The Alkali Creek Story: 40 Years of Gully Control

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In the early 1960s, Burchard Heede of the Rocky Mountain Forest and Range Experiment Station designed and implemented a whole-basin (356-hectare) gully restoration plan in Alkali Creek, Colorado. This modest experiment and its results still serve as some of the benchmark research in gully control 40 years later. The project elements included perimeter fencing for cattle exclusion, check dams in a variety of forms, headcut control measures, revegetation, and conversion of several gullies to vegetation-lined waterways. These original designs are presented along with a discussion of findings after approximately twelve years, as well as the present status four decades after project implementation.

Keywords: *watershed restoration, gully control, check dams, vegetation-lined waterways, riparian vegetation*

Introduction

Many of the specific details of the Alkali Creek experiment are chronicled in detail in a number of publications by Burchard Heede (e.g., Heede 1976, 1977). Therefore this paper focuses on how the project came into being, what was done and why, and the resulting changes after four decades.

Study Area

Location

The study site is located in the headwaters of Alkali Creek on the Rifle Ranger District of the White River National Forest, approximately 32 km south of Silt, Colorado. Alkali Creek is a tributary to West Divide Creek, which enters the Colorado River at Silt. The 356-hectare study site ranges in elevation from 2,320 to 2,560 m.

Climate

The annual temperature varies from a maximum mean monthly temperature of 27°C in July to a minimum mean monthly temperature of -16°C in January. Between 1962 and 1974 the project area received about 48 cm of precipitation annually. Precipitation throughout the year was fairly evenly distributed with a low of 3 cm in January to a high of nearly 6 cm in September (Heede 1977). Snow is typical between October and April.

M Furniss, C Clifton, and K Ronnenberg, eds., 2007. *Advancing the Fundamental Sciences: Proceedings of the Forest Service National Earth Sciences Conference, San Diego, CA, 18-22 October 2004*, PNW-GTR-689, Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Vegetation

The project area is representative of the oakbrush-sagebrush-grasslands of the western slope of the Rocky Mountains in Colorado. Sagebrush (*Artemisia* spp.) and grasslands primarily occupy the valley bottoms and southern aspects while thick stands of oakbrush (*Quercus gambeli*) dominate the upper parts of the northern aspect. Typical grasses include Kentucky bluegrass (*Poa pratensis*), western wheatgrass (*Agropyron smithi*) and small amounts of introduced crested wheatgrass (*Agropyron cristatum*). Small amounts of serviceberry (*Amelanchier alnifolia*) and snowberry (*Symphoricarpos albus*) are present along with occasional groups of aspen (*Populus tremuloides*) near the valley bottom.

Geology and Soils

The parent geology of the project area is the Tertiary Wasatch formation, which is composed of clay shale and sandstone. The sandstone varies from fine- to coarse-grained and, in places, is strongly calcareous.

The soils are formed predominantly from shale and beds of sandstone (Fox and Nishimura 1957). Mechanical analysis of the soil done in the mid-1960s showed the distribution of clay, silt, and sand averaged 52%, 28%, and 20%, respectively, with the clay content as high as 65% (Heede 1977). Coarse materials, such as gravel or boulders, are essentially absent from the gullies.

Soil properties were measured in the early 1960s during project design. The disturbed soils in the valley bottoms, where grazing pressure was concentrated, typically had infiltration rates that were 4 to 5 times lower than adjacent upslope oakbrush areas with relatively light grazing impacts. The compaction of valley floor soils decreased the amount of precipitation needed to generate overland flow and led

to the subsequent erosion of gullies into the fine grained soil. Recovery of soil porosity and permeability would eventually be a key component in the stabilization of the drainage network.

Gully Stream Flows

Stream flows in the gullies typically occur only during the spring snowmelt and at times of intense summer thunderstorms. During 1963 and 1964, the measured peak spring runoff in the project area was 0.57 to 0.71 m^3/s (20 to 25 ft^3/s). Heede (1977) determined these to be normal precipitation years bases on regression with nearby long term weather stations in Collbran and Glenwood Springs, Colorado. Measured peak discharges in 2005, an average precipitation year, did not exceed 0.09 m^3/s (3 ft^3/s). These measurements corroborate past observations in project file memos of considerable overland flow during snowmelt prior to project implementation versus little evidence of overland flow today.

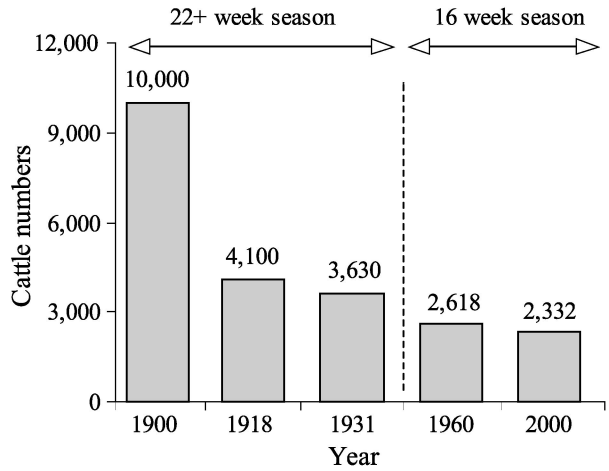
Grazing History

The Alkali Creek watershed is a small part of the 182-km^2 West Divide cattle allotment. The south aspects of the project area also serve as winter range for elk (*Cervus elaphus nelsoni*) and mule deer (*Odocoileus hemionus hemionus*).

Cattle grazing likely began in the watershed commensurate with the settlement along the Colorado River and its tributaries in the late 1800s. Local ranchers estimate that as many as 10,000 head of cattle grazed the present allotment boundaries in the early 1900s. Figure 1 shows the change in cattle numbers within the West Divide allotment over time. A notable feature of Figure 1 is the reduction in the grazing season from 22 weeks to 16 weeks that occurred in the mid 1950s. This reduction occurred in the early part of the season, which kept the cattle off the soils soon after snowmelt when moisture content was more likely to be optimum for detrimental soil compaction.

As early as 1916 there are written accounts in the allotment files from the range conservationist discussing the poor condition of the watershed. This led to decreasing stock numbers through the 1940s. In the late 1940s, a range conservationist named Carl Henderson began documenting the range conditions in the Alkali watershed. There are numerous summaries and field reports in the allotment file that chronicle "excessive overland flow from depleted range." His recommendation was to cease grazing in Alkali Creek altogether. The proposal at the time was a 31 percent reduction in cattle numbers, which he

Figure 1. Bar graph of cattle numbers on the West Divide allotment. Data from the White River National Forest grazing allotment file records and from Heede (1977).



described as "too little, too late." Figures 2, 3, and 4 show the conditions that Carl Henderson saw on the ground. The soil pedestal supporting the large boulder in Figure 2 illustrates the significant loss of topsoil (and therefore water storage) in the area prior to 1957.

The series of photos in Figure 5 depicts the type of changes that occurred on the landscape between 1915 and present. There are anecdotal accounts of being able to cross the gullies shown with on horseback or in a wagon in 1915 (note the line and dots for reference). Between 1915 and 1949 considerable gully incision occurred. The gully widened and stabilized with less bare ground visible by 2004.

Project Development

The gully network, along with the efforts of Carl Henderson to elevate the issue of range condition to the District Ranger, led to the development of the Alkali Creek

Figure 2. Soil pedestal supporting large boulder in 1957 photo. Note camera at the pedestal base for scale. Photo by P. Hauk.

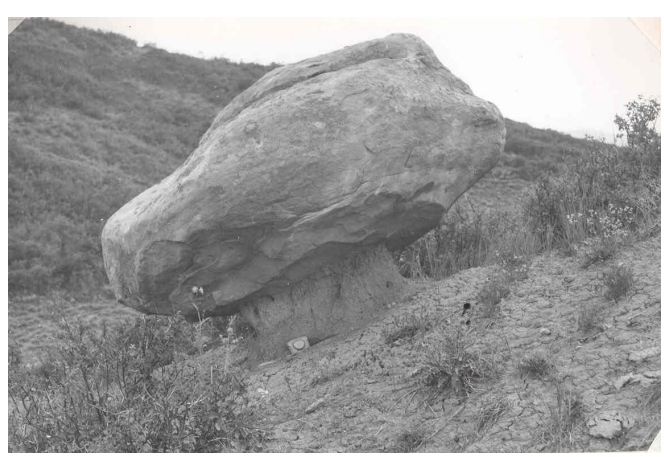


Figure 3. Gully development through former cattle watering location at Mud Springs in 1949. Gully depth is approximately 5 meters. Photo by C. Henderson.

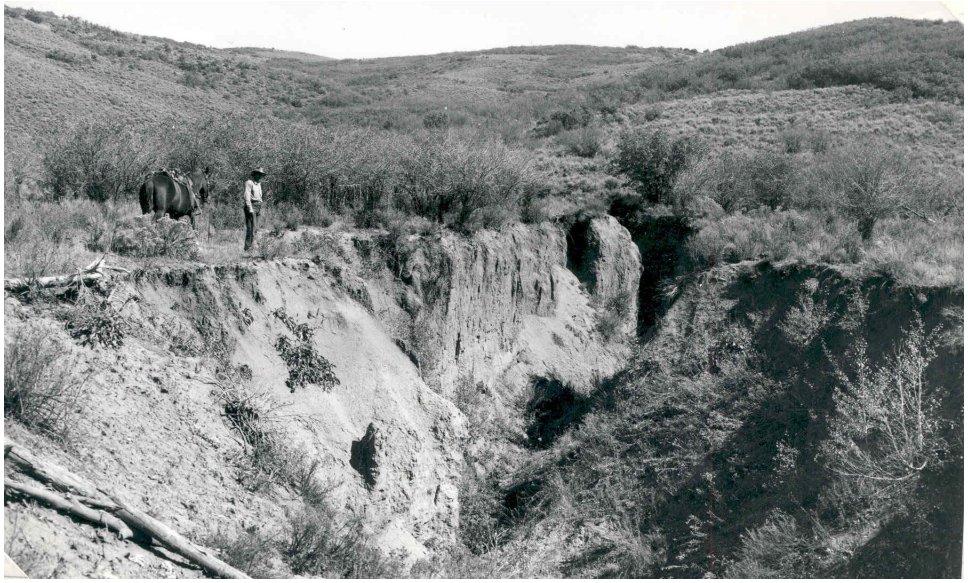


Figure 4. Main gully in 1947 near the downstream end of the eventual project area. Photo by C. Henderson.

Soil and Water Project. The project had a scope larger than active gully control, and included the following:

1947-48 – Construction of stock ponds to distribute cattle away from streams.

1951 – Seeding of 49 ha of disturbed ground with grasses.

1952 – Contour trenching on selected hill slopes to enhance water infiltration.

1953 – Seeding of 53 ha of disturbed ground with grasses.

1958 – Perimeter fencing to exclude cattle from a 356-ha area in Alkali Creek.

1959 – Boy Scouts plant 500 New Mexican locust trees (*Robinia neomexicana*), all of which died.

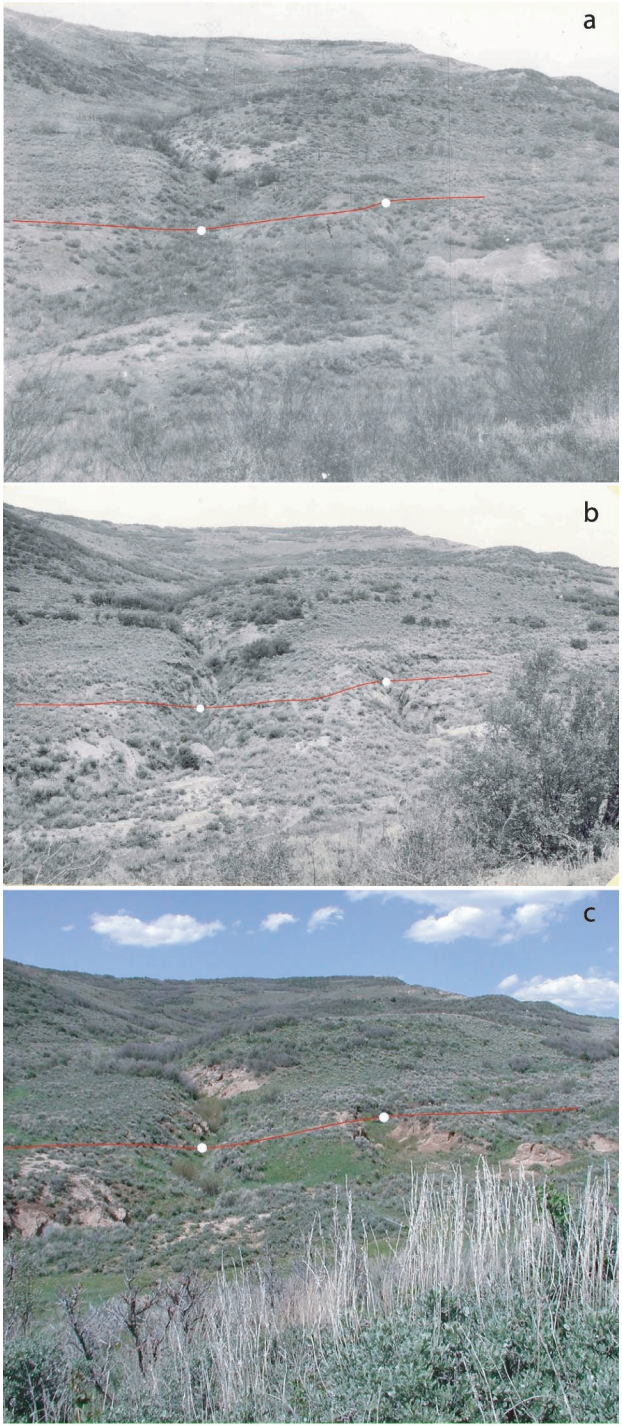
1960 – Cooperative agreement between the White River National Forest, the Rocky Mountain Regional Office (FS Region 2), and the Rocky Mountain Forest and Range Experiment Station for an experimental watershed/gully restoration project in the fenced area of Alkali Creek.

1961-1964 – Gully treatments installed.

Burchard Heede was the principal investigator from the Range and Experiment Station in Fort Collins, Colorado. He designed the gully restoration project, prepared the construction plans, and evaluated the results. The White River National Forest provided the labor and equipment needed to accomplish the survey work and project implementation. The Rocky Mountain Regional Office, Division of Watershed Management, provided funding for the project.

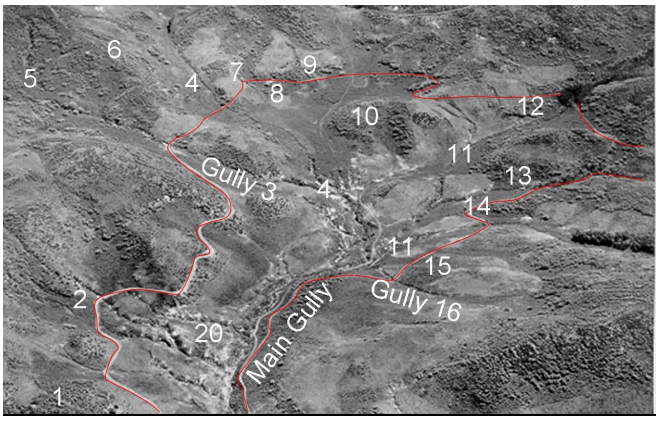
Initial survey and design work began soon after the agreement was in place and the first gully control structures were installed in 1961. A road was constructed in 1962

Figure 5. (a) Gully No. 4 as photographed from control point CP-39 in 1915. Note that it can still be crossed by wagon or on horseback (see horizontal line and dots for location). File photograph. (b) By 1949 the gully had deepened considerably, with very steep side walls. Photo by P. Hauk. (c) By 2004, the gully had stabilized and the side walls had flattened and become more vegetated. Photo by M. Weinhold.



to provide equipment access to the gullies higher in the basin. Figure 6 shows the location of the access road and the numbered gullies proposed for treatment. Project implementation was largely complete in 1963, with maintenance occurring throughout 1964.

Figure 6. Oblique view of the Alkali Creek project area. The red line shows the alignment of the access road. The numbers identify gullies proposed for treatment. File photograph.



Treatments included an assortment of check dams, headcut treatments, and vegetation-lined waterways. The type and number of structures are shown in Table 1. A variety of treatment types with different unit costs was intentionally used because cost effectiveness was a key component of the project evaluation program.

Table 1. Gully treatment types employed at Alkali Creek, Colorado.

Structure Type	Number Used	See Figure No.
Precast concrete check dam	1	12
Loose rock check dam	56	7, 13
Gabion check dam	7	7
Single fence rock check dam	12	8
Double fence rock check dam	40	9, 11
Headcut control structure	15	
Vegetation-lined waterway	4	10, 14

Gabion and loose rock check dams (Figure 7) are essentially the same type of structure, except that the former is wrapped in a wire fence mesh for added stability. Single fence check dams, shown in Figure 8, used steel fence posts and wire fence to support the rock fill on the downstream side to reduce the amount of rock required for construction. Similarly, double fence rock check dams (Figure 9) had post and wire fences on the upstream and downstream faces of the structure, with a 60-cm-thick layer of rock between. Headcut armoring consisted of

Figure 7. Typical loose rock check dam, in this case wrapped in wire mesh for added stability. Photo by B. Heede.

Figure 8. Typical single fence check dam. Photo by B. Heede.

placing a layer of rock over the flattened headcut with a loose rock check dam immediately downstream.

Four gullies were converted to vegetation-lined waterways. While this method had been successfully employed in flat farmland across the country, this was a new approach to gully restoration on mountain slopes. The existing gullies were filled and a new, wider sinuous channel was built. Increased sinuosity extended the length of the waterway and consequently reduced the gradient. The combination of a lower gradient and shallow, wide cross section decreased the erosive energy of the water so that a thick layer of vegetation would prevent gully development. The sequence of construction is shown in Figure 10.

Results and Discussion

The photo pairs in Figures 11 through 14 clearly show the recovery that occurred in the Alkali Creek watershed over the last four decades. In each case, the initial photo was taken soon after project implementation in the early

Figure 9. Typical double fence check dam. Photo by B. Heede.

1960s and the second photo was repeated in 2004. An effort was made to reoccupy the same photo point and provide a person in the same location for scale.

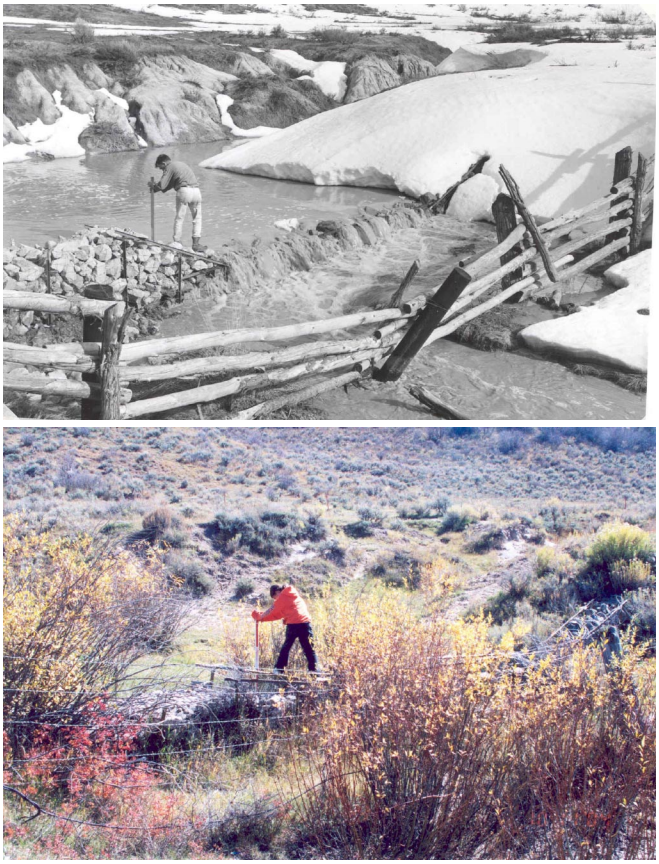
A striking result of this project was that none of the 131 gully control structures failed permanently. This high rate of structure stability was unique for the 1960s when check dam failure was the order of the day. On the other hand, nearly half of these check dams required some sort of maintenance between 1961 and 1964. This maintenance was primarily targeted at filling pore spaces in the rock structures created by poorly graded, large rock that did not meet design specifications. No maintenance has occurred since 1964.

There are several reasons for the high success rate of the structures built in Alkali Creek. Perhaps the most important was vegetation management. This primarily occurred through grazing management with the construction of the perimeter fence around the project area in 1958. This not only allowed the vegetation to recover, but it allowed soil properties to recover as well. These two parameters, increased vegetation and increased infiltration, would ultimately reduce the amount of overland flow, the original driving force for gully formation and enlargement. The perimeter fence is still maintained today.

A second reason for success was that detailed structural and hydraulic designs were developed for each gully control structure. Careful attention was given to design flows, structure dimensions, keying structures into the gully sidewalls, and overflow scour protection. Burchard Heede was a hydraulic engineer and he approached the work of gully control very quantitatively. This is clear in his summary publications on Alkali Creek (Heede 1977) and gully control in general (Heede 1976) where literally all aspects of design and evaluation are captured in formulae. For example, he provides a formula for calculating everything from the notch depth in a spillway to the

Figure 10. (a) Vegetation lined waterway construction sequence. Original gully configuration. (b) Shaping the new waterway after filling and compacting the old gully. (c) Completed waterway after establishment of vegetation. Note that the new flow line is offset from the original gully location. Photos by B. Heede.

Figure 11. (a) Double fence check dam at the base of the main gully (structure M0) during peak snowmelt runoff in the spring of 1964. Photo by B. Heede. (b) The same double fence check dam during the fall of 2004. Photo by M. Weinhold.



number of fence posts needed to construct a double fence check dam.

A third reason that no structures failed is that, in retrospect, the project area was over-treated. Approximately 44 percent of all check dams did not see enough flow in the first 12 years to have measurable sediment deposits. Only 27 percent of the check dams filled entirely, and these were primarily located along the main gully. This over-treatment was related to a gully's position in the watershed: nearly two-thirds of second order streams collected no sediment. As such, confining check dams to third- and fourth-order streams would have reduced project costs by 30 percent (Heede 1977). Even gullies that were not directly treated saw some benefit due to the establishment of base-level control provided by treatments at the confluence with larger, more active gullies.

Another result of the Alkali project, which had been observed in other gully restoration projects, was that ephemeral flow in the lower reaches of the main channel became perennial seven years after treatment. This was likely due to the water storage provided behind the

Figure 12. (a) Precast concrete check dam at the base of the main gully during spring runoff in 1964. Photo by B. Heede. (b) The same structure during the early summer of 2004. Photo by C. Hirsch. Note that the right half of the structure is covered by willows.

Figure 13. (a) Rock check dam on the main gully (structure M5) during spring runoff of 1964. Photo by B. Heede. (b) Same rock check dam in the fall of 2004. Photo by M. Weinhold.

sediment-filled check dams along the length of the main gully.

The vegetation-lined waterways were not immediately stable, due to their dependence on a robust layer of vegetation prior to exposure to overland flow. In some cases, burlap strips were buried perpendicular to the thalweg of the waterways to slow the flow during the first few runoff seasons and prevent rill formation (see Figure 14a). The burlap rotted away after several years. Fertilization was also necessary at all waterway sites due to a lack of phosphorus in the disturbed soils. Fertilizer was reapplied to all four vegetation-lined waterways in spring 2005 and minor headcuts were filled with small rock.

The Legacy of Burchard Heede and Alkali Creek

Gully control has been an ongoing process in the United States since the late 1700s. Burchard Heede created his legacy in that field by bringing gully control to the mountains and to the Forest Service. Even though gully control had been occurring on national forests in the southeast prior to Burchard Heede, he made substantial gains in quantifying the science of gully control and making that research and design guidance available to users in the Forest Service and beyond. He was an advocate for treating gullies as a system, with special attention paid to gully formation processes.

The printed legacy of the Burchard Heede's Alkali Creek experiment is extensive. Publications began rolling off the press within a year of project completion. Below is a partial list of the project related publications; complete references are contained in the bibliography.

- 1964. A pavement breaker attachment to drive steel fenceposts.
- 1965. Multipurpose prefabricated concrete check dam.
- 1966. Design, construction and cost of rock check dams.

Figure 14. (a) Vegetation-lined waterway No.16 in early 1960s with burlap strips in place to disperse flow. Photo by B. Heede. (b) The same waterway in the early summer of 2004. Photo by C. Hirsch.

- 1967. Fusion of discontinuous gullies: A case study.
- 1968. Conversion of gullies to vegetation-lined waterways on mountain slopes.
- 1970. Morphology of gullies in the Colorado Rocky Mountains.
- 1971. Characteristics and processes of soil piping in gullies.
- 1974. Stages of development of gullies in western United States of America.
- 1975. Submerged burlap strips aided rehabilitation of disturbed semi-arid sites in Colorado and New Mexico.
- 1976. Gully development and control: The status of our knowledge.
- 1977. A case study of a watershed rehabilitation project: Alkali Creek, Colorado.

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Heede, BH. 1977. A case study of a watershed rehabilitation project: Alkali Creek Colorado. Res. Pap. RM-189. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 18 p.