livestock use. When stubble height was considered as a percentage change, several additional observations from the big game exclosures could be included as "zero percent change." Correlation analyses were used to determine general associations between all variables. Multiple linear regression was used to determine the ability of RG parameters to predict stream channel form in response to livestock grazing (SAS Institute 1988).

Stream channel cross-sectional indices were regressed on the RG measurements. Year effects and all interactions were included in the models. When year effects, and (or)interactions were found to be insignificant (P>0.05) they were dropped from the model and reduced models were calculated. All main effects, significant year effects, and significant interactions were included in the reported models. Partial mean squares for regression coefficients were tested for significance (P<0.05) using F-statistics. All tests were considered statistically significant at the α=0.05 level.

CHAPTER 4

RESULTS

Correlation Analysis

Data from 1994 and 1995 were combined for the correlation analysis to improve the strength of statistical tests. Exploratory correlation analyses indicated that relationships were unchanged regardless of whether years were considered separately or combined.

Results of the correlation analysis suggest the RG parameters were not strongly associated with stream channel morphology (Table 2, and 3). For example, the strongest individual correlation, between G_{change} and stubble height, could only explain 19% of the observed variability in stream channel response during the grazing season (Table 3).

Forage utilization was the RG parameter that was most related to changes in stream channel morphology in response to livestock grazing regardless of how stubble height was considered. This is likely a result of the duration of livestock use rather than a direct relationship between vegetation and stream morphology, because vegetation does not appear to be a primary factor controlling channel stability (Sheilds et al. 1995; Trimble 1994).

Table 2. Correlation coefficients among stubble height (S), forage utilization (F), woody plant utilization (W), altered bank (A), and cross-sectional indices using raw stubble height measurements, Long Creek Allotment 1994-1995.

	AREA	ABS	G_{change}	W/D_{change}	S	F	W	A
AREA	1.00							
ABS	0.39**	1.00						
G_{change}	-0.66**	-0.27*	1.00					
W/D_{change}	-0.35**	0.16	-0.11	1.00				
S	-0.22	-0.08	0.29*	0.14	1.00			
F	0.22	0.31*	-0.29*	-0.04	-0.77**	1.00		
W	0.15	-0.13	-0.29*	-0.24	-0.48**	0.29*	1.00	
A	0.002	0.19	0.03	0.10	-0.19	0.17	0.19	1.00

*, ** Indicates significance at the 0.05, and 0.01 levels, respectively.

Of the cross-sectional indices, G_{change} had the most consistent association with the RG parameters, producing 3 significant ($P<0.01$) correlation's with stubble height, forage, and woody utilization (Table 2, and 3). Conversely, W/D_{change} was not correlated ($P>0.05$) with any of the RG parameters. These relationships held true using the raw stubble height measurements, as well as the percent change in stubble height calculations.

Table 3. Correlation coefficients among stubble height (%S), forage utilization (F), woody plant utilization (W), altered bank (A), and cross-sectional indices using percentage change in stubble height measurements, Long Creek Allotment 1994-1995.

	AREA	ABS	G_{change}	W/D_{change}	%S	F	W	A
AREA	1.00							
ABS	0.36**	1.00						
G_{change}	-0.69**	-0.25*	1.00					
W/D_{change}	-0.30*	0.16	-0.15	1.00				
%S	-0.27*	-0.20	0.43**	-0.06	1.00			
F	0.28*	0.30**	-0.38**	0.02	-0.81**	1.00		
W	0.21	-0.08	-0.37**	-0.16	-0.46**	0.43**	1.00	
A	0.09	0.20	-0.11	0.15	0.01	0.35**	0.34**	1.00

*, ** Indicates significance at the 0.05, and 0.01 levels, respectively.

Colinearity existed among many of the measured variables. This complicated efforts to develop meaningful relationships. Several highly significant correlation's ($P<0.01$) existed among RG parameters and among cross-sectional indices. However, correlation's among cross-sectional indices did not affect the analyses because the indices were considered dependent variables. When raw stubble height measurements were used, altered bank was the only RG parameter not associated with the other RG parameters (Table 2). However, when stubble height was considered as a percentage change, the only two RG parameters not correlated ($P>0.05$) with each other were altered bank and percent change in stubble height.

Regression Analysis

Regression results indicated that RG parameters explained very little of the observed variability in stream channel form in response to livestock grazing. Using the four independent variables, the model with the largest r^2 explained 51% (r^2=0.51) of the variability in stream channel form (Table 5). This occurred when ABS was used as the dependent variable, and percentage change in stubble height was considered rather than the raw stubble height measurements. However, when the raw stubble height measurements were used, year became a significant factor (Table 4). Several significant interactions, including some with year, occurred regardless of how stubble height was considered.