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Hydrologic Outputs from Woodland, Shrubland, and Grassland Ecosystems in Relation to Grazing Management Strategies: An Annotated Bibliography



Special Report 640

September 1981

Agricultural Experiment Station
Oregon State University, Corvallis

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Funding

This work was funded by the Cooperative Oregon Range Evaluation Project, USDA Forest Service with coordination from the Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Cover

Bear Creek Butte in Central Oregon, J. L. Mattison photo

Statement of Problem

Hydrologic outputs from woodland, shrubland, and grassland ecosystems have been researched by a variety of methods over a period of years.

There are difficulties in comparing the information, however, because studies have not tested the outputs with any degree of uniformity of methods. Nevertheless, ample evidence exists to point out the negative hydrologic impacts of heavy or abusive grazing in terms of reduced infiltration and increased compaction rates associated with that level of use. What is less well understood is the role that properly balanced grazing strategies would have on the long range hydrologic condition of the rangeland watersheds.

Several papers in this group deserve special notation because of their unique or detailed approach:

Balckburn (198) represents a detailed look at the literature associated with livestock grazing and hydrologic responses from a number of eco-geographic regions.

Buckhouse and Mattison (1980) attempted to express hydrologic outputs from a more definitive ecological expression than is commonly used. They broke ecosystem classification into habitat types, based on the Daubenmire systems. They found quantification of hydrologic responses became more specific through the use of this detailed ecological approach.

The Gifford and Hawkins (1978) paper is unique. It attempts to collate the available literature and discusses the prospects of using models for response prediction.

ALDON, EARL F. and GEORGE GARCIA. 1973. Seventeen-year sediment production from a semiarid watershed in the Southwest. USDA, Forest Service, Rocky Mountain Forest and Range Experiment Station, Res. Note RM-248. 4 p.

Average annual rate of sediment production declined 71 percent in the period 1967-71 compared with the period 1956-66 on a 471-acre watershed on the Rio Puerco drainage in New Mexico. This decline was a result of an increase in plant size and litter production on the alluvial flood plain.

ALLIS, JOHN A. and ARMINE R. KUHLMAN. 1962. Runoff and sediment yield studies on rangeland watersheds. J. Soil and Water Conserv. 17(2):68-71.

A runoff and sedimentation research program was initiated in 1957 in the Northern Great Plains. Established at Newell, South Dakota, the project involves 16 grassland watersheds ranging in size from 30 to 13,000 acres. Data collected during a 3.5-year period show more than three times as much runoff from the fine-textured soils as from the medium-textured soils of the rangeland. Also, dissipation of stored water by evaporation, percolation and seepage from reservoirs may be quite significant. The data on water sediment yield that are being obtained are applicable in western South Dakota, southwestern North Dakota, northeastern Wyoming and central and eastern Montana. This part of the Northern Great Plains comprises about 104 million acres.

BARNETT, A. P., E. R. BEATY, and A. E. DOOLEY. 1972. Runoff and soil losses from closely grazed fescue, a new concept in grass management for the Southern Piedmont. J. Soil and Water Conserv. 27(5):168-170.

During the last decade, a new grass management system has evolved in the Southern Piedmont which emphasizes fescue growth and utilization during winter as well as other seasons. The system provides forage that is both economical and of good quality. It is based on heavy utilization (close grazing), which keeps new growth tender and promotes a warmer soil in winter. Conservationists are concerned that this heavy utilization will increase soil erosion. However, comparison of the system of heavy utilization through close grazing with the old system of allowing the grass to reach a height of 3 or more inches showed that both systems were equally effective in controlling soil erosion. Soil loss was 0.002 ton per acre per erosion index unit (EI) for both systems.

BLACKBURN, W. H. 1975. Factors influencing infiltration and sediment production of semiarid rangelands in Nevada. Water Resour. Res. 11(6):929-937.

Simulated rainfall was used to study infiltration rates and sediment production of 28 plant communities and soils of five watershed areas in central and eastern Nevada. Two antecedent

moisture conditions were used: soil initially air dry and initially at field capacity. Infiltration and sediment production of the various soils are largely controlled by extent and surface morphology of dune interspace soils. Vesicular horizons are unstable in dune interspace surface soils. These horizons seldom occur in coppice dunes or in well-aggregated dune interspace soils. Infiltration rate is negatively related, and sediment production positively related to the occurrence and morphology of vesicular horizons. More sediment is produced from soils with antecedent moisture initially at field capacity than from initially dry soil because of the instability of vesicular horizons when the soils were saturated.

BLACKBURN, W. H. 198_. Impacts of grazing intensity and specialized grazing systems on watershed characteristics and responses. Presented at National Academy of Sciences/National Research Council, Committee on Developing Strategies for Range Management. El Paso, Texas. March 16-17, 1981. In press.

A literature review attempting to tie the effects of grazing to hydrologic and watershed response. Rangeland areas are divided into several eco-geographic zones and studied separately. These zones are: sagebrush/grass, salt-desert shrub, southwest semidesert shrub/grass, California grasslands, Northern Great Plains, Southern Great Plains, pinyon-juniper woodland, ponderosa pine/bunchgrass, high elevation rangeland, eastern hardwood or pine forest. Blackburn pointed out that livestock grazing influences watershed hydrologic properties by removing protective plant cover and by trampling. He said that the literature is filled with examples of the adverse impacts of heavy or abusive grazing on watershed. However, few research projects have studied seasonal or long-term hydrologic impacts of grazing systems or proper grazing management.

BLACKBURN, W. H. and C. M. SKAU. 1974. Infiltration rates and sediment production of selected plant communities in Nevada. *J. Range Manage.* 27(6):476-480.

Infiltration rates and sediment production of 29 plant communities and soils on five rangeland watersheds were studied in central and eastern Nevada. Three inches per hour of simulated rainfall was applied to soil initially dry and to soil initially at field capacity. Infiltration rates and sediment production for the various plant communities and soils varied considerably within and between watersheds. Highest infiltration rates and lowest sediment production occurred on sites with well-aggregated surface soils free of vesicular porosity.

BOLOGNANI, D. A. 1982. Simulated storm runoff characteristics between natural and altered ecosystems in the Oregon Range Validation Area. Masters Thesis. Oregon State University.

On four of nine mountain grassland ecosystems which had been altered (seeded), the control (natural) had significantly higher infiltration rates for the entire 28-minute simulated rainstorm. On two others, no significant differences occurred

immediately (3-8 minutes), but the control had significantly higher infiltration rates during the remaining portion of the storm. In another instance, the control had significantly higher infiltration rates only for the 3-8 minute time interval, after which no significant differences were found. In another case, significantly higher infiltration rates occurred only during the 3-8 and 23-28 minute time intervals for the treated and control areas respectively. At the ninth site, there were no significant differences in infiltration rates between the treated and control areas throughout the storm. However, the control area had a significantly higher average potential sediment loss in all cases except four. In three of these, no significant differences in sediment loss were found. On the remaining site, the treated area exhibited the significantly higher sediment loss. On the sagebrush ecosystem sampled, where sagebrush was mechanically removed and the area seeded, the treatment area had significantly lower infiltration rates than the control and a lower average potential sediment loss.

BRANSON, F. A., G. F. GIFFORD, and J. R. OWEN. 1972. Rangeland Hydrology. Society for Range Management, Denver, Colorado. Range Science Series No. 1. 84 p.

Rangeland hydrology, or rangeland watershed management, is the study of hydrologic principles as applied to range ecosystems. Although rangelands encompass many different climatic zones, this booklet deals chiefly with rangeland hydrology in arid and semiarid regions.

BRANSON, F. A., R. F. MILLER, and I. S. McQUEEN. 1962. Effects of contour furrowing, grazing intensities, and soils on infiltration rates, soil moisture, and vegetation near Fort Peck, Montana. J. Range Manage. 15(3):151-158.

Treatments of contour furrowing and seeding of crested wheatgrass were applied to an area near Fort Peck, Montana. Vegetation measurements were made after a period of ten years. Three grazing intensities and two soil conditions were also studied.

BUCKHOUSE, JOHN C. and GEORGE B. COLTHARP. 1976. Soil moisture response to several levels of foliage removal on two Utah ranges. J. Range Manage. 29(4):313-315.

Range plant clipping studies were conducted at two elevations on Utah's Wasatch Plateau during 1966 and 1967. It was found that extreme clipping treatments (complete denudation) resulted in significantly less soil moisture withdrawal than the unclipped controls at the mid-elevation location. No significant differences were found among clipping treatments at the sub-alpine location, however.

BUCKHOUSE, JOHN C. and GERALD F. GIFFORD. 1976. Grazing and debris burning on pinyon-juniper sites--some chemical water quality implications. J. Range Manage. 29(4):299-301.

During 1973 and 1974 a water quality study was conducted in San Juan County, southeastern Utah. Water quality data were collected from the study location which had been chained to remove pinyon-juniper vegetation six years earlier. Debris burning and livestock grazing treatments were studied. An "undisturbed, natural" woodland was left adjacent to the treatments to serve as a control area. After burning, significant increases in potassium and phosphorus were observed in overland flow from infiltrometer plots. No significant treatment changes were detected for sodium, calcium, or nitrate-nitrogen. No treatment differences from grazing were detected at the soil surface after cattle use (stocking rate was 2 ha/AUM).

BUCKHOUSE, JOHN C. and GERALD F. GIFFORD. 1976. Sediment production and infiltration rates as affected by grazing and debris burning on chained and seeded pinyon-juniper. J. Range Manage. 29(1):83-85.

Sediment production and infiltration rates were measured in conjunction with an analysis of burning and grazing treatments in a chained pinyon-juniper study in southeastern Utah. Although high natural variability was present among sites, no significant changes in sediment production were detected after our prescribed burning or grazing treatments. After treatment, however, both the burned and grazed sites exhibited significantly depressed infiltration rates during certain time intervals in comparison to the "undisturbed, natural" woodland control location.

BUCKHOUSE, JOHN C. and GERALD F. GIFFORD. 1976. Water quality implications of cattle grazing on a semiarid watershed in southeastern Utah. J. Range Manage. 29(2):109-113.

No adverse effects from fecal contamination were detected after cattle grazing was introduced in a semiarid watershed near Coyote Flat in southeastern Utah. The area was seeded to crested wheatgrass in 1967 after pinyon-juniper chaining and windrowing of debris, and it was protected from grazing until 1974 when it was cattle-stocked at 2 ha/AUM. There were no significant changes in fecal and total coliform production, indicating that potential health hazards from fecal pollution during such grazing are minimal. Most dry rangelands such as those covering the southwestern United States have few, if any, permanent streams. Thus, there is little or no effective streambank area from which bacteria can be flushed into a water course. On most chainings, especially those with debris in place, runoff water cannot flow any distance overland and very little rainfall runs off.

BUCKHOUSE, J. C. and J. L. MATTISON. 1980. Potential soil erosion of selected habitat types in the High Desert region of central Oregon. *J. Range Manage.* 33:282-285.

A Rocky Mountain infiltrometer was used to simulate high intensity rainfall over 468 sediment plots. The Bear Creek watershed was divided into seven ecological land units which were further refined into 10 tentative habitat types. Tractor logging in the mixed forest caused a significant increase in soil loss. In non-forested units, a high natural variability in sediment production within sites tended to mask any differences that may have resulted from a management treatment. Specific ecosystems showed the following responses (in kg/ha): Mixed forest = 189; Low sagebrush = 740; Sandy shrubland = 785; Adobeland = 785; Big sagebrush = 1437; Juniper woodland = 1636; Mixed steppe = 2300.

BURGY, R. H. and V. H. SCOTT. 1952. Some effects of fire and ash on the infiltration capacity of soils. *Trans. Amer. Geophys. Union* 33(3):405-416.

This paper is a preliminary report on the effects of certain physical and chemical relationships that may influence the movement of water into soils and the infiltration rates of some typical brushland soils. Factors studied were the effects of the presence of ash, the application of heat, the burning of brush, and the chemical constituents of the brush ash and their ramifications. Results tend to indicate that infiltration rates of soils may be influenced by burning brush and the presence of ash on the surface of soils. On the soils tested no decrease in infiltration rates occurred.

DUNFORD, E. G. 1949. Relation of grazing to runoff and erosion on bunchgrass ranges. USDA, Forest Service, Rocky Mountain Forest and Range Experiment Station, Res. Note RM-7 2 p.

Runoff and erosion were measured over a period of 12 years at Manitou Experimental Forest near Colorado Springs. Two grazing intensities were studied for their effect on watershed values. Results indicated that moderate grazing would be allowable on relatively gentle slopes if the resulting loss of runoff water did not cause critical shortages of moisture for vegetative productivity.

ENGLAND, C. B. and G. R. STEPHENSON. 1970. Response units for evaluating the hydrologic performance of rangeland watersheds. *J. Hydrology* 11(1):89-97.

A technique is presented for isolating areas within rangeland watersheds which are homogeneous enough in hydrologic characteristics to permit their use as field experimental units or as computational units in hydrograph synthesis. A study of the interactions among geology, soils, topography, and climate on the 90-square mile Reynolds Creek Experimental Watershed, Idaho, revealed predictable relations among these features and the capacity of a given unit of landscape to retain precipitation. The range site concept incorporates similar considerations and may be used in deriving hydrologic units for synthesizing the hydrology of ungaged areas.

FFOLLIOTT, PETER F. and DAVID B. THORUD. 1975. Vegetation management for water and range improvements. In: Watershed Management, Proc. of a Symposium conducted by Comm. on Watershed Manage., Irrigation and Drainage Div., American Society of Civil Engineers, Utah Sec. Utah State University, Logan. August 11-13. 249-266 p.

A review is presented of current water yield improvement experiments in Arizona to illustrate ways to enhance the beneficial and reduce the detrimental effects of vegetation management on water and herbage production. Seven vegetation zones are considered distinguishable for characterizing and describing water yield improvements.

FFOLLIOTT, PETER F. and DAVID B. THORUD. 1977. Water resources and multiple-use forestry in the Southwest. J. Forestry. 75(8):469-472.

Research indicates that modification of vegetation on upstream watersheds can increase water yields in the arid Southwest, while still permitting--and sometimes enhancing--other resource values.

FFOLLIOTT, PETER F. and DAVID B. THORUD. 1977. Water yield improvement by vegetation management. Water Resour. Bull. 13(3):563-571.

Vegetation management aimed at increasing the amount of usable water yield from precipitation falling on upstream watersheds may be one alternative for supplementing water supplies. Indications are that water yields can be increased within a multiple-use framework, which can benefit or at least be compatible with other natural resource objectives. Through changes in vegetation on a watershed, it is possible to reduce evaporation losses only slightly but significantly increase streamflow runoff. In an assessment of potentials for water yield improvement in Arizona, experimental studies on various vegetation zones are reviewed. Because of either limited acreage or limited rainfall, the alpine, grassland, aspen, and desert shrub vegetation zones are not realistic management areas for Arizona. Furthermore, manipulation of pinyon-juniper woodlands does not appear promising at this time. Conversion of chaparral to grasses and forbs does appear to be a possible treatment for water yield improvement, as well as various silvicultural treatments of mixed conifer and ponderosa pine forests. Streamflow increases are given for experiments in chaparral, mixed conifer, and ponderosa vegetation zones. However, complete information on possible constraints for these zones is not currently available. Specific assessment of water yield management options for riparian vegetation is difficult to make, because of incomplete knowledge of water yield changes and other constraints for this vegetation zone. Before the final adoption of management practices, results of experimental work must be coupled with economic and social considerations.

FISSER, HERBERT G. 1968. Soil moisture and temperature changes following sagebrush control. J. Range Manage. 21(5):283-287.

Soil moisture and temperature were measured for a five-year period on a mesic foothill grassland and on an arid cold desert shrub type in western Wyoming. Herbage production increased

on both the arid and mesic sites after the sagebrush and grazing control treatment with the greatest increase occurring on the mesic site. Average annual soil temperature was greatest at the arid site and was warmest in the shrub-dominated areas at both sites. Soil moisture recharge during the spring period was greatest at the mesic site under the non-use treatment, but at the arid site, grazing treatment did not significantly influence moisture accumulation. Under the shrub central treatment, soil moisture recharge was little influenced at the mesic site and at the arid site, greatest soil moisture recharge occurred in the non-controlled shrub area. Soil moisture withdrawal was similar at both the arid and mesic sites in that the least amounts of moisture were taken from the soil under the grazed and non-controlled shrub treatments. Soil moisture accumulation during the spring period was greatest at the mesic site from 24 to 60 inches below the soil surface and the greatest values occurred in the shrub-controlled grassland area. At the arid site high moisture levels occurred only down to the 12-inch depth.

FISSER, HERBERT G. 1975. Study of rangeland soil movement characteristics. In: Watershed Management, Proc. of a Symposium conducted by the Comm. on Watershed Manage. of the Irrigation and Drainage Division of the Amer. Soc. of Civ. Eng., Utah Sec. Utah State University, Logan. August 11-13. p. 421-422.

A low sagebrush (Artemisia arbuscula) study area was established in western Wyoming in 1963. Treatments applied included protection and non-protection from grazing and application and non-application of a commercial herbicide. A very strong statistical significance was associated with chemical treatments as regards soil movement. The interaction of grazing and chemical control of shrubs resulted in an extremely significant soil movement.

FRANK, ERNEST C., HARRY E. BROWN, and J. R. THOMPSON. 1975. Hydrology of Black Mesa watersheds, western Colorado. USDA, Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-13 11 p.

In 1956, three experimental watersheds were instrumented on Black Mesa in western Colorado. The hydrology of these mesa lands previously had been almost entirely ignored. Of primary concern was the determination of sediment/ground cover relationships on these important livestock grazing areas. Eleven years of runoff and suspended sediment data show no relationship to bare soil intercept. This lack of relationship was caused by the experimental error in measuring these small amounts of sediment. Bare intercept decreased on each watershed during the 1957-67 period even though grazing utilized an average of 40 percent of the grass in the open parks on one of the watersheds. While suspended sediment concentration after summer storms can be as much as six times that sampled during snowmelt, total yield averages 91 lb/ac from spring runoff and 11 lb/ac from storm runoff because of the small volume of flow. Based on current erosion classification schemes, these are very minor amounts of "geologic erosion."

GAITHER, R. E. 1981. Storm runoff characteristics of various plant communities within the Range Validation Area. M.S. thesis. Oregon State University. Corvallis. 153 p.

Sediment values ranged from 1,572 kg/ha in juniper ecosystems to 1,284 kg/ha in sagebrush ecosystems to 431 kg/ha in grassland ecosystems following investigation with a Rocky Mountain infiltrometer set to simulate a 28-minute convectional storm with an intensity of about 10 cm/hr. Specific sediment production rates in kg/ha were larch = 15; meadow = 22; lodgepole pine = 36; Douglas-fir = 109; alpine = 140; ponderosa pine = 183; spruce-fir = 217; mountain grassland = 431; sagebrush = 1,284; juniper = 1,572.

GIFFORD, GERALD F. 1968. Rangeland Watershed Management: A Review. Nevada Agricultural Experiment Station, Max C. Fleischmann College of Agriculture, University of Nevada. Project 3-37-5483. 50 p.

This review discusses hydrologic characteristics of various western rangelands regarding grazing and range improvement practices. References are also provided so the reader can obtain more detailed investigations on topics of interest.

GIFFORD, GERALD F. 1972. Infiltration rate and sediment production trends on a plowed big sagebrush site. J. Range Manage. 25(1):53-55.

The trend was toward lowered infiltration rates following plowing and seeding of a big sagebrush site. The greatest decline occurred during the fall period of the second year following treatment. Sediment production rates increased following plowing, but yields were variable. The ability to predict infiltration rates using cover characteristics alone in multiple regression equations varied with time, both within a given storm event and also on a seasonal basis. Ability to predict infiltration rates was not particularly affected by the plowing treatment.

GIFFORD, GERALD F. 1973. Runoff and sediment yields from runoff plots on chained pinyon-juniper sites in Utah. J. Range Manage. 26(6):440-443.

Runoff and sediment production from a chained pinyon-juniper site in both southeastern and southwestern Utah was measured from about June 6 to October 1 over a 5-year period (1968-1972) using .04-hectare (0.11 acre) runoff plots. Treatments evaluated included chained-with-debris-windrowed, chained-with-debris-in-place, and natural woodland. All treatments were fenced to exclude livestock. Runoff events occurred at both sites during only two years (1968, 1970) of the study. Results indicate that chained-with-windrowing plots yield from 1.2 to 5 times more water during a runoff event than respective woodland plots. Runoff from debris-in-place plots was equal to or less than that measured from the natural woodland for all storms. Runoff data and sediment indexes indicate that when runoff exceeds about 0.1 cm from the woodland, from 1.6 to 6 times more sediment can be expected from windrowed sites than from adjacent woodland. Sediment yields from debris-in-place sites were similar to those from adjacent unchained woodland for all storms during this study.

GIFFORD, GERALD F. 1975. Approximate annual water budgets of two chained pinyon-juniper sites. *J. Range Manage.* 28(1):73-74.

Approximate annual water budgets for various pinyon-juniper treatments (chaining-with-windrowing, chaining-with-debris-in-place, and natural woodland) have been compiled for a three-year period near Milford, Utah, and for a two-year period near Blanding, Utah. Results of the analysis indicate that most of the annual precipitation falling on each treatment is lost through evapotranspiration, with much of the balance being lost through interception. When runoff did occur, it was greatest from windrowed treatments and least from debris-in-place treatments.

GIFFORD, GERALD F. 1975. Beneficial and detrimental effects of range improvement practices on runoff and erosion. *In: Watershed Management, Proc. of a Symposium conducted by Comm. on Watershed Management, Irrigation and Drainage Div., Amer. Soc. of Civ. Eng., Utah Sec. Utah State University, Logan. August 11-13. p. 216-248.*

Subjects discussed in this publication include: pitting, ripping or subsoiling, plowing, chaining, seeding, contour furrows, contour trenches, gully plugs, small reservoir construction, and water spreading. Range improvement practices are not all beneficial from the standpoint of runoff and sediment production, and in fact, most research has shown that improvement practices which involve severe mechanical disturbance should not be expected to improve hydrologic conditions. Since the life of most mechanical treatments is relatively short, it is imperative that a desirable vegetative cover be established and properly maintained.

GIFFORD, GERALD F. 1979. Infiltration dynamics under various rangeland treatments on uniform sandy-loam soils in southeastern Utah. *J. Hydrology* 42:179-185.

Studies were made, over a 3-to-8-year period, of mean seasonal and yearly changes in infiltration rates under various rangeland management practices within the pinyon-juniper (Pinus spp. - Juniperus spp.) type. Results of the study indicate that mean upper limits in measured infiltration rates range from a surprising 1.37 to 3.47 times the mean minimal rates, each mean value representing from 6 to 20 replications for a given sampling date. Soil biology may be important in determining seasonal trends in infiltration rates, as well as overwintering freeze-thaw activity. Suggestions are given for sampling infiltration rates.

GIFFORD, G. F., J. C. BUCKHOUSE, and F. E. BUSBY. 1976. Hydrologic impact of burning and grazing on a chained pinyon-juniper site in southeastern Utah. Utah Water Research Laboratory, Logan. Publication PRJNR 012-1. 22 p.

Bacterial analysis (fecal and total coliform) of runoff water from infiltrometer plots indicated that the potential public health hazard of livestock grazing on semiarid open range on gentle slopes is probably minimal. Significantly increased amounts of phosphorus and potassium were measured in overland sites, but no changes were detected in calcium, sodium, or nitrate contents in runoff from differences in land treatment. One

season of grazing was sufficient to depress infiltration rates, though no significant changes were recorded in terms of potential sediment production under either grazing or burning. Soil moisture patterns were not significantly altered during the course of this study as a result of either the grazing or burning treatment.

GIFFORD, GERALD F. and FRANK E. BUSBY. 1974. Intensive infiltrometer studies on a plowed big sagebrush site. *J. Hydrology* 21(1):81-90.

Intensive infiltrometer studies were made over a four-year period on a plowed big sagebrush (*Artemisia tridentata*) site in southern Idaho. Results of the study indicate there was a natural decay in absorptive capabilities of surface soils because of the plowing treatment. The apparent result of grazing was not to reduce the minimal infiltration capacities measured on the respective site, but rather to eliminate seasonal trends so that infiltration rates were at the low end of the scale throughout the year. Grazing did not increase sediment production potentials beyond the increases expected as a result of mechanical disturbance associated with plowing. Attempts at predicting infiltration rates and potential sediment production indicate that easily measured soil cover characteristics do not adequately reflect the potential (actual) hydrologic performance of a big sagebrush site which has been grossly modified by activity such as plowing or grazing.

GIFFORD, GERALD F. and RICHARD H. HAWKINS. 1978. Hydrologic impact of grazing on infiltration: a critical review. *Water Resour. Res.* 14(2):305-313.

The hydrologic importance of grazing is receiving increased attention on rangelands in the United States. The literature on this topic is fragmented. This paper explores the available literature or information useful in understanding the hydrologic impacts of grazing intensity as related primarily to infiltration and runoff. Generally, data relative to range condition are not adequate for evaluating hydrologic impacts. Data relating grazing intensity to infiltration rates are available, yet distinct limitations are evident. These limitations are discussed in terms of identifying future research needs. The greatest need appears to be a detailed definition of the long-term effects of range condition and grazing intensity. Once obtained, infiltration rates must be coupled with an appropriate method for generating runoff volumes, storm hydrographs, and long-term water yields.

GIFFORD, GERALD F. and R. H. HAWKINS. 1979. Deterministic hydrologic modeling of grazing system impacts on infiltration rates. *Water Resour. Bull.* 15(4):924-934.

Techniques for predicting the hydrologic effects of grazing schemes have heretofore been unavailable. The available literature on grazing intensity influences on infiltration rates is used as a basis for a model of infiltration behavior in response to grazing systems. Background, development, cautions, and an example are given.

GIFFORD, GERALD F. and CONNOR B. SHAW. 1973. Soil moisture patterns on two chained pinyon-juniper sites in Utah. *J. Range Manage.* 26(6):436-440.

Soil moisture patterns were studied under chaining-with-windrowing, chaining-with-debris-in-place, and natural woodland at one site each on both southwestern and southeastern Utah. Results of the study indicate the greatest moisture accumulation occurred under the debris-in-place treatment (as compared to woodland controls), during the first 6 months of each year at Milford and regardless of season at Blanding. The woodland had the least soil moisture throughout most of each year. Most moisture flux took place in the upper 60-to-90-cm of soil profile, with only minor changes occurring at greater depths. Differences in soil moisture patterns have been attributed to changes in microclimates from chaining, different rooting depths and length of growing season, mulching effect of litter on the debris-in-place treatment, and possible differences in snow accumulation. Variation in vegetation density on the chained treatments did not influence soil moisture patterns. There was no evidence of deep seepage on any chaining treatment at either site.

GIFFORD, GERALD F. and RONALD K. TEW. 1969. Evaluating rangeland water quality with small plot infiltrometers. *J. Soil and Water Conserv.* 24(2):65-67.

Disturbing the soil on western rangelands alters the chemical qualities of runoff water, and small plot infiltrometers appear to be one means of measuring the chemical change.

GIFFORD, GERALD F. and RONALD K. TEW. 1969. Influence of pinyon-juniper conversions and water quality on permeability of surface soils. *Water Resour. Res.* 5(4):895-899.

In experimental plots, a natural cover of pinyon and juniper was removed by chaining and debris was cleared in one plot, another was chained but not cleared, and a third plot was left undisturbed. A Rocky Mountain infiltrometer was used to apply high intensity rainfall on each plot at over 2.7 in/hr. Significant changes in Ca and K concentrations resulted from land treatment. The pH of all runoff from treated plots decreased, and electrical conductivity increased. There was no relationship between runoff water quality and volume or duration of runoff.

GIFFORD, GERALD F., GERALD WILLIAMS, and GEORGE B. COLTHARP. 1970. Infiltration and erosion studies on pinyon-juniper conversion sites in southern Utah. *J. Range Manage.* 23(6):402-406.

Infiltration and sediment data from small-plot studies (325 infiltrometer plots) utilizing high intensity simulated rainfall indicate that areas cleared of pinyon-juniper trees and seeded to grass in southern Utah generally show no consistent decrease or increase in sediment yields or infiltration rates at a given point. Of 14 sites studied, four indicated decreased infiltration rates and two indicated increased infiltration rates during one or more time intervals at specific points on the treated areas; one site

had significantly less sediment yield and two sites had significantly higher sediment yields from points on the treated areas. These results nearly parallel those obtained during similar studies of 14 pinyon-juniper sites in central Utah.

HANSON, CLAYTON L., ARMINE R. KUHLMAN, CARL J. ERICKSON, and JAMES K. LEWIS. 1970. Grazing effects on runoff and vegetation on western South Dakota rangeland. *J. Range Manage.* 23(6):418-420.

Four 2-acre watersheds were established in 1962 on each of three pastures that had been grazed at different intensities (heavy, moderate, and light) since 1942. These watersheds were at the Cottonwood Range Field Station, Cottonwood, South Dakota. The mean seasonal runoff from May 14 through October 31 for 1963 through 1967 was 0.79, 0.56, and 0.42 inch for the heavy, moderately, and lightly used watersheds, respectively. The mean weight of live and dead standing crop of vegetation plus mulch in late July was 1,752, 2,092, and 3,700 pounds per acre for the heavily, moderately, and lightly used watersheds, respectively.

HANSON, CLAYTON L., H. G. HEINEMANN, A. R. KUHLMAN, and J. W. NEUBERGER. 1973. Sediment yields from small rangeland watershed in western South Dakota. *J. Range Manage.* 26(3):215-219.

Sedimentation studies were made between 1958 and 1969 on stock water reservoirs to determine sediment yields from rangeland and watersheds on two soil textural groups of western South Dakota. Watersheds having fine-textured soils had a mean annual sediment yield of 3.47 tons per acre, while watersheds with medium-textured soils had a mean annual sediment yield of 1.03 tons per acre. The average sediment volume-weight was 62 and 81 lb/ft³ for the reservoirs on watersheds with fine- and medium-textured soils, respectively.

HORTON, JEROME S. and C. J. CAMPBELL. 1974. Management of phreatophyte and riparian vegetation for maximum multiple use values. USDA, Forest Service, Rocky Mountain Forest and Range Experiment Station, Research Paper RM-117. 23 p.

Summarizes the status of our knowledge about environmental relations of vegetation along water courses in the southwestern United States, and impacts of vegetation management to reduce evapotranspiration on other resource values. Reviews the literature on measurement and evaluation of water losses from moist-site vegetation, ecological relationships, other resource uses of phreatophyte and riparian areas, and control methods. Suggests approaches to management of moist-site areas by zones based primarily on water table depth, elevation, and tree species.

INGEBO, PAUL A. and ALDEN R. HIBBERT. 1974. Runoff and erosion after brush suppression on the natural drainage watersheds in central Arizona. USDA, Forest Service, Rocky Mountain Forest and Range Experiment Station, Res. Note RM-275. 7 p.

Brush cover on two small watersheds totaling 26 acres in central Arizona was chemically suppressed in 1954-55. Annual streamflow

subsequently increased 22 percent (0.36 area-inch), much less than on other treated chaparral watersheds. Most of the increase in streamflow occurred during the winter season. Annual sediment movement from the treated watersheds was reduced by about 1 ft³/acre. Grasses, forbs, and half-shrubs, which were not sprayed, increased after the chemical treatment.

JOHNSON, CLIFTON W. and JEFFREY P. SMITH. 1978. Sediment characteristics and transport from Northwest rangeland watersheds. Trans. Amer. Soc. Agr. Eng. 21(6):1157-1163.

Rangeland hydrology and sedimentation studies on a main stem and three source watersheds within the Reynolds Creek Experimental Watershed show a wide range in precipitation, runoff, sediment yield, and particle-size characteristics from year to year and from station to station. Results are useful in rangeland erosion and sediment models.

JOHNSON, STEVEN R., HOWARD L. GARY, and STANLEY L. PONCE. 1978. Range cattle impacts on stream water quality in the Colorado front range. USDA, Forest Service, Rocky Mt. For. and Range Exp. Sta., Res. Note RM-359. 8 p.

Studies on two adjacent pastures along Trout Creek in central Colorado indicated only minor effect of cattle grazing on water quality. Bacterial contamination of the water, however, significantly increased. After removal of the cattle, bacterial counts dropped to levels similar to those in the ungrazed pasture.

JOHNSTON, ALEXANDER. 1962. Effects of grazing intensity and cover on the water-intake rate of fescue grassland. J. Range Manage. 15(2):79-82.

Ungrazed areas and areas that had been grazed by cattle at four rates for 10 years were studied in southwestern Alberta. Results indicated that soil erosion by water was not a critical factor in management even after 10 years of heavy grazing. Increasing amounts of standing vegetation and natural mulch were associated with increased water-intake rates.

KINCAID, DAVID R. and GERALD WILLIAMS. 1966. Rainfall effects on soil surface characteristics following range improvement treatments. J. Range Manage. 19(6):346-351.

Range improvement treatments--brush clearing, pitting, and seeding to grass--were imposed on 24, 6-by-12-foot plots near Tombstone, Arizona. One summer's rainfall of average amount and intensity reduced roughness caused by pitting; and such other surface characteristics as erosion pavement and exposed soil approached a state of stability similar to untreated plots. Surface runoff exhibited little correlation with treatment, but showed a statistically significant negative correlation with crown cover of vegetation.

KRIVAK, JOSEPH A. 1978. Best management practices to control nonpoint-source pollution from agriculture. J. Soil and Water Conserv. 33(4):161-166.

The use of Best Management Practices (BMP's) to control nonpoint source pollution in agriculture is advocated. BMP's should attempt to achieve water quality standards, but should not be hampered by water quality goals that have not been fully defined. Implementation of BMP's require tough management decisions and farmer acceptance. Pollutants associated with production of crops, irrigated crops, confined animals, and pastured or grazing animals are surveyed. BMP's that apply to these pollution sources are outlined.

LEITHEAD, HORACE L. 1959. Runoff in relation to range condition in the Big Bend-Davis Mountain section of Texas. J. Range Manage. 12(2):83-87.

Runoff was found to increase in the Davis Mountain-Big Bend area as range condition deteriorated. As range condition deteriorated, moisture absorption by soil became slower. It was concluded that a range site in good condition could absorb moisture five to six times faster than the same range site in poor condition.

LOOPE, WALTER L. and GERALD F. GIFFORD. 1972. Influence of a soil microfloral crust on select properties of soils under pinyon-juniper in southeastern Utah. J. Soil and Water Conserv. 27(4):164-167.

Cryptogamic soil crusts on the Colorado Plateau were studied to determine their effect on infiltration rates, potential sediment production, permeability, and several chemical properties of the soil. Six crust stages were identified. Undisturbed soil cores were used to determine intrinsic permeability under three treatments, and disturbed soil samples were analyzed for pH, percent organic matter, soil texture, calcium plus magnesium content, and total conductivity. Cryptogamic crust had little effect on soil chemical properties. Analysis of undisturbed soil core data indicated that high cryptogamic cover tended to reduce intrinsic permeability, an effect that was reinforced when cores were irrigated. Sites with any degree of cryptogamic cover had significantly higher infiltration rates than chained areas (no lichen cover). Patterns of sediment production revealed a potential for increased sediment once the crust had been disturbed.

LUSBY, GREGG C. 1970. Hydrologic and biotic effects of grazing vs. non-grazing near Grand Junction, Colorado. J. Range Manage. 23(4):256-260.

The effect of grazing on hydrology of salt-desert type rangeland has been studied near Grand Junction, Colorado, for the past 14 years. Measurements of precipitation, runoff, erosion, and vegetation have been made in four pairs of watersheds. One of each pair has been grazed by cattle and sheep as is normal in the region, and the other has not been used since the beginning of the study. Measurements made 10 years apart show that all four

grazed watersheds have had a slight increase in the amount of bare soil and rock and a decrease in ground cover; cover on ungrazed watersheds has remained essentially unchanged. Runoff in the ungrazed watersheds has been about 30 percent less than in the grazed watersheds and sediment yield has been about 45 percent less. The greatest change in each of the relationships occurred about three years after livestock were excluded from one watershed of each pair. Preliminary studies indicate that within areas of similar physiography, runoff is directly related to the percentage of bare soil on a watershed.

LUSBY, GREGG C. 1979. Effects of converting sagebrush cover to grass on the hydrology of small watersheds at Boco Mountain, Colorado. Geological Survey Water-Supply Paper 1532-J. 36 p.

Changes in runoff and sediment yield caused by changing sagebrush cover to grass cover were studied at four small watersheds in western Colorado during a nine-year period, from 1965 to 1973. Measurements of runoff and sediment yield from the four watersheds were made for three years, then two watersheds were plowed and seeded to beardless bluebunch wheatgrass. The same measurements were then continued for an additional six years. Measurements indicated that conversion to grass caused a reduction in runoff from summer rainstorms of about 75 percent. Runoff from spring snowmelt increased about 12 percent, and annual runoff from treated watersheds decreased about 20 percent when compared to control watersheds. Sediment yield from the seeded watersheds was reduced about 80 percent; most of this reduction is related to the decrease in runoff from summer rainstorms. The size of barren interspaces between plants was reduced on the converted watersheds to about 30 percent of those on the untreated watersheds. Linear regression analysis indicates that a reduction of 38 percent in the amount of bare soil resulting from planting grass would result in a decrease of 73 percent in sediment concentration.

LUSBY, GREGG C., VINCENT H. REID, and O. D. KNIPE. 1971. Effects of grazing on the hydrology and biology of the Badger Wash Basin in western Colorado., 1953-66. Geological Survey Water-Supply Paper 1532-D. 90 p.

An intensive study of the effect of grazing on the hydrologic and biotic characteristics of small drainage basins on the Colorado Plateau was begun in the fall of 1953. This report presents data obtained during the first 13 years of the proposed 20-year study. For the period of record 1954-66, runoff from grazed watersheds has averaged about 33 acre-feet per square mile per year. Runoff from ungrazed watersheds averaged from 71 to 76 percent of that from grazed watersheds. During the last six years of the period, however, ungrazed watersheds produced 69 to 71 percent as much runoff as grazed watersheds. The sediment yield from grazed watersheds during the same period was about 3 acre-feet per square mile per year. Sediment yield from ungrazed watersheds ranged from 51 to 75 percent of that from grazed watersheds and averaged

66 percent. The largest change in these relations occurred about two years after livestock were excluded from certain watersheds. The causative factors for changes in the runoff and sediment yield relations are not entirely clear. At the end of 13 years, a significant change had occurred in the amount of bare soil and rock, in the ground-cover index, and in the litter and moss on the grazed watersheds. These items remained essentially unchanged on ungrazed watersheds. The changes in ground-cover factors were not of large magnitude and did not occur at the same rate as the changes in runoff and sediment yield. A large part of the difference appears to have been caused by a change in the structure of surface soil, which was brought about by the elimination of trampling by livestock.

MEEHAN, WILLIAM R. and WILLIAM S. PLATTS. 1978. Livestock grazing and the aquatic environment. *J. Soil and Water Conserv.* 33(6): 274-278.

A thorough understanding of relationships between livestock grazing and fisheries is needed to manage range adjacent to coldwater streams. Research concerning the impacts of livestock grazing on aquatic resources of adjacent lands is considered. Early studies of grazing on forest rangeland show that overgrazing can adversely affect water quality by increasing erosion and sedimentation, and by increasing bacterial concentrations from animal wastes. Recent research shows that range practices also affect water quantity. Studies of fish habitats in Montana and Oregon indicate that adjacent grazing can reduce stream quantities of brown trout by reducing streamside cover.

MEEUWIG, RICHARD O. 1970. Infiltration and soil erosion as influenced by vegetation and soil in northern Utah. *J. Range Manage.* 23(3): 185-188.

The influences of vegetation, soil properties, and slope gradient on infiltration capacity and soil stability of high-elevation herbland on the Wasatch Front in northern Utah were investigated under simulated rainfall conditions. Results emphasize the importance of vegetation and litter cover in maintaining infiltration capacity and soil stability. Infiltration is also affected significantly by soil properties, notably bulk density, aggregation, and moisture content.

MENZEL, R. G., E. D. RHOADES, A. E. OLNES, and S. J. SMITH. 1978. Variability of annual nutrient and sediment discharges in runoff from Oklahoma cropland and rangeland. *J. Environ. Qual.* 7(3): 401-406.

Nitrogen and phosphorus discharges in runoff from nearly level cropland and 3 percent sloping rangeland were measured from July 1972 to June 1976. Sediment discharges and runoff amounts from these 5- to 18-ha watersheds were measured from July 1966 to July 1976. Sediment and nutrient discharges varied greatly from year to year and between different land uses. We concluded that long records are needed to compare discharges from different management practices. The average and maximum annual sediment discharges, respectively, were 3,600 and 8,900 kg/ha from

irrigated cotton (Gossypium hirsutum), 900 and 3,900 kg/ha from dryland wheat (Triticum aestivum), 400 and 1,800 kg/ha from range with limited grazing, and 9,000 and 23,000 kg/ha from overgrazed range. Maximum annual sediment discharges occurred during the period in which nutrient discharges were measured. Maximum annual nutrient discharges were 13 kg/ha total N, 4 kg/ha nitrate N, 11 kg/ha total P, and 2 kg/ha soluble P. The average annual discharge for each nutrient form and land use was about half of its maximum value. Nitrate accounted for 10 to 30 percent of the total N discharged. Soluble phosphate accounted for about 20 percent of the total P discharged from cropland, and <10 percent of that discharged from rangeland. Annual deposition in rainfall averaged 5 kg/ha N and 0.15 kg/ha P.

OLNESS, ALAN, S. J. SMITH, E. D. RHOADES, and R. G. MENZEL. 1975. Nutrient and sediment discharge from agricultural watersheds in Oklahoma. *J. Environ. Qual.* 4(3):331-336.

Seven cropland watersheds and four rangeland watersheds in central Oklahoma were monitored for surface hydrology and discharge of nitrogen, phosphorus, and sediment over a one-year period. Precipitation and runoff were much above normal during the study. Sediment losses from the continuously grazed rangeland watersheds ranged from 18 to 23 metric tons/ha during the study. None of the sediment losses from the other watersheds exceeded 10 metric tons/ha. Total nutrients discharged in runoff ranged from 2 to 15 kg/ha of N and 1 to 11.5 kg/ha of P. Flow-weighted mean concentrations ranged from 1 to 6 ppm of total N, 0.2 to 1.9 ppm of nitrate-N, 0.5 to 4.8 ppm of total P, and 0.04 to 0.9 ppm of soluble P. Runoff losses of soluble inorganic nitrogen were generally less than those quantities received in rainfall. Concentrations of soluble phosphorus in runoff from the cropland watersheds were much greater than from the rangeland watersheds. Losses of fertilizer nitrogen and phosphorus did not exceed 5 percent of the most recent applications, although surface runoff was 4- to 10-fold greater than that observed in previous years.

PEARSE, KENNETH and SAMUEL B. WOOLLEY. 1936. The influence of range plant cover on the rate of absorption of surface water by soils. *J. Forestry* 34:844-847.

While much attention of late has focused on the construction of engineering works as a means of meeting water deficiencies in the semiarid valleys of the West, comparatively little consideration has been given to the regulatory influence of the soil and rocks of the watersheds, or of the part played by herbaceous range plants in maintaining the efficiency of these natural reservoirs. This study, which is based upon measurements with inexpensive and portable equipment, reveals that range plants exert a marked influence on the rate water is absorbed by surface soils. Moreover, because plants which are most conducive to water absorption are also of greatest value for grazing purposes, the study clearly suggests that proper range management and adequate watershed protection go hand in hand.

PETERSON, H. V., and F. A. BRANSON. 1962. Effects of land treatments on erosion and vegetation on range lands in parts of Arizona and New Mexico. *J. Range Manage.* 15:220-226.

Earth-fill dams, earth dike water spreaders, loose rock spreaders, hand-placed rock spreaders, brush spreaders, "cement worm" spreaders, cable and wire spreaders, and rock-rubble gully-control structures were evaluated as to their effectiveness for vegetation improvement, longevity of structures, and amount of sediment retained by the structures. Earth dikes, when not breached, provided for improvement in vegetation. Brush spreaders were not very effective in providing vegetation improvement, but did result in slightly reduced sheet erosion.

RAUZI, FRANK. 1960. Water-intake studies on range soils at three locations in the Northern Plains. *J. Range Manage.* 13(4):179-184.

Infiltration studies were conducted on rangelands at three locations in the Northern Plains. High condition range sites absorbed water almost three times as much as did low condition range sites. Results indicated that on two of the three areas the amounts of standing vegetation contributed more to infiltration than mulch material.

RAUZI, FRANK. 1963. Water intake and plant composition as affected by differential grazing on rangelands. *J. Soil and Water Conserv.* 18(3):114-116.

Since moisture is the principal factor limiting herbage production on rangelands, retention of precipitation on the land where it falls is essential if the highest yields of herbage are to be obtained. This study shows that loss of surface cover through close grazing reduces a soil's rate of water intake and results in a significant change in the species composition of vegetation on a range site.

RAUZI, FRANK and CLAYTON L. HANSON. 1966. Water intake and runoff as affected by intensity of grazing. *J. Range Manage.* 19(6):351-356.

Water intake rates on differentially grazed rangeland watersheds were nearly linear, with the heavily grazed watershed having the lowest and the lightly grazed watershed the highest rate. Annual runoff was greatest from the heavily grazed watersheds and least from the lightly grazed. Storm characteristics were a factor in the production of runoff.

RAUZI, FRANK and DARRYL E. SMIKA. 1963. Water intake on rangelands as affected by simulated grazing and fertilization. *J. Range Manage.* 16(3):125-128.

Infiltration studies were conducted at the Northern Great Plains Field Station, Mandan, North Dakota, in 1961. Grazing was simulated by three harvesting conditions for a four-year period. Influence of nitrogen fertilization was also studied. Greater infiltration rates were obtained where herbage was clipped in the fall as compared with frequent clippings throughout the season.

RAUZI, FRANK and FREEMAN M. SMITH. 1973. Infiltration rates: three soils with three grazing levels in northeastern Colorado. *J. Range Manage.* 26(2):126-129.

The influence of soil type, grazing level, and vegetation on infiltration rates was evaluated at the Central Plains Experimental Range near Nunn, Colorado. Total plant material was significantly correlated with infiltration rates on two of the three soil types tested. Heavy grazing significantly decreased infiltration rates on two of the soil types. Grazing influences did not reduce infiltration rates until after 20 minutes of simulated rainfall.

RICKERT, DAVID A. and GARY L. BEACH. 1978. Assessing impacts of land management activities on erosion-related nonpoint source problems. *J. Water Pollution Control Fed.* 50(11):2439-2445.

This paper deals with Phase II of Oregon's Section 208 water quality planning process. A detailed basin assessment project aimed at relating stream quality to both natural terrain characteristics and to land management activities within forestry, grazing, and agriculture. Its goal is to determine relative erosion potential and most suitable management activities for different terrains. The assessment emphasizes erosion and sedimentation because these are the most widespread and pervasive non-point pollution problems in Oregon.

ROUNDY, BRUCE A., W. H. BLACKBURN, and R. E. ECKERT, JR. 1978. Influence of prescribed burning on infiltration and sediment production in the pinyon-juniper woodland, Nevada. *J. Range Manage.* 31(4):250-253.

On arid and semiarid rangelands, areas between woody plants are named dune interspaces. Soil and litter accumulate under plants to form mounds which are called coppice dunes. The loss of soil-protecting litter after burning pinyon-juniper communities in eastern Nevada decreased rates of water infiltration on coppice dune soil at field capacity and increased sediment production from coppice dunes with the soil dry and at field capacity. Differences in infiltration rates and sediment production of dune interspace soil were related to preburn soil morphological differences, not to burning. Vesicular soil crusts and surface-soil bulk density of coppice dunes were not increased by burning. Coppice soil organic matter was not significantly lower on burned areas, although mean values were slightly lower than those on unburned areas. Soil-water repellency was decreased by burning. Burning is not expected to increase runoff or soil loss substantially on similar areas with coarse-textured soils, because post-burn infiltration rates on coppices in these tests exceeded rainfall rates expected from natural storms.

SARTZ, RICHARD S. and DAVID N. TOLSTED. 1974. Effect of grazing on runoff from two small watersheds in southern Wisconsin. *Water Resour. Res.* 10(2):354-356.

Storm runoff from two small open pasture watersheds was measured for 11 years: during the first seven years both were grazed,

and during the last four years only one was grazed. Their runoff behavior was similar when both were grazed, but by the third year after cessation of grazing, runoff from the ungrazed watershed had dropped sharply. The ungrazed/grazed ratio for mean total flow had dropped from 1.17 to 0.10 and for mean peak flow from 0.82 to 0.03. After three years without grazing, a heavy mat of bluegrass blanketed the ground and soil bulk density was significantly lower.

SCHREIBER, H. A. and K. G. RENARD. 1978. Runoff water quality from varying land uses in southeastern Arizona. *J. Range Manage.* 31(4):274-279.

Surface runoff waters from three kinds of activity on rangeland were examined for suspended solids and some indicator chemical constituents. We compared ungrazed brush-covered rangeland with recently subdivided rangeland, originally and still partly brush-covered, but whose surface was disturbed by man's urbanizing influence. Water quality indicators showed the urbanized watersheds had poorer water quality. Comparisons between the brush-covered watersheds and a third--grass covered and grazed--were made only on the runoff water's dissolved constituents. Despite the grazing activity, the waters were of better quality. A contrast in the geology between the grass and brush areas suggested that mineral sources affected qualitative changes in the dissolved solids. Calcareous soils produced waters higher in Ca and total dissolved solids and lower in other cations. Phosphate in runoff averaged higher from the grass-covered, non-calcareous area than from the brush-covered calcareous watershed. It is hypothesized that the phosphate originated from soil sources, rather than from grazing activity. Nitrate levels were comparable in runoff from all the non-urban areas, but increased in runoff from the semi-urban area. Thus, the non-agricultural complex of activities associated with a housing development were more detrimental to water quality than those from undisturbed or grazed rangelands.

SCHUMM, S. A. and G. C. LUSBY. 1963. Seasonal variation of infiltration capacity and runoff on hillslopes in western Colorado. *J. Geophys. Res.* 68:3655-3666.

Hillslope erosion was studied during four years along 25 slope profiles on Mancos shale hillslopes in western Colorado. Erosion was measured by the movement of markers and exposure of stakes. During winter the soil surface is loosened by frost action, and the stakes show minimum exposure in the spring. Rain-beat during the spring and summer compacts the soil, and the stakes show maximum exposure during the fall. Frost action and compaction cause creep to occur in the upper two inches of the lithosols. During spring and summer, compaction of the soil by rain-beat decreases infiltration capacity, and runoff increases. Rills form on the slopes, but these are soon destroyed by winter frost action and creep, and the infiltration capacity of the soil is increased. Measurement of sediment yield and runoff from small drainage basins on the Mancos shale shows that mean annual runoff is

relatively low, but sediment yields are normal for this type of terrain. An analysis of precipitation and runoff data reveals that average runoff and the ratio of runoff to precipitation are less in the spring than in the fall, reflecting the seasonal changes of soil characteristics. Therefore, seasonal changes in the soil, which cause a seasonal change in infiltration capacity, not only control the rate and process of hillslope erosion, but also significantly affect the hydrologic characteristics of these small drainage basins.

SCOTT, V. H. 1956. Relative infiltration rates of burned and unburned upland soils. *Trans. Amer. Geophys. Union* 37(1):67-69.

To increase the value of rangeland densely covered by brush, a number of management practices are being employed. One practice, clearing by the use of fire, has raised the question as to its effect on the infiltration capacity of the soil. Application of single-ring infiltrometers for determining relative infiltration rates of upland soils is discussed. Values of the relative infiltration rates, for burned and unburned areas are presented. In all cases the burned soils had substantially higher rates after a fire. One year later, the results were similar with one exception.

SHARP, A. L., J. J. BOND, J. W. NEUBERGER, A. R. KUHLMAN, and J. K. LEWIS. 1964. Runoff as affected by intensity of grazing on rangeland. *J. Soil and Water Conserv.* 19:103-106.

Because heavy grazing reduces the amount of vegetation on native ranges, the amount of runoff is expected to be greater from rangelands subjected to heavy grazing than from those only lightly grazed. This expectation is normally correct according to the findings presented in this progress report on research underway in South Dakota. However, data are also given that indicate an abnormal sequence of precipitation events may result in greater amounts of runoff from lightly grazed areas than from heavily grazed ones.

SKINNER, QUENTIN D., JOHN C. ADAMS, PAUL A. RECHARD, and ALAN A. BEETLE. 1974. Effect of summer use of a mountain watershed on bacterial water quality. *J. Environ. Quality* 3(4):329-335.

The water quality of a mountain watershed during the summers of 1970, 1971, and 1972 is presented. Samples were collected at six sample sites in the watershed. The standard plate count of 20 c and the aerobic bacteria enumerated on trypticase soy agar at 20 c numbered about 5×10^3 cells/ml in July, and remained at this concentration for the rest of the summer. The standard plate count at 35 c was generally constant at near 50 cells/ml each summer at all sample sites. The total coliforms in 9 of 17 cases exhibited a tenfold increase in numbers in late July or August over the values of 10 or less per 100 ml found in June. Fecal coliforms in 11 of 17 cases increased 10- to 100-fold in concentration in July or August over values obtained in June or September. Maximum numbers of fecal streptococci were

usually seen at all sample sites in July or August except for 1972, when sheep (Ovis aries) were being grazed in September. A stream in a natural area of the watershed appeared to be less polluted than other streams in the watershed which were influenced by human use. The use of the fecal coliform to fecal streptococci ratio to determine the source of pollution appeared to be of questionable value in this study.

SKINNER, QUENTON D., JOHN C. ADAMS, PAUL A. RECHARD, and ALAN A. BEETLE. 1974. Enumeration of selected bacterial populations in a high mountain watershed. *Canadian Journal of Microbiology* 20(11):1487-1492.

Nitrate-reducing bacteria, sulfate-reducing bacteria, fluorescent bacteria, and the total viable count were enumerated in three stream systems within a high mountain watershed over a period of two winters and two summers from 1970 to 1972. Spread plate and most probable number procedures showed that the number of fluorescent bacteria, sulfate-reducing bacteria, nitrate-reducing bacteria, and the total count were generally constant throughout the year at the lowest sampling site on the stream systems. However, in some cases and for short periods of time, the numbers of these bacteria appeared to be influenced by recreational use of the land and stream flow. For example, denitrifying bacteria increased in number during the winter recreational period and gave the lowest counts in July.

SMEINS, FRED E. 1975. Effects of livestock grazing on runoff and erosion. In: *Watershed Management, Proc. of a Symposium conducted by The Comm. on Watershed Manage., Irrigation and Drainage Div., Amer. Soc. of Civ. Eng., Utah Sec. Utah State University, Logan. August 11-13. p.267-274.*

Results of this study indicated that moderate grazing may not increase erosion, but may significantly increase runoff as compared to lightly grazed or ungrazed areas. Moderate grazing has the potential to maintain a favorable forage resource, may not increase the hazard of erosion, and could possibly produce good quality runoff water for use outside the watershed.

STEPHENSON, G. R. and L. V. STREET. 1978. Bacterial variations in streams from a southwest Idaho rangeland watershed. *J. Environ. Qual.* 7(1):150-157.

Sources and variations in bacterial indicators are reported from stream sites over a three-year period on a 233-km² rangeland in southwest Idaho. The occurrence of fecal coliforms was directly related to the presence of cattle on summer range and winter pastures. Fecal coliform counts in adjacent streams were found to increase soon after cattle were turned in and remained high for several months after cattle were removed. Runoff from rainstorms increased both total and fecal coliform concentrations in streams on summer range with limited management and adjacent to winter pastures, but runoff from snowmelt had little effect. Total coliform counts varied more with change in streamflow than did fecal coliform counts. In fenced summer range allotments, under deferred grazing management, the effects were the same, except

bacterial counts were not as high or persistent. The decrease in bacterial concentrations at several downstream sampling sites indicated that certain stream segments were self-purifying. The presence or absence of livestock along the streams overshadow any effect variations in chemical concentration of the water might have on bacterial concentrations.

STEWART, GEORGE and C. L. FORSLING. 1931. Surface runoff and erosion in relation to soil and plant cover on high grazing lands of central Utah. J. Am. Soc. Agron. 23:815-832.

Two high elevation watersheds in central Utah were studied to determine differences in surface runoff as related to soil and plant cover. Approximately 3 to 5 times as much surface runoff was produced on the watershed with poorer plant cover. Runoff was 10.33, 8.74, and 5.49 percent of the total rainfall on the area with the poorer plant cover as compared with 4.10, 2.88, and 1.05 percent for the continuously well-vegetated watershed.

STURGES, DAVID L. 1973. Soil moisture response to spraying big sagebrush the year of treatment. J. Range Manage. 26(6):444-447.

Spraying big sagebrush with 2,4-D in Wyoming reduced soil moisture loss 24 percent between June 24, the treatment date, and September 30. A-1 reduction accrued by August 4, during the time of active vegetative growth. Moisture was measured to a six foot depth and 83 percent of the reduction was located in soil 2 to 6 feet deep.

STURGES, DAVID L. 1975. Hydrologic relations on undisturbed and converted big sagebrush lands: the status of our knowledge. USDA, Forest Service, Rocky Mountain Forest and Range Experiment Station, Research Paper RM-140, 23 p.

The status of our knowledge of watershed management for big sagebrush rangelands is discussed. Climate, soils, vegetation, snow accumulation, and water yields are described, followed by a review and discussion of how management practices alter vegetative composition and the hydrologic regime. Potential hydrologic benefits from managing blowing snow in the big sagebrush type are outlined and research needs are highlighted.

STURGES, DAVID L. 1975. Sediment transport from big sagebrush watersheds. In: Watershed Management, Proc. of a Symposium conducted by the Comm. on Watershed Manage. of the Irrigation and Drainage Div. of the Amer. Soc. of Civ. Eng., Utah Sec. Utah State University, Logan. August 11-13. p. 728-737

Sediment transport was studied in two experimental watersheds with perennial flow located on the Stratton Sagebrush Hydrology Study Area 20 miles west of Saratoga at a 7,000 foot elevation. Sedimentation characteristics of Loco and Sane Creek may not be typical of much of the big sagebrush type as the watersheds have a higher than usual precipitation, a productive vegetative cover reflecting sound land management, and stable soils. Most sediment movement occurred during snowmelt runoff when flows and suspended sediment concentrations were high. In years with over-snow runoff, sediment movement was elevated.

TABLER, RONALD D. 1968. Soil moisture response to spraying big sagebrush with 2,4-D. *J. Range Manage.* 21(1):12-15.

Spraying big sagebrush with 2,4-D reduced the rate of soil moisture withdrawal. About 75 percent of the difference in total moisture depletion occurred within the 3- to 6-foot soil depth; an opposite effect in the second foot indicated that the increase in grass herbage production is most strongly reflected in that zone. Total evapotranspiration losses from the 0- to 6-foot soil profile were reduced about 14 percent over the four-month growing period the second year after spraying.

THOMPSON, J. R. 1968. Effect of grazing on infiltration in a western watershed. *J. Soil and Water Conserv.* 23(2):63-65.

Infiltrometer measurements, along with personal observations, suggest that grazing affects infiltration less than seasonal changes in surface soil characteristics.

TIEDEMANN, ARTHUR R., GLEN O. KLOCK, LEE L. MASON, and DONALD E. SEARS. 1976. Shrub plantings for erosion control in eastern Washington - progress and research needs. USDA, Forest Service, PNW For. and Range Exp. Sta., Res. Note PNW-279. 11 p.

In August 1975, survival measurements and vigor estimates were made in 14 species of shrubs planted on road cut and fill slopes between 1971 and 1973 on the Wenatchee, Okanogan, and Colville National Forests. Their average survival ranged from 37 to 53 percent and was better at low than high elevations and greater on fill slopes than cut slopes. Of species planted on enough sites to enable a good assessment of survival, blue elderberry, bush penstemon, wild rose, and serviceberry had the highest survival. Vigor of blue elderberry and penstemon was good, but vigor of wild rose and serviceberry was only fair to poor. Survival rate of bitterbrush, squaw carpet ceanothus, and snowbrush ceanothus was reduced on cut slopes because plants were covered by raveling soil material. However, good survival and growth of these plants on fill slopes indicate they can probably be used successfully on many sites of this type.

TROMBLE, JOHN M. 1976. Semiarid rangeland treatment and surface runoff. *J. Range Manage.* 29(3):251-255.

Effects of pitting and rootplowing on surface runoff were determined on a desert shrub range in southeastern Arizona, and the time-dependent changes in the soil surface characteristics resulting from these practices were studied. Additional detention storage was provided by increased roughness in microtopography, thereby decreasing surface runoff when compared to the control. Rock and gravel were negatively correlated with surface runoff. Combining the two parameters showed a significant reduction in surface runoff. Increases in runoff were associated with exposed soil. Crown cover significantly reduced runoff. Litter was not significant in the reduction of runoff. Regulation of surface runoff is important for on-site rangeland improvements as well as reducing sediment yields.

TROMBLE, J. M., K. G. RENARD, and A. P. THATCHER. 1974. Infiltration for three rangeland soil-vegetation complexes. *J. Range Manage.* 27(4):318-321.

A rotating disk rainfall simulator was used to examine infiltration/runoff relations from selected rangeland sites as influenced by a soil-vegetation complex. The simulator assisted in quantifying infiltration rates for different management practices on different soil types. Infiltration was greater for brush-dominated plots without grazing. Antecedent soil moisture decreased infiltration rates. Crown cover was approximately twice as much on brush plots as on grass plots and significantly influenced infiltration.

VALE, THOMAS R. 1974. Sagebrush conversion projects: an element of contemporary environmental change in the western United States. *Biological Conservation* 6(4):274-284.

More than 40 million ha of the western United States support a vegetative cover of big sagebrush, Artemisia tridentata. The meager grass understory beneath the woody shrubs offers scant forage for range cattle, the primary economic product of the region.

To improve grass supplies, both government agencies and private ranchers have undertaken a continuing program of shrub eradication and grass planting. Various problems arise from this transformation of brushlands into grassland, including questions of accelerated erosion, herbicide residues, and declining wildlife populations. If planned to produce a heterogeneous plant cover, however, sagebrush conversion projects could improve habitat for both domestic livestock and wildlife, while also maintaining a healthy range ecosystem.

WHITE, CARLETON S. 1976. Factors influencing natural water quality and changes resulting from land-use practices. *Water, Air, and Soil Pollution* 6(1):53-69.

Surface water and precipitation samples were collected from September 1972 through August 1973 on the northern slopes of Mount Taylor in west-central New Mexico. The samples were analyzed for pH, conductivity, silica, Ca, Mg, Na, K, bicarbonate, alkalinity as CaCO₃, sulfate, chloride, nitrate, phosphate, and total solids. The natural water quality was primarily determined by the contact with the different geologic formations. The water originating on or from the basaltic terrain was of better quality and lower in dissolved solids than the water on or from the sedimentary terrain. The effects of grazing, irrigation, water impoundment, vegetation clearing, and road construction upon the natural water quality was determined. Road construction had the greatest effect upon water quality of these land-use practices, but all of the practices had a significant effect on at least one or more of the dissolved constituents.

WILLIAMS, GERALD, GERALD F. GIFFORD, and GEORGE B. COLTHARP. 1972. Factors influencing infiltration and erosion on chained pinyon-juniper sites in Utah. *J. Range Manage.* 25(3):201-205.

Relationships between vegetal and edaphic factors and infiltration rates and erosion as measured on 550 infiltrometer plots at chained pinyon-juniper sites in Utah were analyzed by multiple regression analysis. Those factors most important for predicting infiltration rates (regardless of time interval) included total porosity in the 0-3 inch layer of soil, percent bare soil surface, soil texture in the 0-3 inch layer of soil, and crown cover (percent or tons per acre). The ability to predict infiltration rates (as determined by R^2) varied with time and geographic location. Not only did predictive ability vary, but independent variables explaining such variance also changed with time and location. Factors that influence sediment discharge were so variable from one geographic location to another that no consistent relation was found.

WINK, ROBERT L. and HENRY A. WRIGHT. 1973. Effects of fire on an ash juniper community. *J. Range Manage.* 26(5):326-329.

In an ash juniper (*Juniperus ashei*) community a minimum of 1,000 kg/ha of fine fuel was needed to carry a fire to kill juniper seedlings and burn piles of dozed juniper. Grasses recovered quickly and soil erosion was minimal when burning was done during a wet winter and spring. During a dry winter and spring, however, burning increased drought stress on plants, reduced herbaceous yields, and exposed soil to wind and water erosion for a long period of time when soil moisture was low.

WRIGHT, HENRY A., FRANCIS M. CHURCHILL, and W. CLARK STEVENS. 1976. Effect of prescribed burning on sediment, water yield, and water quality from dozed juniper lands in central Texas. *J. Range Manage.* 29(4):294-298.

Prescribed burning was applied to six miniwatersheds that were each paired with an unburned watershed. Erosion losses, runoff, and water quality were unaffected on level areas, but adverse effects lasted for 9 to 15 months on moderate slopes and for 15 to 30 or more months on steep slopes. Rates of erosion losses stabilized within 18 months on all slopes when vegetative cover reached 63 to 68 percent.