BACKGROUND FOR NEPA REVIEWERS:

GRAZING ON FEDERAL LANDS

February 1994

U.S. Environmental Protection Agency
Office of Federal Activities
401 M Street SW
Washington, DC 20460

DISCLAIMER AND ACKNOWLEDGEMENTS

The mention of company or product names is not to be considered an endorsement by the U.S. Government or by the U.S. Environmental Protection Agency (EPA). This document was prepared by Science Applications International Corporation (SAIC) in partial fulfillment of EPA Contract 68-C8-0066, Work Assignment C-4-71.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

BACKGROUND FOR NEPA REVIEWERS - GRAZING ON FEDERAL LANDS

INTRODUCTION

The primary purpose of the Guidance for NEPA Reviewers - Grazing On Federal Lands is to assist U.S. Environmental Protection Agency (EPA) staff in providing scoping comments and comments on National Environmental Policy Act (NEPA) documents associated with grazing on Federal lands, such as grazing Environmental Impact Statements (EISs) and Resource Management Plans. Pursuant to NEPA and Section 309 of the Clean Air Act (CAA), EPA reviews and comments on proposed major Federal agency actions significantly affecting the quality of the human environment. This document has been developed to assist the EPA reviewer in considering issues related to grazing in the development of NEPA/Section 309 comments.

This guidance is not intended to be all inclusive; rather, the document focuses on EPA's major concerns with surface and ground water, soils, and ecosystems as related to livestock overgrazing and provides technical background material explaining these issues. It does not restate traditional NEPA concerns about impacts on archaeological resources, economics, and so on, but rather addresses the technical environmental concerns related to overgrazing.

EPA realizes that rangeland management is often complex, and recognizes that each livestock grazing operation and each EIS is unique. Thus, reviewers will have to conduct additional analyses to fully understand projected impacts. The reviewer should not rely solely on this document as a definitive list of potential impacts or areas that should be covered by NEPA documentation. This document is more of a guide or introduction to issues associated with livestock overgrazing on Federal lands and does not replace early involvement in the NEPA process, defining objectives, developing alternatives, and determining effects based on knowledge of the issues and characteristics of specific areas.

Overview of Grazing Practices and Associated Impacts

Grazing on the open ranges of the Great Basin began in the mid 1800's and became a major industry in the western U.S. as early as the 1870's, with peak numbers of cattle and sheep being grazed by 1890. By 1900, many unrestricted lands were overstocked and significantly, sometimes even permanently, impacted. Impacts included trampled and compacted soils, lowered water tables in some areas, and replacement of quality vegetation with less desirable, more shallow-rooted species. As early as 1889, writers acknowledged that destructive grazing appeared responsible for denuding slopes of vegetation, increased runoff, erosion, and severe flooding in some western States (Gifford, NRC 1984).

In 1934, the system of free access to Federal lands ended with the passage of the Taylor Grazing Act and the establishment of the Division of Grazing, later to become the Bureau of Land Management, within the Department of the Interior. Although the Act was intended to rehabilitate rangelands, livestock numbers were not controlled and little rehabilitation occurred. This act was the first of many statutes directing the use of public lands for grazing. These statutes include the Multiple Use - Sustained Yield Act of 1960, the Forest and Rangelands Renewable Resources Planning Act of 1974, the National Forest Management Act of 1976, the Federal Land Policy and Management Act of 1976, and the Public Rangelands Improvement Act of 1978. National grasslands were bought under Forest Service management through the Bankhead-Jones Farm Tenant Act. The Fish and Wildlife Service oversees grazing on National Wildlife Refuges and in National Parks.

Both the Bureau of Land Management (BLM) and the Forest Service, acting as caretakers for lands under their jurisdiction, use an allotment system to control livestock grazing on Federal lands. Ten year renewable permits are issued for each allotment with the total fee based on the number of livestock and length of stay, calculated in terms of Head Months (HMs), or Animal Unit Months (AUMs). The Forest Service defines a Head Month as one month's use and occupancy of the range by one animal (one weaned or adult cow with or without calf, bull steer, heifer, horse, burro, mule or 5 sheep or goats). An AUM is defined as the amount of forage needed to support a 1000 pound cow and calf or 5 sheep for one month and consists of between 800 to 1000 pounds of forage. Currently, Federal grazing allotments cover approximately 30 percent of the total 853 million acres grazed nationwide, with most grazing on Federal Lands occurring in the western U.S.

Both the Forest Service and the BLM have separate requirements that apply to grazing. As part of their management responsibilities, both the Bureau of Land Management and the Forest Service develop area-specific management plans called Resource Management Plans or Forest Plans. These plans provide a comprehensive framework for managing and allocating uses of public lands and resources, such as fluid and locatable minerals, riparian resources, wildlife and fish habitat, and livestock grazing. Based on the management plans, the Bureau of Land Management and the Forest Service develop allotment management plans and issue grazing permits for those allotments, which present decisions on grazing at a more detailed level. More detail on these activities is provided in Forest Service and BLM Handbooks.

Each of these activities or decisions, ranging from developing a plan to issuing a lease or taking a specific range management action, may be subject to NEPA review. Typically the Bureau of Land Management or the Forest Service prepares an EIS for each Resource Management Plan or Forest Plan. For more detailed or allotment-specific activities, additional NEPA documentation is usually tiered (based on the existing Resource Management or Forest Plan EISs). Activities that are not addressed in existing NEPA documentation may require additional NEPA review, such as an Environmental Assessment (EA) and/or an EIS, if the proposed action "significantly affects the quality of the human environment." Under the CAA Section 309, EPA has the authority to review and comment on each EIS.

Despite attempts to control environmental impacts caused by overgrazing and recent improvement in rangelands according to some sources (Platts, 1990), many problems still exist in both upland and riparian areas. Issues characterizing upland areas, especially in arid environments, include the sensitivity of desert ecosystems and the extreme difficulty in reclaiming upland areas after impacts have occurred. Riparian areas are often of more concern to the public and Federal land managers for several reasons. Cattle tend to congregate in riparian areas, using them for shade and drinking water and spending a disproportionate amount of time foraging and trampling these areas rather than upland areas, posing a potentially higher level of damage. Also, riparian areas support a higher diversity of terrestrial and aquatic organisms than upland areas and provide critical habitat for both terrestrial and aquatic organisms. Erosion caused by overgrazing can reduce a streambank's water retention capabilities, lowering the surrounding water table and often changing the character of the stream from perennial to intermittent (GAO, June 1988a). Livestock and wildlife overgrazing can cause direct impacts on upland and riparian areas, such as loss of vegetation and soil compaction that lead to indirect impacts on the hydrology of an area and the ecosystems, both terrestrial and aquatic, that rely on it.

The remainder of this document describes important issues associated with the grazing of livestock on Federal Lands. Specifically, the document is arranged in the following sections:

- technical description of grazing;
- potential environmental impacts, both direct and indirect, associated with grazing;
- possible prevention/mitigation measures;
- types of questions that can be posed as part of the Agency's response to review of NEPA documentation; and
- explanation of the statutory and regulatory framework under which grazing on Federal lands occurs.

As discussed above, this document does not substitute for indepth knowledge of rangeland management concepts and site-specific issues.

TECHNICAL DESCRIPTION OF GRAZING ON FEDERAL LANDS

National and Regional Perspectives

Over 95 percent of livestock grazing on Federal lands occurs in the western U.S. The BLM and the Forest Service manage a total of 461 million acres of public land. Of this, approximately 367 million acres are in the western U.S.[1] with grazing allotments covering about 70 percent of this area. Specifically, the BLM has approximately 165 million acres with approximately 22,000 separate grazing allotments (BLM, 1990). Of the Forest Service's 191 million acres, 104 million acres are allotted to grazing (95 percent of these allotments are located in the west) with approximately 50 million acres classified as suitable for grazing (e.g., slopes are not too steep) (GAO, May 1991). This compares with private grazing lands of approximately 603 million acres nationwide with 372 million acres of private grazing acreage in the western states[1]. Figure 1 shows both Federal and non-Federal grazing lands in the U.S. Texas has the most non-federal grazing lands with approximately 115 million acres; however, there are no BLM or Forest Service lands in Texas (Department of Agriculture, 1982).

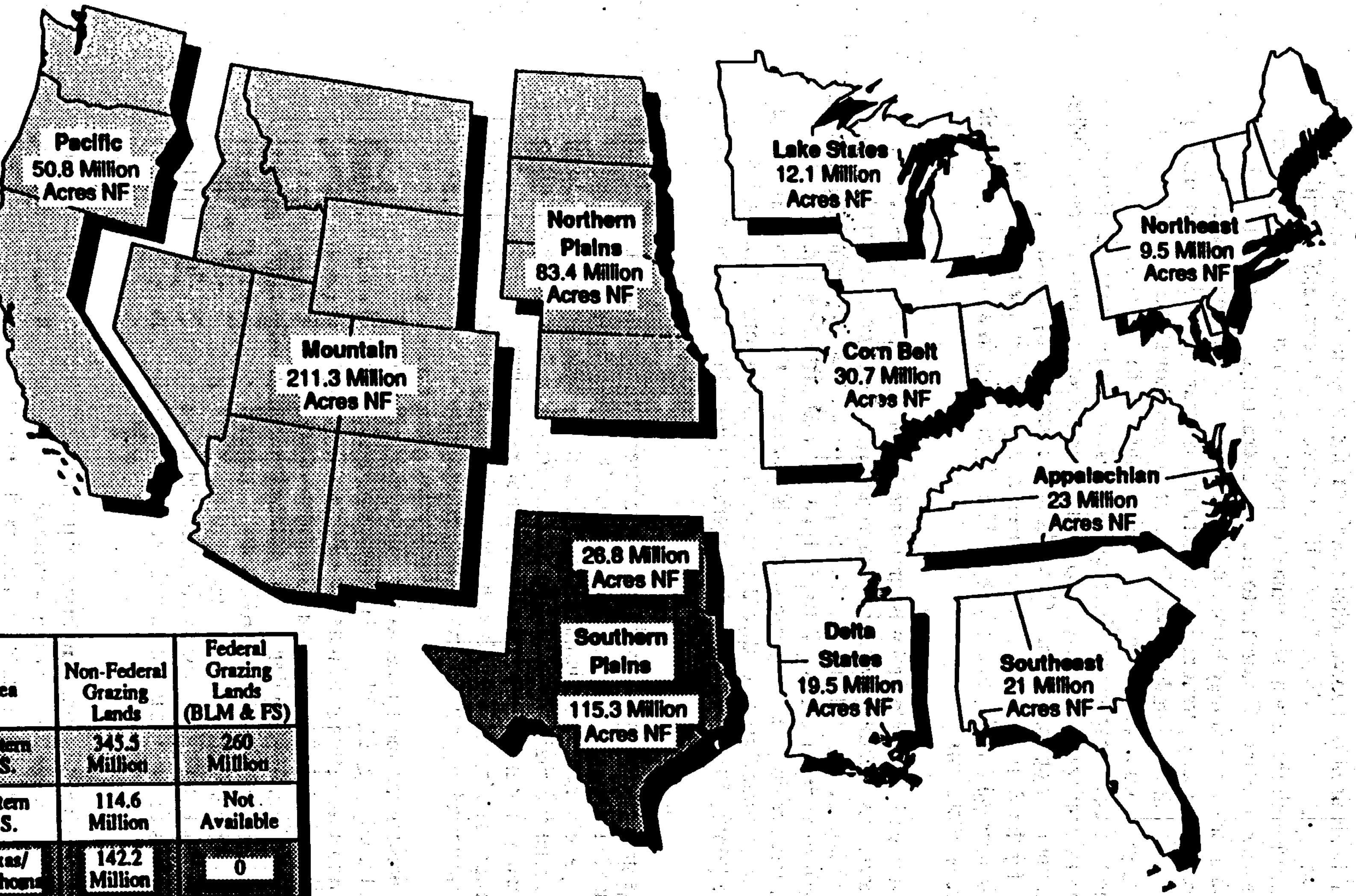
BLM and the Forest Service manage public lands through allotments that typically have ten year permits and sometimes yearly or seasonal licenses (which are more specific than 10 year permits). Permits specify the number and type of livestock, an authorized season of use, and the AUMs (a measure of the amount of grazing available). The acreage required to provide one AUM varies from region to region, ranging from a low of 6.1 acres in Montana to a high of 21.8 acres in Nevada. The overall average AUM is 13.7 acres. The average grazing allotment is approximately 8,500 acres (13 square miles) with allotments as small as 40 acres and as great as 1 million acres (GAO, June 1988b). In many cases, allotments are interspersed with private lands, creating the checkerboard pattern seen on most Federal lands maps. This checkerboard pattern hampers effective control by Federal land managers, and requires constant cooperation between land mangers and ranchers.

According to 1990 statistics, BLM had about 165 million acres of grazing allotments, with almost 20,000 operators and 4 million head of livestock using 13.5 million AUMs (BLM, 1990). In 1986, the Forest Service had about 102 million acres in grazing allotments (in 36 states) with 13,805 permits using a total of 8.6 million AUMs. GAO estimates that 25 to 30 percent of the Forest Service allotments are in a declining condition and/or are overstocked.

As described above, Federal livestock grazing allotments cover about 30 percent of the total area grazed in the U.S. (not including Alaska); however, Federal lands produced 13 percent of the total AUMs nationally. According to 1988 estimates, less than 5 percent of the nations beef cattle and 30 percent of the sheep graze on Federal lands. In western states, one third of the beef cattle is grazed at least part of the year on Federal Lands. About 2.2 million cattle and 2.1 million sheep graze on BLM allotments each year. In many cases, large (greater than 500 head of cattle) livestock operators use the public rangelands (15 percent of the operators use 58 percent of the allotments) (GAO, June 1988a and b).

---

[1] Includes the states of Arizona, California, Colorado, Idaho, Kansas, Nebraska, Nevada, New Mexico, North Dakota, South Dakota, Oklahoma, Utah, Washington and Wyoming.



Area	Non-Federal Grazing Lands	Federal Grazing Lands (BLM & FS)
Western U.S.	345.5 Million	260 Million
Eastern U.S.	114.6 Million	Not Available
Texas/ Oklahoma	142.2 Million	0
Total	603 Million	461 Million

*NF - Non-Federal lands, acreage based on 1982 figures.

Figure 1. Federal and Non-Federal grazing land in the United States, by Farm Production Regions.
Source: U.S. Grazing Lands: 1950-1982, Department of Agriculture.

Grazing Fundamentals

Livestock grazing on Federal lands usually involves either cattle or sheep operations. Typically, cattle are grazed in one of two types of operations, "cow/calf" or "steer." In cow/calf operations, cows and their calves are grazed until the calves are weaned to produce a calf crop. Each year, the calf crop is sold between the ages of 6 and 12 months, to feed lot operations or to other ranchers as breeding stock. A limited number of calves may be retained by the rancher to become breeding stock. Unlike cow/calf operations, steer operations are seasonal and use forage for 3 to 9 months to fatten cattle that are then sold to feedlots. Unlike cow/calf and steer operations, sheep are typically herded through allotments and graze on a seasonal basis to take advantage of more succulent and palatable forage. As the prime forage is consumed, the sheep are moved to new areas. Different species of livestock graze in different ways. Herded sheep usually use slopes and upland areas, while unherded cattle prefer lesser slopes or bottom lands. Of the forage consumed by livestock, cattle consume the most, estimated by the Bureau of Land Management and Forest Service as 87 to 89 percent of allotted Federal land forage (GAO, June 1988b). Wildlife grazing, in addition to livestock grazing, will also impact forage allotments.

When and where to graze livestock in order to optimize profits and provide ecologically-desirable results depends on many factors. Availability of forage such as grasses, forbs, or even brush is one of the prime considerations, as is easy access to water. Grazing animals prefer leaf tissue over stem tissue, and green plant material over dry material (Wallace, 1984). As would be suggested by these general rules, in some areas, streamside grazing by cattle often is more than twice the overall pasture use, with reports of riparian areas comprising less than 2 percent of the total allotments providing over 80 percent of the forage (Platts, 1986). Allotment management plans, however, can moderate this phenomenon.

Although prediction of forage growth and proper grazing may be scientifically modelled, sustainability of forage production from one year to the next depends on how heavily the area is grazed, as well as other site specific factors and variables such as annual precipitation. Most plants can withstand some loss of foliage and maintain their competitive position in the ecosystem and, in some instances, moderate grazing may increase the production of plant material. However, the approach to estimating the proper grazing intensity is complex, weighing site specific factors such as plant physiology, soils, micrometeorology, plant demography, and competitive ecology.

In monitoring grazing areas, plant vigor and species composition and diversity are major elements in determining if the area is too heavily grazed. Plant vigor reflects the capacity to rapidly produce both vegetative and reproductive shoots, the storage of nutrient reserves and effective root system volume, especially depth, when soil moisture and temperature are conducive to growth. Specific measures of vigor include numbers of tillers produced following defoliation, total plant height, leaf length, seed production, soluble carbohydrate concentrations, and root growth (Caldwell, 1984). In some cases, empirical measures are used to evaluate plant vigor. These include the ability to overwinter, to endure subsequent drought following defoliation, or to produce seed in a year following defoliation. However, less than positive results of empirical evaluations may not be known until the impact has occurred.

In general, livestock grazing can be characterized in terms of intensity, duration and timing. In a simplistic manner, grazing intensity is indicative of the amount of forage in a pasture that is grazed. Grazing intensity is measured by number of animals per unit month and ranges from light to heavy; light grazing is considered as use of 20 to 40 percent of the available forage, and moderate grazing is estimated as use of between 40 and 60 percent of available forage. The term moderate grazing also indicates that stocking rates are between those in a lightly grazed pasture and those in a heavily grazed pasture. Heavy grazing, 60 to 80 percent of available forage, is still practiced, and is considered a likely cause of poor conditions of riparian and other areas. Heavy grazing may also be defined as the amount of forage consumed in a pasture in excess of its sustainable capability. In assessing the impacts, however, much more is required than just the level of forage use. No grazing strategy is implemented the same on every allotment. Rangeland management requires the integration of complex site-specific factors, only a few of which are described here.

The timing for a first release of livestock into an area is an important factor in grazing management, sustaining plant growth from season to season, and in trapping of sediment to rebuild riparian areas. Early grazing begins when the cool season plant growth has peaked and warm season plants are beginning their growth. Early grazing ends with the flowering of key species. Late grazing is conducted only after seed ripe time when the period of maximum warm season plant growth is over and seeds have been produced; the seeds then may be trampled into the ground by livestock. Some growth of cool season plants may occur if moisture and soil temperatures allow. In order to maintain seasonal grazing, livestock are often rotated from pasture to pasture, utilizing different pastures at different stages of the growing season. Though rotation of livestock has typically been associated with heavy stocking for short durations, it has also been used for short or long periods and with light stocking.

Using these concepts, grazing systems have been developed to manage livestock. Grazing systems are plans that differ with respect to periods of grazing, intensity of grazing, season, and stage of growth of vegetation. Grazing systems are useful in that they may increase productivity of the land and, ultimately, of livestock, by controlling grazing by both wildlife and livestock. Certain specific systems have proven to be especially effective in riparian areas that are more susceptible to degradation from overgrazing. Examples of various grazing systems are provided below for descriptive purposes. Actual design and implementation of a grazing system requires the collection of site-specific data and the analysis and integration of complex site-specific variables by personnel trained in the field.

In addition, no grazing system is implemented the same on every allotment. Allotments are unique, and management can only be designed through a comprehensive, integrated approach. Management strategies are only as good as the permittee responsible for implementing the system. The best possible system will fail without the commitment from the permittee to make it work. It should not be assumed that a system will work in every situation. For example, while rotational grazing using sheep is generally a good system for riparian protection, the system may not work if the herder concentrates the sheep in streamside areas. Examples of grazing strategies are described below (Platts, 1986, 1990, and 1991).

Continuous Season-Long. Under this grazing scenario, livestock have unrestricted access to a specified range area for an entire vegetation growing season. Advantages are that season-long continuous grazing permits maximum forage selectivity, while minimizing disturbances to livestock by gathering, moving, and change in quality of vegetation (Platts, 1990). Drawbacks may be that livestock overgraze certain vegetation or areas before others. In addition, livestock will generally obtain much of their diet along riparian areas, typically minor portions of grazing allotments (Platts, 1986).

A 1977 study by Marcuson found that average channel width in a riparian area to be much wider after season long grazing at 0.11 ha/AUM than in a comparable ungrazed area. This study also found that heavy grazing and trampling by cattle left only 224 meters of undercut bank per kilometer in the grazed area versus 686 meters of undercut bank per kilometer in the ungrazed area. As a result of these erosional impacts to riparian areas under this grazing scenario, Platts does not consider this strategy to be useful in those areas, as fishery productivity would be seriously impacted.

<u>Short Duration - High Intensity</u>. Short duration, high intensity grazing generally describes high stocking, high intensity use in a designated area, over a short period of time. Livestock are placed in an area for a period of one day to several weeks before being moved to the next area. This type of strategy requires numerous pastures in order to ensure that a grazed section is unused for a significant amount of time to permit regrowth. The layout of pastures is sometimes subdivided to resemble a "wagon-wheel." This method requires almost daily checks on vegetative conditions to prevent overuse. In general, this method is out-dated and is infrequently used.

<u>Three Herd - Four Pasture</u>. Also referred to as the Merrill Pasture System, this strategy allows each pasture a period of nonuse within one four year cycle. Useful in upland areas, the Merrill Pasture System requires less animal movement than other heavy use strategies, and has succeeded in generating higher plant productivity in conditions with sufficient precipitation. However, one four-month period of nonuse over a four year period is not sufficient to rehabilitate a heavily impacted riparian area.

<u>Seasonal Suitability</u>. This strategy requires substantial fencing and frequent movement of animals from pasture to pasture, providing heavily used areas with periods of nonuse for regeneration, during selected periods of the grazing season. Depending on the extent of use prior to periods of nonuse, riparian areas may not be able to regenerate sufficiently before livestock are re-introduced to the area. In addition, there is seasonal variation in streambank stability, with greater potential for erosion during the dryer hot season.

<u>Holistic Method</u>. This grazing strategy may be less straight-forward than others, requiring training and management skills to enable heavy stocking and frequent movement dependant upon the growth cycle of plants and other environmental factors. This method also utilizes livestock as a soil churning mechanism to break up the soils, and increase soil porosity (its effectiveness is under debate). While upland areas may benefit from this type of management, this grazing method may erode streambanks in riparian areas, impacting streamside vegetation and overall riparian habitats.

<u>Deferred</u>. Deferred grazing strategy defers grazing in one or more pastures to permit desired growth or regrowth or to produce ripe seeds prior to being grazed. The period of deferment may continue for several years to allow vegetation to reestablish itself. This grazing strategy requires a substantial amount of fencing and cattle movement, though the periods of rest offer opportunity for regrowth of preferred grazing vegetation. Deferred rotation in a riparian area may be a useful grazing strategy in a riparian area if overstocking is prevented in order to avoid streambank shear and erosion.

<u>Deferred Rotation</u>. The deferred rotation strategy delays grazing of key species until seeds have matured by systematically rotating livestock among a number of pastures. If one pasture is grazed early one year, pasture use sequence would change the following year so that a different pasture was grazed early. This method requires a fair amount of fencing, however, vegetation is able to store carbohydrates and set seed every other year. The period of nonuse will vary throughout the each year, allowing areas of nonuse during critical periods to allow plant cover to increase.

Stuttered Deferred Rotation. Similar to the deferred rotation strategy, one pasture is deferred for part of the plant growth period. The deferment is passed on to a different pasture but in the stuttered method grazing use occurs on one pasture early for the first two years and another late the following two years, whereas deferred rotation changes every year. A great deal of fencing, and movement of livestock is required under this grazing scenario. However, as with the use of Deferred Rotation, brushy species are given an opportunity for regrowth.

Rest-Rotation. This grazing strategy involves rotating livestock from one range area to another in order to prevent overgrazing. Though this method may be costly since it may require fencing to carve out range areas within an allotment, it allows grazed rangeland to rehabilitate while cattle are occupying another portion of an allotment. This strategy has shown measurable success in some habitats.

The rest rotation strategy is a multi-pasture design strategy that provides at least one year of rest for a grazed pasture. This strategy is frequently combined with deferred, early, and late grazing techniques so that pastures are rested until seed ripe time, and rested for seedling establishment. Depending upon vegetation types and soil moisture content and temperature, three or more pastures are needed for rest rotation to be successful.

Double Rest-Rotation. Under this strategy, an area or pasture with the highest riparian and stream values would receive twice the amount of rest compared to the amount of rest allocated under the normal rest-rotation grazing cycle. In a three pasture system, the most valuable riparian-stream area would receive 2 years rest. A Forest Service study of a double-rest-rotation system, graze early then rest 2 years, then graze late and rest 2 years, showed no adverse riparian-stream impacts.

Rest-Rotation with Seasonal Preference. This strategy is most often applied to sheep since this method requires frequent movement of the livestock in response to signs of range, riverine or riparian habitat deterioration. The strategy encourages use of areas during periods of least impact to vegetation, allowing plants to be grazed at particular times to allow rest to recover from past grazing use.

Riparian Pasture. This grazing strategy places the riverine-riparian system within a controlled unit, to permit grazing only in those areas of the stream that can provide vegetation without being negatively impacted. Additional fencing is required under this scenario to prepare riparian pastures that encourage utilization of both riparian and upland areas. Overuse of upland areas of the pastures is also a concern in the event of increased sediment, or overland flows impacting the stream. The advantage of individual pastures is the ability to encourage distribution evenly within each pasture.

Seasonal Riparian Preference. As with the Riparian pasture method, use of this strategy encourages grazing of plants and streambanks during periods when the vegetation is less vulnerable to sustaining damaging impacts. Fencing and frequent animal movement are also necessary in order for this strategy to be successful, and grazing within each pasture must happen over a narrow period of time.

Winter. A form of seasonal grazing, winter grazing takes place when range vegetation is dormant and streambanks frozen. Impacts to riparian areas may diminish under these conditions, since streambanks tend to be more capable of withstanding the impacts of hooves while frozen. In riparian areas, winter grazing in areas of low temperatures but little snow can be beneficial to the extent that streambanks are sturdier, and vegetation dormant.

Holding. The holding strategy is a short to long term method of containing livestock in a specific area of land prior to moving them. This strategy permits animals freedom to move within a designated area. These holding areas are useful not only to allow other pastures to be prepared for grazing, but can also be used as disease treatment facilities, and for breeding purposes. Pros and cons associated with this grazing strategy are similar to those under the season long continuous strategy, such as preferred plants and riparian areas receiving excessive use (Platts, 1990).

Corridor fencing. Stream corridor fencing in riparian areas prevents overuse of streamside vegetation, and assists in the rehabilitation of denuded portions of a riparian zone. This strategy usually requires extensive fencing and involves high maintenance costs.

Rest. Certain areas may be rested until vegetation and/or riparian habitats are permitted to re-establish themselves and regrow.

Rangeland Management

Modifications to rangelands can be used to mitigate impacts of livestock and wildlife grazing and are discussed in a later section on mitigation. While modifications to rangeland can enhance grazing opportunities, modifications may also result in adverse effects on water quality, as well as aquatic and terrestrial ecosystems, if not properly planned and managed. Platts (1991) alluded to the variety of activities that could occur as part of rangeland management, including the fertilization of lands; irrigation and drainage of wetlands; brush, forb, and pest control; debris disposal; mechanical treatment of the soil; seeding, prescribed burning; water supply development; fencing; and timber thinning. Depending on the frequency, extent and appropriate implementation of these range improvement practices, both positive and negative effects can occur. Potential negative impacts include erosion and sedimentation, hydrologic modification, chemical contamination (pesticide and fertilizer), and unfavorable ecosystem alteration. However, if rangeland improvements are tied to the attainment of specific resource objectives, then such improvements may reduce the severity of grazing impacts, thus the implementation of sound grazing practices.

POTENTIAL SIGNIFICANT ENVIRONMENTAL IMPACTS

Both livestock and wildlife overgrazing may cause direct impacts resulting in physical changes to the rangeland, such as the removal of protective plant cover and damage from hoof action and trampling to ground surfaces. These direct impacts may contribute to a host of indirect impacts such as erosion and stream channel modification. Both direct and indirect physical impacts often result in changes to terrestrial and aquatic ecosystems. These changes to the rangeland from overgrazing occur in both upland and riparian areas. Impacts in both environs can affect stream water quality, although activities in the riparian zone often cause more immediate and severe impacts. While it is difficult to make generalizations concerning the effects that livestock and wildlife grazing practices have on rangeland due to the geographic variability of vegetation, soils, climate, and topography, the majority of the research reviewed for this document points out some common trends. To fully assess the applicability of these trends, a knowledge of the site-specific conditions is important. Even the grazing species is important; cattle and sheep have different impacts on streambanks. The stream and its watershed function as a unit and therefore, management is most effective on a basin-wide approach (Platts, 1986). Because much Federal land is intermingled with private land in a checkerboard pattern, it is important to plan for the total ecosystem, considering grazing activities on adjacent and nearby private land, as well as the activities on Federal land. For example, overgrazing on private land upstream of public land may cause impacts to the public land. Although the land manager's administrative responsibility does not apply on private land, recognizing impacts on a watershed basis and integrating these into grazing management strategies is important.

One of the more significant hydrologic and water quality effects associated with overgrazing results from impacts on soil from livestock hoof action and trampling. For example, hoof action and trampling can disrupt natural soil conditions (e.g., soil structure, bulk density, and permeability) and cause soil compaction, which leads to increased runoff and associated soil erosion and loss. The removal of plant cover by the grazing animals exacerbates these problems by leaving even more soil bared to disruption and compaction. Also, the removal of plant cover by grazing animals frequently changes the overall density and composition of the native vegetation. As grazing-related activities create conditions that increase runoff and soil erosion from the rangeland, stream water quality is primarily affected by the increased amount of sedimentation. Also, hydrologic changes to the stream channel due to increased water velocity and flow can occur. The reduction in plant cover can indirectly affect water temperatures, especially expanding the range of temperatures experienced in the stream and increasing maximum temperatures. Compaction can also affect the ability of vegetation to establish, thus exacerbating erosion.

The effects caused by overgrazing result from a variety of interrelated factors such as climate, vegetation, topography, soil characteristics, and the intensity, type and duration of livestock and wildlife grazing. Therefore, the nature and extent of impacts from overgrazing will vary from location to location due to the normal variability of ecosystem specific factors. Despite these variabilities, the mechanisms causing the impacts (e.g., soil compaction and increased runoff) are similar. Impacts can also vary significantly between grazing strategies. Because activities throughout a stream's watershed (i.e., upland and riparian areas) can affect stream water quality, grazing strategies should address both areas.

Livestock and wildlife grazing activities are associated with other causes of surface water degradation such as bacterial/fecal contamination of water bodies, stream bank erosion and modification associated with hoof or head (scratching, butting or digging) action, withdrawal of water for irrigation of grazing areas, and drainage of wet meadows.

Figure 2 illustrates some of the interrelated impacts that stem from livestock and wildlife foraging and trampling, such as changes in vegetative cover (density and type), affecting physical soil condition or surface water hydrology. In general, the adverse effects associated with grazing increase as the intensity of grazing increases.

This chapter is divided into two major sections: Direct Impacts and Indirect Impacts. Indirect Impacts are further divided into physical impacts and ecosystem impacts. The major direct effects includes a description of the effects of overgrazing and livestock trampling on vegetation and ground surface conditions and the ensuing changes to physical characteristics of the rangeland, and changes to infiltration rates. The discussion of the indirect impacts addresses erosion and sedimentation, channel modification, water table changes, bacterial contamination, and temperature changes. While not all grazing results in adverse impacts, and there may be some favorable impacts that are the result of grazing, this section focuses on the potential adverse impacts of grazing activities.

Direct Impacts

Overgrazing of livestock and wildlife can affect rangeland in two major ways: (1) by reducing the density (i.e., percent-cover) and quality of vegetation, and (2) by disrupting soil conditions and causing soil compaction by hoof action and trampling. Each of these effects creates conditions which lead to increased surface water runoff, sedimentation, and erosion. Livestock foraging reduces the amount of cover provided by vegetation (including plant litter), which in turn creates a situation where soil compaction, reduced rainfall infiltration, increased runoff, and soil erosion can occur. The trampling by livestock further compacts soil, reducing infiltration and increasing surface runoff and resulting soil erosion. (Blackburn, 1984 and Kauffman and Krueger, 1984)

Vegetation. Livestock overgrazing can reduce the health and vitality of rangeland vegetation, therefore, reducing the amount of ground cover provided by the vegetation. Vegetation is specifically affected by livestock in the following ways:

- trampling causes soil compaction, thus decreasing water infiltration, causing increased runoff, and decreased water availability to plants;
- herbage is removed, which allows soil temperatures to rise and increases evaporation to the soil surface;
- physical damage to the vegetation occurs by rubbing, trampling, and browsing (Kauffman and Krueger, 1984).

An additional factor is that as foliage is removed, plants put a greater portion of energy into regrowth of leaves and less toward root growth which has the effect of reducing root biomass which in turn reduces soil stability and leads to increased erosion. Altering vegetation patterns can result in greater susceptibility to draught, fire, insects, and exotic plant competition.

As vegetation is harvested, total plant density and cover may decline, and a compositional change may occur (e.g., decrease of grasses and forbs and increase of sagebrush). In some cases, less desirable species may result. By altering the amount of vegetative cover and composition, overgrazing ultimately increases the amount of bare soil on the rangeland that is subject to runoff and erosion. It also creates conditions that can modify stream temperatures, thus causing a host of ecological changes. Also, changes to vegetation from overgrazing can often result in an overall decrease in the grazing capacity of the rangeland.

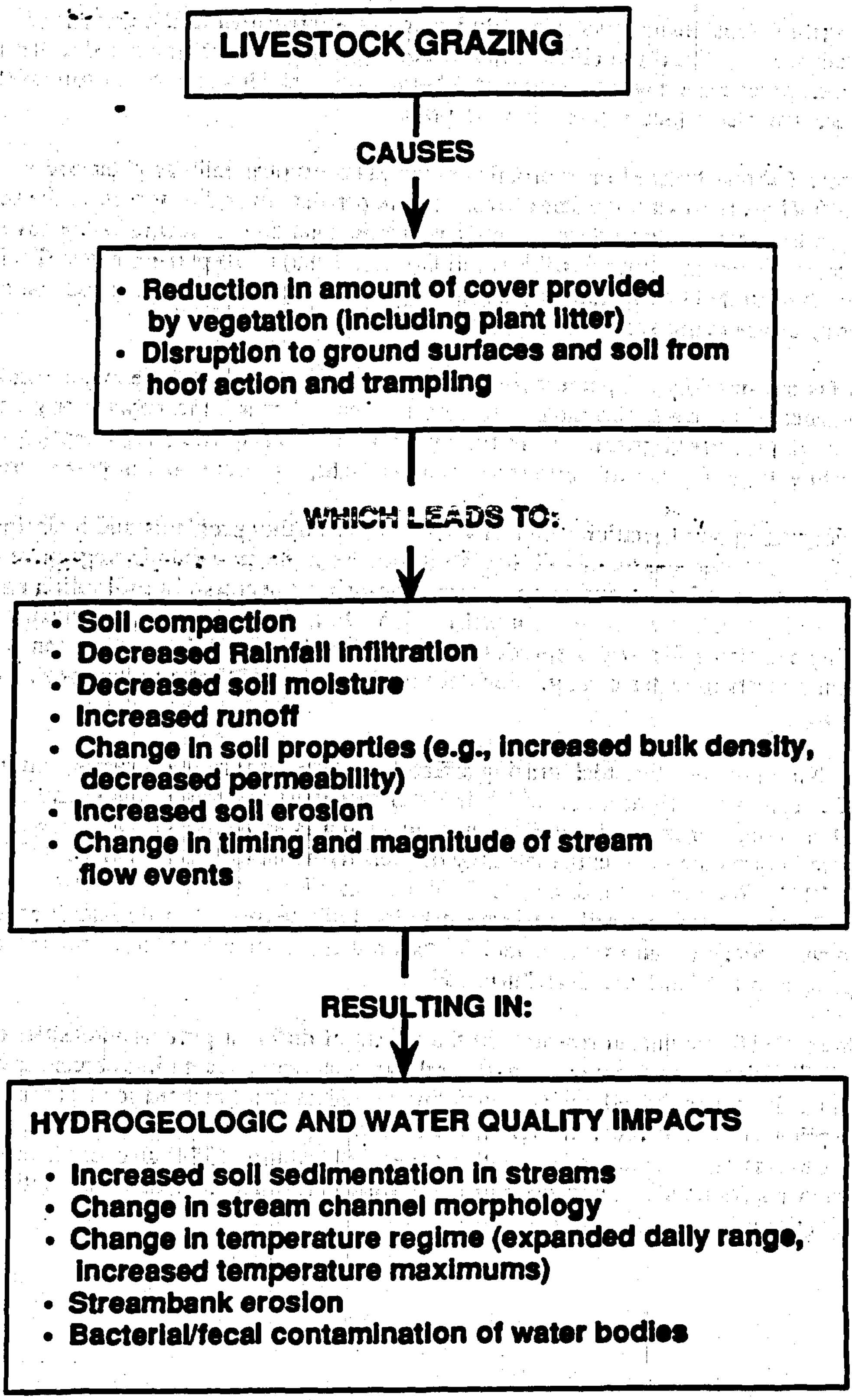


Figure 2. The Interrelationship of Grazing Impacts.

Impacts to the rangeland (and ensuing water quality impacts) are intensified as the amount of vegetative cover decreases. Blackburn (1984) summarized two studies which attempted to define a cover threshold (i.e., percentage cover by vegetation) below which serious impacts to soil infiltration and associated increased runoff (and soil erosion) occurred.

For example, Figure 3 shows that sediment production increases exponentially as plant cover decreased. These findings represent one study area, and the percent cover that serves as the threshold point varies with location according to a variety of site specific conditions. Generally the cover thresholds range from 50 percent cover (Dadkhah and Gifford, 1980) to 70 percent cover (Packer, 1953). However, the threshold point can vary depending on the initial amount of vegetation at the site and the intensity of use at the site.

Grazing intensity (as measured by the percentage of ground trampled) is one of the major factors that affects the maintenance of the cover threshold. As common sense dictates, the impacts of grazing on vegetation increase with increased grazing intensity; high intensity grazing (i.e., high density) causes serious impacts, while there may be little difference between light, moderate, and ungrazed areas.

The impacts of overgrazing on vegetation result in surface water quality problems and hydrologic modification largely due to the amount of soil that is exposed from the reduction in vegetative cover. This can increase the impact of raindrops on soil, possibly causing a decrease in infiltration rates, increase in surface runoff, and/or an increase in soil erosion. In a similar manner, livestock hoof action and trampling can also affect soil properties and ground surface conditions which can cause a range of subsequent impacts to water quality. Each of these impacts (infiltration rates, sedimentation) are described below.

<u>Infiltration Rates</u>. Not only does livestock grazing affect the rangeland through foraging, but the hoof action and trampling causes soil compaction which leads to decreased infiltration rates, and increased runoff, and/or soil erosion. Innumerable studies have shown that infiltration rates decrease as a result of trampling. These impacts increase as the intensity of grazing increases (Warren et al., 1986; Wood and Wood, 1988; Wood and Blackburn, 1981; Weltz and Wood, 1986). The most important factors affecting infiltration rates are: soil aggregate stability, bulk density, organic matter content, and initial soil moisture content; and extent of mulch, standing crop, ground cover, perennial grass cover, and total grass cover (Wood and Blackburn, 1981).

Dadkhah and Gifford (1980) conducted research on the effects of different grazing intensities on infiltration rates. Infiltration rates decreased significantly with increased trampling percentages up to 40 percent trampling. In this study, 40 percent trampling served as the threshold for infiltration reductions; at trampling rates 40 percent or higher, the researchers found no significant differences in infiltration rates regardless of the extent of vegetative cover. Blackburn (1984) also summarized a number of infiltration studies conducted on the Northern Great Plains that compared infiltration rates to grazing intensity (Table 1).

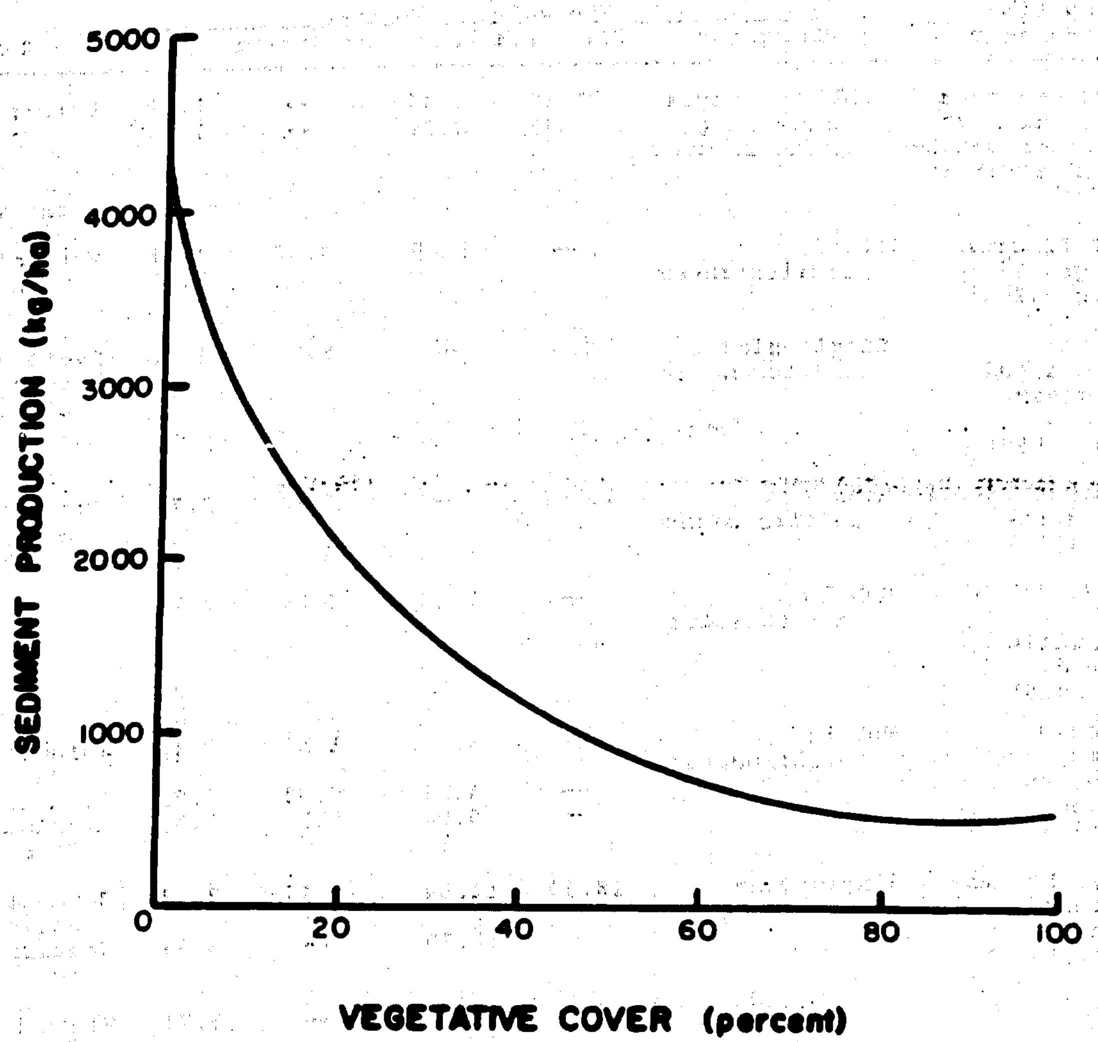


Figure 3. Sediment production as a function of vegetation cover*.
Source: Dadkhah and Gifford, 1980.
*** will vary widely depending on geography, soils, climate**

Table 1. Summary of studies of the influence of livestock grazing on infiltration on the Northern Great Plains.

Study Site and Reference	Equipment	Infiltration Capacity (cm/h) by Grazing Intensity: Ungrazed	Light	Moderate	Heavy	Remarks
Fort Peck, Montana Nuttall saltbush and crested wheat-grass (Branson et al., 1962)	USGS tube-type sprinkling infiltrometer	0.65	0.45	--	0.92	Unfurrowed
		3.02	2.29	--	1.10	Furrowed, seeded averaged over soil type and years
Southwest Alberta Fescue grassland (Johnson, 1962)	Mobile infiltrometer	--	5.69	4.06	4.14 3.53	Very heavy grazing
Hays, Kansas Blue grama and Buffalograss (Knoll and Hopkins, 1959)	Single-ring infiltrometer	6.55	--	5.28	4.01	Exclosure had not been grazed for 13 years
Mandan, North Dakota Mixed Prairie (Rauzi, 1963)	Mobile infiltrometer	10.84	--	6.10	3.76	Exclosure had not been grazed for 21 years
Cottonwood, South Dakota Mixed Prairie (Rauzi and Hanson, 1966)	Mobile infiltrometer	--	7.49	4.24	2.76	
Nunn, Colorado Blue grama and Buffalograss (Rauzi and Smith, 1973)	Mobile infiltrometer	--	1.40	1.14	1.27	Shingle sandy loam
		--	4.32	5.33	2.03	Nunn loam
		--	5.00	5.13	2.03	Ascalon sandy loam
Miles City, Montana Mixed Prairie (Reed and Peterson, 1961)	Single-ring infiltrometer	18.58	11.04	10.96	7.19	Blue grama upland
		--	12.29	--	5.69	Western wheat-grass bench
			17.12	--	6.74	Western wheat-grass bench
Western North Dakota Mixed Prairie (Whitman et al., 1964)	Single-ring infiltrometer	15.24	--	--	7.87	

While there was some variability among the results due to site-specific conditions and variations in study methodology, the following general trends were noted for all of the research evaluated:

- Differences between light and moderate grazing were usually very small.
- Heavy grazing almost always caused a reduction in infiltration rate.
- Soil bulk densities appeared to increase with grazing intensity and were higher on grazed pastures than on ungrazed pastures.

Some researchers have attempted to examine infiltration rates in the context of different grazing strategies. In general, these findings supported the above assertions that as stocking intensity and density increase, infiltration rates tend to decrease. Wood and Blackburn (1981) noted that infiltration rates in deferred-rotation treatments approached the near-optimum infiltration rates demonstrated in the grazing exclosures and exceeded those in the heavily stocked, continuously grazed treatment. Infiltration rates in a high intensity, low frequency (HILF) treatment were similar to those of the heavily stocked, continuously grazed treatment (Figure 4). Research by McGinty, et al. (1978) also found that infiltration rates for a pasture subject to a 4-pasture deferred-rotation grazing system were similar to those of a 27-year exclosure, while infiltration rates were significantly lower for a heavily, continuously grazed pasture.

Indirect Physical Impacts

The previous section described how poor management of livestock grazing may create conditions that can decrease infiltration, increase runoff, and increase sedimentation and erosion from rangelands. These direct impacts can affect the hydrologic regime and water quality of receiving streams, ranging from channel modification to problems associated with sedimentation. The following section describes some of these indirect impacts, including sedimentation, channel modification, changes in the water table, bacterial contamination, and changes to a stream's temperature regime.

<u>Erosion and Sedimentation</u>. The decrease in infiltration normally associated with increased grazing intensities results in an increase in overland flow. This increase in runoff (especially volume and velocity) often results in increased erosion and sediment production. Also, the loss of vegetation resulting from livestock grazing leaves more ground bare further exacerbating the sedimentation problems associated with grazing. As mentioned earlier, Dadkhah and Gifford (1980) found that sediment yield increased exponentially as the amount of plant cover decreased.

Lusby (1979) conducted extensive research on the effects of overgrazing on the hydrology of salt-desert shrub rangeland in west central Colorado. Runoff and sediment were measured in reservoirs at the lower end of grazed and ungrazed reservoirs and watersheds. Runoff from grazed watersheds averaged from 131 to 140 percent of that from ungrazed watersheds from 1954 through 1966. Sediment yields during the same time period ranged from 134 to 196 percent of that from ungrazed watersheds.

Studies examining sediment production as function of grazing intensity generally echoed the results of the studies examining infiltration rates, finding that sedimentation increases as grazing intensity increases. Wood and Blackburn (1981 a,b) conducted research examining the effects of various grazing strategies on sediment production, as well as a number of other physical parameters at the Texas Experimental Ranch. Table 2 summarizes these results. Wood and Blackburn (1981a) found that sedimentation rates from the heavily stocked, continuously-grazed pastures and the HILF pasture exceeded those of the deferred-rotation pastures and exclosures at the site in Texas.

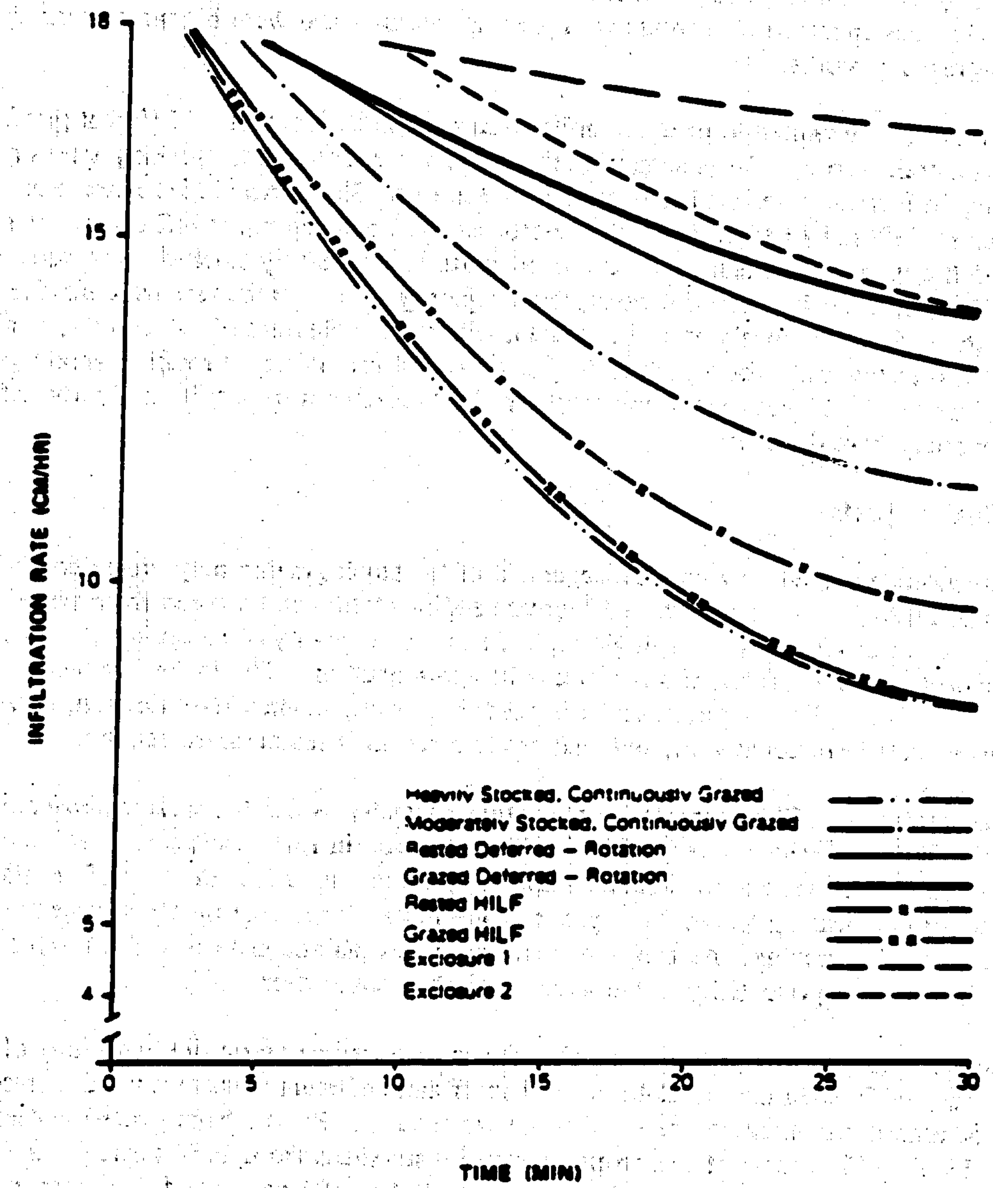


Figure 4. Mean infiltration rates of the midgrass community for various grazing practices at the Texas Experimental Ranch. Source: Wood and Blackburn, 1981a.

Grazing Treatment	Grass Standing Crop (kg/ha)	Mulch (ton/ha)	Bare Ground (%)	Bulk Density (g/cc)	Organic Matter (%)	Aggregate Stability (%)	Infiltration rate after 30 min (cm/h)	Sediment Production (kg/ha)
Heavy continuous	1508 d [1/]	1.2 d	25 a	1.8 a	2.6 c	35 d	8.1 c	115 a
Moderate continuous	3333 abc	4.5 bc	6 b	1.6 b	3.7 b	48 bc	11.4 bc	28 abc
Rested deferred-rotation	3865 ab	5.1 bc	1 b	1.6 b	5.5 a	57 ab	13.1 ab	10 c
Grazed deferred-rotation	2894 c	6.1 b	5 b	1.8 a	4.1 b	56 ab	13.9 ab	14 bc
Rested HILF	2437 c	3.2 cd	17 b	1.9 a	4.3 b	60 a	9.6 bc	28 abc
Grazed HILF	2414 c	4.5 bc	17 a	1.9 a	3.5 b	45 c	8.2 c	39 ab
Exclosure 1	4569 a	12.2 a	1 b	1.3 c	4.3 b	62 a	16.5 a	4 c
Exclosure 2	4243 a	11.5 a	4 b	1.8 a	2.3 c	39 cd	13.9 ab	17 bc
All treatments	2988	6.1	9	1.7	3.8	50	11.6	32

1/ Means followed by the same letter within each column are not significantly different at the .05 level of probability.

Table 2. Watershed parameter means for the midgrass interspace areas in each grazing treatment at the Texas Experimental Ranch.
Source : Wood and Blackburn, 1981a, 1981b.

Weltz and Wood (1986) also conducted research supporting the above assertions. At a study site in central New Mexico, they asserted that total sediment production was greater on all grazed treatments than on the exclosure. Doubling the stocking rate and applying a short-duration system resulted in significantly greater sediment concentrations and total sediment production. The researchers attributed these findings to the changes in vegetation to a less desirable weedy condition, a decrease in the amount of litter load, and an increase in bare ground resulting from overgrazing. Overall, the researchers concluded that after rangelands were grazed in a short-duration paddock the soil surface was susceptible to accelerated erosion, whereas scattering the cattle over a larger area created problems with distribution and herd control, but seemed to have lower risks of environmental damage as expressed by soil erosion, at least in the short-term.

One of the primary impacts of livestock overgrazing to surface water bodies is the increase in sedimentation associated with grazing activities (e.g., vegetation removal, trampling). The increase in runoff and sedimentation from rangelands can significantly increase sediment loads in water bodies. This can result in many serious water quality impacts, particularly those relating to the health of the aquatic ecosystem. The water quality impacts associated with sedimentation are discussed in more detail in a later section of this document on aquatic ecosystems.

Channel Modification. As described in the previous section, the impacts of livestock overgrazing associated with vegetative removal and trampling can create conditions (i.e., bared and compacted soil) which may result in increased volume and velocity of runoff and increased peak flow discharges. This input of additional runoff water into streams can result in fairly significant channel modification and a host of related effects (e.g., reduction in the cover and area suitable for fish habitat). Depending on soil and subsurface conditions, these rapid adjustments may take two forms: excessive downcutting or incision, including head-cutting (not just down cutting, but cutting back upstream as well), or excessive lateral or sideward migration of the stream (Bureau of Land Management, 1990).

Incised channels typically occur when the stream is in early stages of development and/or is characterized by unresistant bottom materials. For example, channels in fine, deep alluvial soils are prone to incision. They result from either downstream base-level lowering or localized gullying initiated by increased runoff rates and/or lowered resistance to erosion. This type of deep channel incision can result in the following two important changes in the local stream environment, particularly in riparian areas: (1) advancing gully systems increase peak discharge making the stream very efficient at scouring channel beds and banks and transporting sediment, and (2) degrading channel beds produce a drop in the local water table therefore creating a water stress on the riparian vegetation. The subsequent loss of riparian vegetation further exacerbates hydrologic changes. For example, it may result in an even lowered resistance to surface runoff and higher flow velocities during flood events.

Channels will widen and become laterally unstable if stream bottoms are comprised of relatively resistant materials. For example, coarse alluvial channels or channels with structurally controlled beds tend to respond to increased runoff and flow by becoming wider and shallower with less steep banks. Channels that are laterally unstable may be less capable of carrying high flows and thus can cause serious riparian damage by bank cutting or channel realignment during times of high flow. Increased sedimentation from upstream sources can greatly exacerbate these effects (Bureau of Land Management, 1990). An illustration of the channel changes is shown in Figure 5.

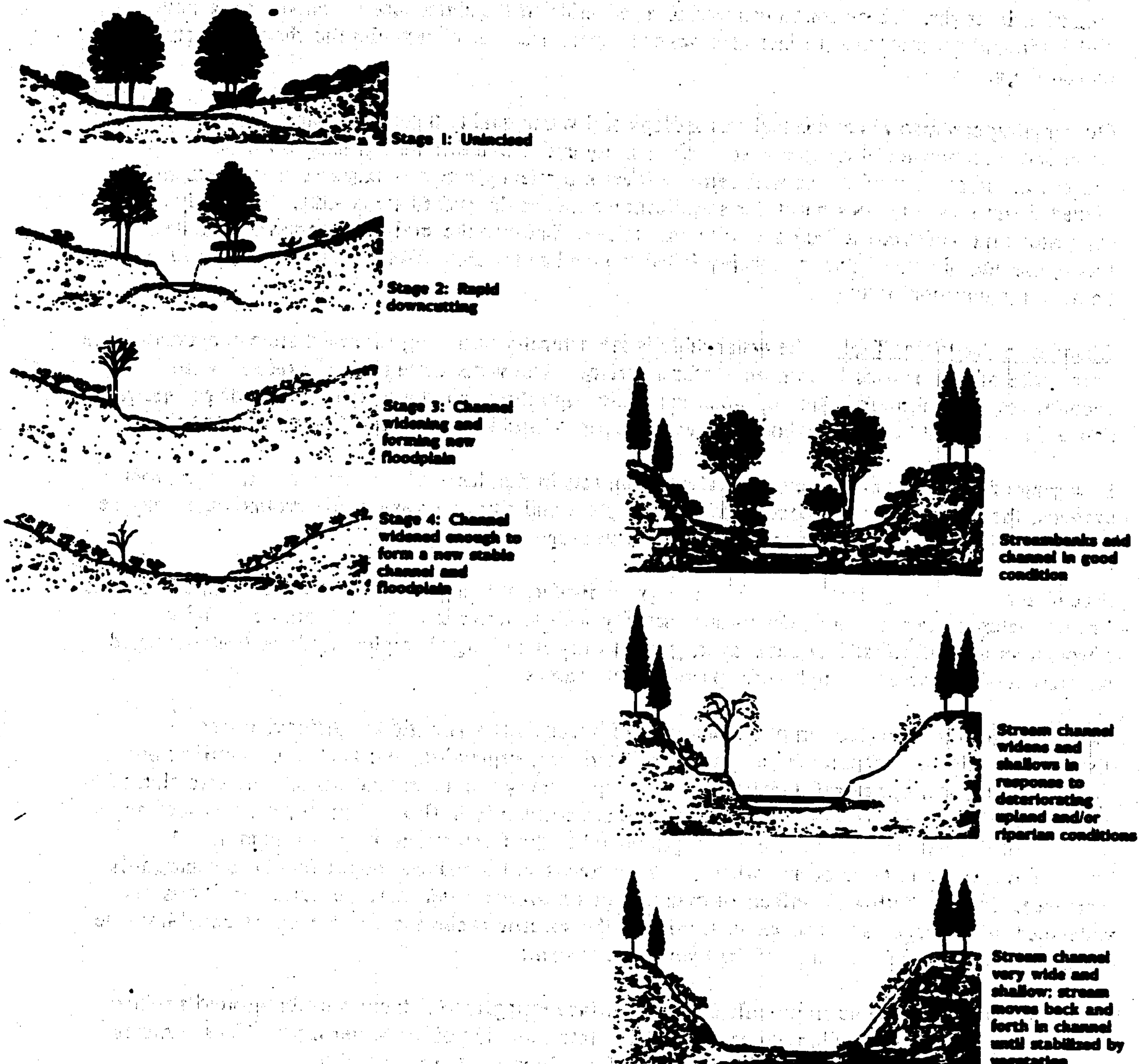


Figure 5: Stream Channel Morphology
Source: "Livestock Grazing on Western Riparian Areas"
Northwest Resource Information Center, Inc., July 1990.

Hubert et al. (1985) examined the impact of various grazing strategies and intensities on the hydrologic conditions of streams. The study examined selected stream parameters (e.g., width) and noted the range of responses to light versus heavy grazing (Table 3). The data showed that, for the most part, intensive grazing caused the widening and shallowing of streams and a subsequent reduction in cover. These conditions lead to a reduction in the abundance of native brook trout, which the authors attributed to increased water temperatures associated with the changes in stream morphology.

Overgrazing can also affect channel morphology and water quality through impacts to stream banks. Bohn and Buckhouse (1986) compared bank stability under five different grazing options. They found that the amount of streambank retreat differs statistically between ungrazed treatments and grazed treatments, but does not differ significantly between the grazed treatments. The study also suggested that bank retreat increases with animal use. Because the study was somewhat limited in scope, the authors stated that it probably failed to simulate the full effects of large-scale cattle grazing on stream bank morphology.

<u>Changes in the Water Table</u>. The water table is the naturally occurring saturated zone contained in the pore space of soil or rock beneath the ground surface. The water table typically refers to the first encountered or shallowest saturated water zone, although there may be isolated lenses of groundwater above the water table. Deeper bodies of water occur as aquifers or isolated lenses of groundwater.

Lowering of the water table may have adverse impacts in that less water is available for plant root systems, the local hydrologic conditions are disrupted, and any other use of the groundwater may be affected such as availability for irrigation or human usage.

Precipitation is the principal source for most groundwater, although groundwater may also come from surface water (stream or lake), agricultural activity such as irrigation, or other human activity. Through an unconfined soil or rock layer, groundwater is recharged (replenished) by the downward infiltration of rainwater through pore space in rock masses.

Factors influencing the location of the water table include site and regional geology, water distribution, climate and precipitation, soil characteristics, vegetation, and land use. Aquifers are dynamic systems with natural fluctuations occurring, usually, on a seasonal basis. The direction of groundwater flow and the depth from the surface are constantly in flux. Human activities such as pumping of groundwater wells or crop irrigation add to the fluctuations in the water table. A lowering of the water table occurs when the input (recharge) is reduced or the output (discharge) is increased. In considering the effects of overgrazing on groundwater or water table conditions, the watershed or drainage basin and its uses, not just the specific rangeland, must be considered because of the complex interrelationships of the hydrologic system.

Because water tables are strongly influenced by surface topography, changes in the ground surface affect the level, quantity, volume, occurrence and flow direction of the water table. Thus, grazing activities that affect the surface topography can adversely affect the water table.

In discussing the effects of overgrazing, there are two geographic zones to consider. First, there is the broader regional upland area, then the more localized riparian stream bed area, which is composed of the stream itself (water column), the stream channel, and the banks of the stream. Beyond and above the banks is the flood plain, which forms an intermediary area between the uplands and the stream zones.

Table 3. Mean Values of Stream Habitat Variables Measured in Heavily and Lightly Grazed Reaches of Pete Creek in 1984.

Variable	Mean Value (n = 3)	
	Heavily Grazed	Lightly Grazed
Width (m)	2.9	2.2*
Depth (m)	0.07	0.11*
Width/depth ratio	43	21
Coefficient of variation in depth	47.3	66.6*
% greater than 22 cm deep	9.0	22.3**
% silt substrate	35	52
% gravel substrate	35	31
% rubble substrate	24	14
% bedrock-boulder substrate	1	3
SRI/CSI	112	110
% overhanging bank cover	2.7	30.0*
% overhanging vegetation	0.0	11.7*
% shaded area	0.7	18.3*
% bare soil along banks	19.7	13.3
% litter along banks	7.0	6.0

* indicates statistically significant difference at p 0.05
** indicates difference at $p \leq 0.10$

In both the uplands and riparian stream zones, overgrazing can adversely impact the water table. Direct effects of upland grazing are loss of vegetation, compaction of soil, and increased runoff (with subsequent decrease in infiltration). Bare soil is exposed to greater evaporation of soil moisture. Stream impacts include all of the upland impacts, plus physical degradation of the stream banks. These effects combine to cause greater erosion of the stream channel. Increased runoff, greater sediment load, sloughing of stream banks, loss of ground cover, and loss of root biomass all contribute to the instability of the stream system causing increased incision (down cutting and head or back cutting) and widening of the stream channel. Changes in the channel morphology may impact groundwater by altering the direction and rate of groundwater flow and the depth to groundwater. Downcutting lowers the streambed and the groundwater table.

Depending on site-specific conditions, groundwater may regularly or periodically flow from the subsurface strata (water table) into stream beds, adding water to the stream flow. Such conditions would add to the vitality of the stream life. Groundwater seeps from the stream banks or up from the bottom into the stream. Conversely, water may discharge from a stream to the water table.

Lowering of the water table may significantly reduce or halt water flow into a stream thus accentuating stream degradation. Physical degradation of stream banks by livestock can alter the flow of groundwater and reduce discharge to streams by compacting the soil or otherwise altering the water flow.

Another adverse impact of lowering the water table is the potential effects on plants. Roots obtain their necessary moisture through capillary action that draws water (moisture) upwards through the soil to the root zone where it is available for plant use. Excessive or improper grazing activities may cause greater evaporation of soil moisture by denuding the ground of vegetative cover and increasing soil temperature, thus drying out the soil and leaving insufficient moisture needed for plant life.

Bacterial Contamination. Livestock grazing can also cause increases in the level of bacterial pollutants (i.e., fecal coliform) in water, as well as nutrient enrichment. The level of severity is related to the intensity of grazing activities and the proximity of animals to the water. Tiedemann et al. (1988) presented research results suggesting that increasing the intensity of cattle grazing can increase the amount of fecal coliform (FC) in water to very high and potentially problematic levels. In their research, Tiedemann et al. (1988) measured concentrations of fecal coliform weekly during summer 1984 in streamwater of 13 wildland watersheds managed under four management scenarios: (A) no grazing, (B) grazing without management, (C) grazing with management for livestock distribution, and (D) grazing with management for livestock distribution and with cultural practices to increase forage. Scenario D equated intensive grazing management to maximize livestock production, including practices to attain uniform livestock distribution and improve forage production with cultural practices such as seeding, fertilizing, and forest thinning.

The researchers found that FC levels in streams associated with scenario D were significantly higher than those of the other streams. Most of the A and C areas had FC levels less than 100 FC/L. Only one sample was available for scenario B and it was 150/L. FC levels for scenario D, on the other hand, ranged from 190/L to 2,270/L. A single sample from C was almost as high, 650/L. The higher elevations in these areas were attributed to the higher density of cattle in Strategy D areas (2.8 ha per animal unit month (AUM) compared to 8.2 and 7.7 ha/AUM for B and C. Also, vegetative characteristics played a role in that the areas with higher FC levels also had meadows desirable for grazing right beside the streams (Tiedemann et al, 1988).

Tiedemann et al (1988) also cited studies demonstrating that cattle noticeably increased fecal coliform counts. Some of these studies noted fecal coliform levels having up to a 10-fold increase over background levels (Coltharp and Darling, 1973; Doran and Linn, 1979; Gary et al., 1983; Skinner et al, 1974). In an earlier study, Tiedemann et al. (1987) found significant increases in streamwater FC counts with increased intensity of grazing management. The largest differences in FC concentrations (10X) occurred between control watersheds (no grazing) and watershed managed for maximum livestock production. Counts of FC in excess of 20000/L were observed when intensive management was used to maximize livestock production. These levels of FC can remain a problem even after the livestock is removed.

Stream Temperature Changes. Livestock can be extremely damaging to vegetation, as described earlier in this section. This disruption in vegetative cover can contribute to serious water quality degradation, especially if riparian areas are disrupted. In particular, vegetative damage (especially in riparian areas) can result in serious damage to aquatic habitats. Therefore, most of these impacts will be discussed in more detail in a later section of this document on aquatic ecosystems.

In terms of water quality, however, damage to vegetation can significantly alter a stream's temperature regime, leading to changes in fisheries and other aquatic life. Streamside vegetation is critical in terms of moderating stream temperatures. Because riparian vegetation intercepts and reduces the intensity of incoming solar radiation and reduces back-radiation, it serves as a form of insulator to the stream, preventing it from experiencing extreme temperatures or temperature ranges. Its shading effects in summer help to reduce excessive heating of the water. If the vegetation cover is decreased, summer stream temperatures can greatly increased, which contributes to a host of water quality problems, particularly a decrease in the amount of dissolved oxygen in the water. These changes to stream water quality may cause a shift in fish species, from salmonids to less sensitive species in many areas. By reducing the amount of back-radiation/reflection from the stream, vegetation also serves a moderating effect in winter. This also can enhance native fish survival, because if winter temperatures fall low enough, anchor ice can form on the bottom of the stream (Platts, 1991). The ability of plants to control stream temperatures depends on the size of the stream and the plant type. As a general rule, the larger the stream, the higher the streamside vegetation must be to effectively intercept the sun's rays over water (Platts, 1991).

Indirect Impacts on Terrestrial Ecosystems

Terrestrial Ecosystem Impacts. Most grazing studies examine changes in vegetation composition and the reduced range quality in terms of a loss of livestock carrying capacity. Little is known about impacts of sustained grazing on an ecosystem-wide level, particularly, impacts on wildlife. Dwyer et al. (1984) note that range management has focused on improvements to support increased livestock production, with little attention to maintaining plant and wildlife diversity within an ecosystem. Dwyer et al. (1984) cites both direct and indirect impacts on wildlife from livestock overgrazing. Direct impacts include competition for palatable species, while stress-producing modifications to the ecosystem induced by livestock (e.g. reduction in protective vegetation cover) are more indirect.

A consistent, direct impact of livestock overgrazing on rangeland is loss of vegetative diversity. Selective grazing by livestock tends to reduce the presence of palatable species while allowing a few, typically unpalatable and undesirable species to increase. The resulting change in plant composition lowers species diversity, changes species function, and reduces both the numbers and the variety of wildlife species the area can support (Dwyer, et al., 1984) To sustain a given wildlife population, the pre-grazing plant composition, structure and function within an ecosystem must remain in balance, following the introduction of livestock. Wildlife that depend on a limited number of plant species to provide a nutritionally optimal diet may be impacted as livestock can rapidly deplete limited food sources within a given area. The depletion of desirable vegetation species within an allotment forces wildlife into marginal, less desirable habitat and into eating less desirable/nutritious vegetation (GAO, 1991; Dwyer, et al., 1984).

Livestock impacts on rangelands extend beyond the direct loss of vegetation to modification of native habitat. Whole ecosystems may be impacted, and depending upon the fragility of the ecosystem, may be permanently altered. Some ecosystems are better able to withstand livestock and wildlife use; water sources, either in the form of precipitation or riparian zones, increase an ecosystem's ability to recover from stress. The increase of sagebrush and other bushy species in place of grasses is an indicator that fragile desert ecosystems have already been significantly impacted by overgrazing. The low rainfall, high temperatures, and high evaporation rates of these areas have produced plants and wildlife uniquely adapted to these regions. The adaptation of these ecosystems and their occupants to inherently harsh environments reduces their capacity to recover from disturbances, such as overgrazing (GAO, November 1991).

Over 250 native species are endangered, threatened or candidate species, in the southwestern Mojave, Sonoran, and Chihuahuan deserts. Poor management and/or overgrazing are factors identified as contributing to a decrease in preferred-diet plant species, destruction of habitat, and reduction of cover needed to hide from predators. In other cases, diseases may be transmitted from domestic to wild animals. In addition to their consumption of prime vegetation, poor management of livestock in the Sonoran desert have forced Sonoran pronghorn antelope away from traditional birthing grounds to less protected areas (GAO, November 1991).

Cosby (1978) noted that livestock grazing does not always impact wildlife negatively. Cosby observed several benefits of rotation grazing systems on wildlife when he found that deferring grazing in several units and altering the season of use actually increased vegetation diversity and cover. Cosby found sandhill cranes utilized grazed units regularly due to an increase in insect populations in the vicinity of "cowpattis". Similarly, native deer utilized units previously grazed to graze on new plant regrowth. Despite these findings, Cosby explains that this same scenario may not be feasible in a different region, and that all grazing treatments must be chosen carefully, on a site-specific basis.

Many livestock grazing researchers acknowledge the importance of avoiding grazing practices which result in the displacement of wildlife species, and to manage rangeland to maintain a healthy ecosystem complete with plant and wildlife diversity (Dwyer, et al., 1984; Carpenter, 1984). However, not all changes in species distribution, should be viewed as adverse impacts. The successional ecosystem stage (early, middle, or late) will help determine the appropriateness of maintaining species diversity and distribution as part of an overall range management plan.

Indirect Impacts on Aquatic Ecosystems

Effects of poor livestock and wildlife grazing management on stream hydromodification and water quality can have serious ramifications on aquatic ecosystems. Potential impacts such as bacterial contamination, increased sedimentation, and temperature changing can reduce the quality of the stream's ambient environment so as to affect the composition and health of aquatic organisms. Likewise, reduction of vegetation and increased runoff and flow may damage the stream's usefulness as aquatic habitat. Such impacts can originate from livestock and wildlife overgrazing in upland and riparian areas, although damage to riparian areas typically cause the most serious stresses to aquatic ecosystems. The following discussion focuses on overgrazing's adverse effects in riparian areas as these most closely and directly effect stream ecosystems. Also, much of the discussion will center on adverse effects on fish habitat; one important measure of the health of an aquatic ecosystem is by the nature and type of fish species present. The ability of an aquatic system to produce and support game fish is one way of measuring a healthy aquatic environment. For example, Van Velson (1979) found that rough fish comprised 88 percent of a fish population before relief from grazing and only 1 percent of the population after 8 years rest from grazing. Platts (1991) also examined a number of research studies, finding that in 20 of 21 studies, stream and riparian habitats were degraded by livestock grazing and that those habitats improved when grazing was eliminated. The majority of the studies also found reductions in salmonid fish populations related to the grazing-related habitat destruction.

Earlier sections of this document described how overgrazing of livestock and wildlife can affect the density and composition of vegetative cover. In upland areas, these impacts can lead to soil compaction and increased runoff. The hydrologic modifications to streams associated with increased runoff effectively destroys much of the desirable stream habitats.

As reported in Platts (1990), ideal trout spawning area is typically devoid of boulders, low in fine sediments, and high in gravel and small rubble. It also has a number of deep pools, well-aerated water, and ample cover and shade. Many of these necessary qualities of trout habitat can be wiped out by excess runoff and sedimentation. For example, increased flows can wipe out cover and habitat provided by fallen trees and brush.

Impacts of overgrazing on vegetation in riparian areas can affect aquatic ecosystems in a number of ways. Some of the impacts are similar to those associated with upland areas, but the impacts from damage to riparian areas are much more extensive and severe. Because of the proximity of riparian areas to streams, they are intimately connected to the stream ecosystem. Also, they are the preferred grazing ground of livestock and winter range for wildlife, thus concentrating much of the grazing-related damage to those areas. Livestock prefer to graze in riparian areas because they provide easily accessible water, favorable terrain, good cover, soft soil, a more favorable microclimate, and an abundant supply of lush palatable forage. Even though riparian areas represent a very small proportion of total rangeland, they provide much of the vegetation consumed by livestock because it is such a preferred grazing area. For example, Roath and Krueger (1982) reported that although the riparian zone constituted only 1.9 percent of the area on one allotment in Oregon's Blue Mountains, it produced 81 percent of the vegetation removed by cattle. Some of the ways that overgrazing (especially in riparian areas) can impact aquatic ecosystems are summarized below.

Disruption/Reduction to Ecosystem Sources. The riparian area serves as a source of energy to the aquatic ecosystem, by providing energy to streams in the form of dissolved organic compounds and particulate organic detritus. Benthic detritivores, the stream bottom bacteria, fungi and invertebrates that feed on the detritus, form the basis of the aquatic food chain. They pass on this energy when they are consumed in turn by larger benthic fauna and eventually by fish (U.S. Department of Agriculture, Forest Service, 1991). Riparian vegetation produces the bulk of the detritus that provides up to 90 percent of the organic matter necessary to support the headwater stream communities (Kauffman and Krueger, 1984). Platts (1991) stated that organic matter from riparian vegetation comprised roughly 50 percent of the stream's nutrient energy supply for the food chain. Disruption (i.e., change in cover density and composition) to riparian vegetation can severely reduce the extent of organic inputs to the stream, thus alter the energy of the ecosystem. Streamside vegetation is also important to the production of fish food. It provides habitat for terrestrial insects which are important food for salmonids and other fish species.

Moderator of Stream Temperatures. Streamside vegetation is critical when it comes to moderating the temperature of streams. It shades the stream and therefore influences water temperature. A loss of vegetative cover can result in increased temperatures in summers, decreased temperatures in winter, and a greater daily range of temperatures at all times. Kauffman and Krueger (1984) reported on literature that showed damage to riparian areas caused increases in stream temperature (one study showed that maximum daily temperatures outside of a grazing enclosure averaged 7 degrees centigrade higher than those within the enclosure) and a greater range in temperature fluctuation (average daily fluctuation was 15 C outside of the enclosure and 7 C inside the enclosure). The increase in summer temperatures increases a trout's demand for dissolved oxygen, while at the same time, reduces the amount of dissolved oxygen in the water. This can cause a shift in fish species, from salmonids to nongame fish in many areas. Vegetation also serves a moderating effect in winter, which can enhance native fish survival. If winter temperatures fall low enough, anchor ice can form on the bottom of the stream. Streams with little or no vegetative canopy are very susceptible to the formation of anchor ice (Platts, 1991; U.S. Department of Agriculture, 1991).

Habitat Benefits. Riparian vegetation strongly influences the quality of habitat for anadromous and resident coldwater fish by providing shade, ameliorating in-stream temperature fluctuations, and providing cover (Kauffman and Krueger, 1984). Many studies have demonstrated the importance of cover to fish by showing that declines in salmonid abundance occur as stream cover is reduced and an increase in salmonid abundance as cover is added. The fringe of bordering riparian vegetation is essential for building and maintaining the stream structure necessary for productive aquatic habitats. This vegetation not only provides cover, but buffers the stream from incoming sediments and other pollutants and the effects of excessive flow (Platts, 1991). For one, fisheries habitat in streams is enhanced by the addition of large woody debris to the stream channel which forms pools and important rearing areas. This debris also provides cover from predators and protection from high flows. Large stable debris also provides the mechanism by which the detritus is held long enough to be processed by the invertebrate community. Without debris dams, much of the organic input from streamside vegetation would be washed downstream without contributing to the life processes of the aquatic food chain (U.S. Department of Agriculture, Forest Service, 1991). Each type of vegetation exerts a special function, as summarized in Platts (1991):

- Trees, shrubs, and sedges provide shade and streambank stability because of their large size and massive root systems. As trees mature and fall into or across streams, they create high quality pools and rifles. Their large mass also helps control the slope and stability of the channel. Input of this large organic debris is essential for maintaining stream stability. In many aquatic habitats, if it were not for this type of input, the channel would degrade and soon flow on bedrock, leaving insufficient spawning gravels and few high-quality rearing pools for fish.

- Brush also builds stability in stream banks through its root systems and litter fall.

- Grasses form the vegetative mats and sod banks that reduce surface erosion and mass wasting of stream banks.

Sediment Trapping. Riparian vegetation is important in slowing the overland flow of water and trapping sediment, therefore contributing to the building of bank form (Platts, 1990). Streamside vegetation is also important as it creates streambank stability. Vegetative mats reduce water velocity along the stream edge, causing sediments to settle out and become part of the bank. This helps to contribute nutrients to the bank soils and increases plant production and vigor. It also reduces the amount of sediments input to the stream (Platts, 1991).

In sum, by affecting the health and vigor of vegetation (especially riparian areas), poor grazing management practices can cause a number of problems that can damage aquatic ecosystems. These are briefly reiterated in the following bullets presented in Platts (1990). Reductions/loss in vegetation can:

- Increase average stream temperatures in summer, decrease them in winter, and expand daily temperature ranges.
- Reduce stream bank strength, enabling sedimentation and erosion, and reducing bank building through sediment deposition.
- Increase the erosive energy of water.
- Amplify effects of floods, ice, or debris flow, or animal trampling.
- Reduce water purification benefits that vegetation provides through infiltration and sediment removal.
- Reduce the ability of riparian areas to contribute to ground water recharge.
- Reduce flood control benefits.

POSSIBLE PREVENTION/MITIGATION MEASURES

This section identifies techniques that may be appropriate for mitigation of potential impacts caused by grazing activities. Mitigation should be evaluated on a site-specific basis and the following measures should only be used as a guide to measures that might be available should the reviewer determine they may be appropriate.

- Active management of livestock grazing allotments typically includes consideration of the following variables in different combinations : 1. grazing frequency, includes complete rest ; 2. livestock stocking rates; 3. livestock distribution; 4. season and timing of forage use; 5. livestock kind and class; 6. control of wildlife herd size and conflicts; 7. forage utilization; and 8. rehabilitation. Active management using these variables may increase forage, as well as improve habitat.
- Avoid high intensity, long duration grazing. The level of utilization must allow for regrowth of vegetation in order to maintain the productive capacity of the pasture.
- Encourage a greater level of control over the numbers of livestock and wildlife and time spent on each allotment.
- Encourage a greater level of oversight on allotments: more frequent assessment of utilization levels and quicker response to move livestock when utilization levels are attained may keep the area from being overgrazed.
- Separate riparian zone from other pastures and develop separate management plans, and if necessary, exclude livestock from riparian (or upland) areas until the desired level of recovery is attained.
- Fence or prevent direct access to streams in riparian areas to reduce trampling, damage of vegetation and the associated channel modification problems (may be costly to maintain, however).
- Use permanent exclosures in areas of high risk or extreme sensitivity where the likelihood of damage is high and the potential for restoration is low.
- Control livestock and wildlife grazing in areas predisposed to damage during periods of high sensitivity (adequate management plans).
- Use planned grazing systems to maintain plant vigor and desired species composition.
- Intensive practices (reseeding, weed control) may be necessary for extremely degraded pastures.
- Late season grazing should occur after the growth of warm season species has peaked and seeds have been produced.
- Know dynamics of plant species within an allotment and their capacity for regrowth.
- Evaluate type of livestock grazed and grazing intensity based on predicted impact to wildlife.

- Periodic minor ground shaping may be necessary to encourage dispersed flow and prevent concentrated flow.

- Plant compatible native trees or shrubs to reduce runoff, establish roots, and provide shade.

- Monitor progress of vegetation growth, bank and channel stability, and overall vitality of rangeland and riparian areas. Seasonal photographs may aid in this effort.

- Stabilize streambanks against erosion, although natural vegetative cover is preferred, artificial means of stabilization such as rubble, concrete or riprap may be necessary.

- Consider use of "in-stream" structures such as gabions, small rock dams, debris catchers, individual boulder placement, rock jetties, or silt log drops, to stabilize stream channels against excessive incision and/or widening.

- Plan periods of rest from grazing to stabilize streams.

- Consider changes in land use allocations, especially in or adjacent to degraded areas.

- Retain flexibility in allotment permits to account for special circumstances, such as excluding livestock during drought periods or other special circumstances, if necessary.

- Monitoring of rangelands is an important activity that will provide opportunity to identify and mitigate impacts. Conduct follow-up monitoring of range trends including conditions and utilizations. Alter actions based on monitoring data.

SUMMARY OF INFORMATION THAT SHOULD BE ADDRESSED IN NEPA DOCUMENTATION

The following is a list of questions that may be appropriate to ask about grazing when reviewing NEPA documentation.

What are the objectives of the management plan? Has a clear idea of the management plan objectives been presented?

Determine what factor, such as bank instability or loss of woody plants, is of primary concern.

Is the area suitable for grazing? Has the kind and class of livestock and the duration and intensity of livestock grazing best suited to the area been determined?

Has the document identified specific species (plant and animal) in the area, what sources were used to determine this, how does it compare with other information on the area?

Are utilization levels related to the specific species of vegetation present?

What utilization levels are planned for this allotment? What is the planned monitoring frequency for the allotment?

How will action be altered or modified based on monitoring information? What are the triggers for determining alterations?

Are there any endangered or threatened species in the area?

Has sufficient forage been allocated to wild herbivores in the riparian management plan? What is considered sufficient?

What tools (fencing, herding cattle/sheep regularly, duration) are proposed to effectively manage the allotment?

What is the seasonal distribution of the allotment (spring, summer have higher production than fall/spring)?

Are any special managements employed in riparian areas? How will stream areas be protected, especially stream banks?

What is the estimated impact on local groundwater, and how will this be monitored?

Have the potential cumulative impacts been described?

What are the designated beneficial uses of water bodies potentially affected by the grazing allotment?

Are these beneficial uses impaired due to exceedance of water quality standards? What is the cause of the impairment?

STATUTORY AND REGULATORY FRAMEWORK

In addition to the National Environmental Policy Act of 1969 (NEPA), there are specific statutes that provide Federal land managers with authority to allow and control grazing on Federal lands under their jurisdiction. Typically, each land managing agency has its own implementing regulations that correlate to each statute's authorities and requirements. In addition to these statutes, there are broad-reaching Federal statutes oriented toward environmental protection, such as the Clean Water Act, and the Federal Insecticide, Fungicide and Rodenticide Act, that may also apply to grazing operations on Federal lands. Explained briefly below are the statutes most appropriately described in the context of grazing.

Taylor Grazing Act. As discussed above, the system of free access to Federal lands ended with the passage of the Taylor Grazing Act in 1934. This was the first official Federal effort at livestock management and placed the administration of the public lands under the U.S. Grazing Service, later to become the BLM.

Multiple Use Sustained Yield Act of 1960. This statute promoted multiple-use management of national forest lands, not limiting the uses based solely on economic returns. The term "multiple-use" denotes management of the lands and their renewable resources in a combination of ways that would "best meet the needs of the American people."

Forest and Rangelands Renewable Resource Planning Act. Passed in 1974, four years after the Public Land Law Review Commission completed its broad review of Federal land policies, this act was an attempt to encourage better economic management of the national forests, as well as providing opportunity for public participation, timber sales, and reforestation.

National Forest Management Act. This statute, passed in 1976, continued an initiative to engage in land-use and resource planning. Like the Forest and Rangelands Renewable Resource Planning Act of 1974, NFMA emphasizes resource inventory, cost/benefit analysis, improvement of the environment, interdisciplinary planning, and public involvement (Clawson, 1983). Though this act encouraged high economic standards, some sections maintain constraints on attainment of full economic management of the federal lands and provided terms for carrying out a multiple-use/sustained yield policy. National grasslands were bought under Forest Service management through the Bankhead-Jones Farm Tenant Act.

Federal Land Policy and Management Act (FLPMA). Passed in 1976, this Statute serves as comprehensive multiple-use legislation for public lands managed by the BLM and supports the notion of public land retention to manage these lands on the basis of sustained yield. FLPMA is also a planning act endorsing multiple-use of resources. Basic principles of the FLPMA include land use planning with public participation, protection of the environment with the cost of damage supplied by the user, receipt of fair market price for private use of public resources, and cooperation with state and local officials. (Brubaker, 1984)

Public Rangelands Improvement Act. Congress passed this Act in 1978 intending to improve the condition of the nation's public rangelands, roughly 268 million acres, and alter the grazing fee formula on Federal lands. The Act prompted an increase in grazing fees from $1.51 per animal unit month (AUM) to $1.89 per AUM. In 1986, Executive Order 12548 extended use of the formula indefinitely. The Public Rangelands Improvement Act also directed the Departments of Agriculture and Interior to maintain an on-going inventory of range conditions, authorized additional funding for range improvement, and encouraged the development of improved allotment management plans.

Clean Water Act. Two main provisions within the Clean Water Act affect grazing activities. Both of these provisions primarily consider grazing as an activity that contributes to nonpoint source pollution; grazing is, therefore, addressed within the context of nonpoint source pollution programs and regulations, specifically, the following:

- Clean Water Act Section 319 - Nonpoint Source Program: This is the principal provision in the CWA that addresses nonpoint source pollution. The program provides Federal funding to qualifying states for the control of nonpoint sources of pollution. To be eligible for funding, States must develop an assessment report detailing the extent of nonpoint source pollution and a management program specifying nonpoint source programs and controls.

- Clean Water Act Section 320 - National Estuary Program: This program may affect grazing activities if such activities occur in one of the estuaries targeted for the program (e.g., Puget Sound, Galveston Bay). This program focuses on point and nonpoint source pollution. EPA assists state, regional, and local governments in developing comprehensive conservation and management plans that recommend corrective actions to restore estuarine water quality. Currently, the majority of the NEP targeted estuaries are located near fairly urbanized areas and issues associated with grazing on Federal lands are not likely to be a high priority.

- Coastal Zone Act Reauthorization Amendments (CZARA): A relatively new program, currently being developed jointly by EPA and NOAA, CZARA has great potential for promoting broad-based nonpoint source pollution controls (including approaches affecting grazing) in coastal areas. Specifically, section 6217 of CZARA requires that states with an approved coastal zone management program develop Coastal Nonpoint Pollution Control Programs to be approved by EPA and NOAA. The major emphasis of the CZARA program is to develop and implement "management measures" for nonpoint source control to restore and protect coastal waters. Management measures defined as economically achievable measures (e.g. best management practices, citing criteria, operating methods) that will control nonpoint source pollution to the greatest degree possible, are required for many different categories of nonpoint source pollution, including grazing.

  The management measure for grazing was developed as part of the agricultural component of the coastal nonpoint source program. The measure focuses on the protection of sensitive areas and the implementation of conservation management systems and/or activity plans. Figure 6 defines the grazing management measure in detail.

  Each CZARA defined management measure essentially represents a specific nonpoint source program goal. Although the States are given a great deal of flexibility in achieving the specified management measures, EPA provided extensive technical guidance (EPA, 1993) on practices that could be used to meet the management measure goals. In the area of grazing, EPA recommended some of the following practices:

- Grazing Management Systems (as defined by the SCS) - deferred grazing, planned grazing, proper grazing use, proper woodland grazing, pasture and hay land management;

- Alternate Water Supplies (as defined by the SCS) - pipelines, ponds, troughs or tanks, wells, spring development;
- Livestock Access Limitation (as defined by the SCS) - fencing, livestock exclusion, stabilized stream crossings;
- Vegetative Stabilization (as defined by the SCS) - pasture and hay land planting, range seeding, critical area planting, brush and weed management, prescribed burning.

The CZARA program provides another important approach to reducing the effects of overgrazing on the natural environment. Although CZARA currently only applies to coastal states, there is a chance that its scope may be expanded inland as part of the overall CWA Reauthorization Amendments.

Figure 6. CZARA Grazing Management Measure (EPA, 1993)

Protect range, pasture and other grazing lands:

(1) By implementing one or more of the following to protect sensitive areas (such as streambanks, wetlands, estuaries, ponds, lake shores, and riparian zones):

(a) Exclude livestock,
(b) Provide stream crossings or hardened watering access for drinking,
(c) Provide alternative drinking water locations,
(d) Locate salt and additional shade, if needed, away from sensitive areas, or
(e) Use improved grazing management (e.g., herding)

to reduce the physical disturbance and reduce direct loading of animal waste and sediment caused by livestock; and

(2) By achieving either of the following on all range, pasture, and other grazing lands not addressed under (1):

(a) Implement the range and pasture components of a Conservation Management System (CMS) as defined in the Field Office Technical Guide of progressive planning approach of the USDA-Soil Conservation Service (SCS) to reduce erosion, or
(b) Maintain range, pasture, and other grazing lands in accordance with activity plans established by either the Bureau of Land Management of the U.S. Department of the Interior or the Forest Service of USDA.

REFERENCES

Blackburn, Wilbert H., "Impacts of Grazing Intensity and Specialized Grazing Systems on Watershed Characteristics and Responses," In: *Developing Strategies for Rangeland Management*, National Research Council/National Academy of Sciences, Boulder, CO, Westview Press, 1984.

Bohn, C.C., and J.C. Buckhouse, "Effects of Grazing Management on Streambanks," In: *Transaction of Fifty-first North American Wildlife and Natural Resources Conference*, Reno, NV, Wildlife Management Institute, March 21-26, 1986.

Caldwell, Martyn M., "Plant Requirements for Prudent Grazing," In: *Developing Strategies for Rangeland Management*, National Research Council/National Academy of Sciences, Boulder, CO, Westview Press, 1984.

Carpenter, L.H., "Impacts of Grazing Intensity and Specialized Grazing Systems on Faunal Composition and Productivity: A Discussant Paper," In: *Developing Strategies for Rangeland Management*, National Research Council/National Academy of Sciences, Boulder, CO, Westview Press, 1984.

Coltharp, G.B., and L.A. Darling, "Livestock Grazing - A Nonpoint Source of Water Pollution in Rural Areas?", In: W.J. Jewell and R. Swan (ed.) Proc. Symp. Rural Environ. Engineering, Warren, VT, Univ. Press of New England, Hanover, NH. September 1973.

Cosby, H.E., "Range Management Benefits Wildlife," Rangeman's Journal, 5: 159-161, 1984.

Dadkhah, M. and G.F. Gifford, "Influence of Vegetation, Rock Cover, and Trampling on Infiltration Rates and Sediment Production," Water Resource Bulletin 16: 979-986, 1980.

Doran, J.W., and D.M. Linn, "Bacteriological Quality of Runoff Water from Pastureland," Appl. Environ. Microbiol. 37:985-991, 1979.

Dwyer, D., J.C. Buckhouse, and W.S. Huey, "Impacts of Grazing Intensity and Specialized Grazing Systems on the Use and Value of Rangeland: Summary and Recommendations," In: *Developing Strategies for Rangeland Management*, National Research Council/National Academy of Sciences, Boulder, CO, Westview Press, 1984.

Gary, H.L., S.R. Johnson, and S.L. Ponce, "Cattle Grazing Impact on Surface Water Quality in a Colorado Front Range Stream," J. Soil Water Conserv. 38:124-128, 1983.

Gifford, Gerald F., "Vegetation Allocation for Meeting Site Requirements," In: *Developing Strategies for Rangeland Management*, National Research Council/National Academy of Sciences, Boulder, CO, Westview Press, 1984.

Gifford, Gerald F., "Watershed Response To Short Duration Grazing," in *Short Duration Grazing*, J. A. Tudeman (editor), Cooperative Extension, Washington State University, pps 145 -150, 1986.

Hubert, Wayne A., R.P. Lanka, T.A. Wesche, and F. Stabler, "Grazing Management Influences on Two Brook Trout Streams in Wyoming," In: *Riparian Ecosystems and Their Management: Reconciling Conflicting Uses*, First North American Riparian Conference, USDA Forest Service General Technical Report RM-120, 1985.

Kauffman, J. Boone, and W. C. Krueger, "Livestock Impacts on Riparian Ecosystems and Streamside Management Implications, A Review," Journal of Range Management, Volume 37, Issue 5, September 1984.

Lusby, G.C., "Effects of Grazing on Runoff and Sediment Yield from Desert Rangeland at Badger Wash in Western Colorado, 1953-1973," USGS Water Supply Paper 1532-1, 1979.

Marcuson, P.E., "The Effect of Cattle Grazing on Brown Trout in Rock Creek, Montana," Fish and Game Federal Aid Program F-20-R-21-11a, 1977.

McGinty, W.A., F.E. Smeins, and L.B. Merrill, "Influence of Soil, Vegetation, and Grazing Management on Infiltration Rate and Sediment Production of Edwards Plateau Rangeland," Journal of Range Management, 32:33-37, 1978.

Northwest Resource Information Center, Inc.; Livestock Grazing on Western Riparian Areas, July 1990.

Packer, P.E., "Effects of Trampling Disturbance on Watershed Condition, Runoff and Erosion," Journal of Forestry, 51:28-31.

Platts, William S., "Livestock Grazing," In: *Influences of Forest and Rangeland Management on Salmonid Fisheries and Their Habitats*, American Fisheries Society Special Publication 19, 1991.

Platts, William S., for Nevada Department of Wildlife; Managing Fisheries and Wildlife on Rangelands Grazed by Livestock: A Guidance and Reference Document for Biologists, December 1990.

Platts, William S. and Rodger L. Nelson, "Characteristics of Riparian Plant Communities and Streambanks with Respect to Grazing in Northeastern Utah," 1989.

Platts, William S., "Riparian Stream Management," National Range Conference Proceedings, Oklahoma City, OK, 1986.

Platts, William S., and Rodger Loren Nelson, "Impacts of Rest-Rotation Grazing on Stream Banks in Forested Watersheds in Idaho," North American Journal of Fisheries Management, pps 547-555, 1985.

Roath, L.R. and W.C. Krueger, "Cattle Grazing Influence on a Mountain Riparian Zone," Journal of Range Management, 35:100-104, 1982.

Skinner, Q.D., J.C. Adams, P.A. Rechard, and A.A. Bettle, "Effect of Summer Use of a Mountain Watershed on Bacterial Water Quality," Journal of Environmental Quality. 3:329-335, 1974.

Tiedemann, A.R., D.A. Higgins, T.M. Quigley, H.R. Sanderson, and D.B. Marx, "Responses of Fecal Coliform in Stream Water to Four Grazing Strategies," Journal of Range Management, 40:322-329, 1987.

Tiedemann, A.R., Higgins, D.A., Quigley, T.M., Sanderson, H.R., and Bohn, C.C, "Bacterial Water Quality Responses to Four Grazing Strategies - Comparisons with Oregon Standards," Journal of Environmental Quality, 17:492-498, 1988.

U.S. Department of Agriculture, Economic Research Service, Arthur B. Daugherty; U.S. Grazing Lands: 1950 to 1982, 1982.

U.S. Department of Agriculture, Forest Service, Forest Service Handbook, Directive System User Guide, FSH 1109.11, Amendment No. 22, July 1989.

U.S. Department of Agriculture, Forest Service; Riparian Forest Buffers: Function and Design for Protection of Water Resources, Forest Resources Management, Radnor, PA, NA-PR-07-91.

U.S. Department of Agriculture, Forest Service Intermountain Research Station; Managing Grazing of the Riparian Areas in the Intermountain Region, General Technical Report INT-263, Warren P. Clary, Bert F. Webster, May 1989.

U.S. Department of Agriculture, Soil Conservation Service, National Handbook of Conservation Practices, Washington, DC, Stock No. 001-007-0090301, 1977

U.S. Department of Interior, Bureau of Land Management; Riparian Management and Channel Evolution, A Self Study Guide, Phoenix Training Center, Course Number SS 1737-2, 1990.

U.S. Department of Interior, Bureau of Land Management; Public Lands Statistics, Volume 175, 1990.

U.S. Environmental Protection Agency, Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters Washington, D.C.: U.S. EPA, Office of Water 840-B-92-002, 1993.

U.S. Government Accounting Office, Rangeland Management; BLM's Hot Desert Grazing Program Merits Reconsideration, GAO/RCED-92-12, November 1991.

U.S. Government Accounting Office, Rangeland Management; Forest Service Not Performing Needed Monitoring of Grazing Allotments, GAO/RCED-91-148, May 1991.

U.S. Government Accounting Office, Public Land Management; Attention to Wildlife Is Limited, GAO/RCED-91-64, March 1991.

U.S. Government Accounting Office, Rangeland Management; BLM Efforts To Prevent Unauthorized Livestock Grazing Need Strengthening, GAO/RECD-91-17, December 1990.

U.S. Government Accounting Office, Public Rangelands; Some Riparian Areas Restored but Widespread Improvement Will Be Slow, GAO/RCED-88-105, June 1988. (a)

U.S. Government Accounting Office, Rangeland Management; More Emphasis Needed on Declining and Overstocked Grazing Allotments, GAO/RCED-88-80, June 1988. (b)

Van Dyne, George M., William Burch, S.K. Fairfax, and William Huey; Forage Allocation on Arid and Semiarid Public Grazing Lands: Summary and Recommendations.

Van Keuren, R. W., J. L. McGuinness, and F. W. Chichester, "Hydrology and Chemical Quality of Flow from Small Pasture Watersheds: I. Hydrology," Technical Reports, Journal of Environmental Quality, Volume 8, No. 2, 1979.

Van Nelson, R., "Effects of Livestock Grazing Upon Rainbow Trout in Otter Creek," In: *Proceedings, Forum-Grazing and Riparian/Stream Ecosystems*, Trout Unlimited, Inc., 1979.

Wallace, Joe D., "Some Comments and Questions on Animal Preferences, Ecological Efficiencies and Forage Intake," In: *Developing Strategies for Rangeland Management*, National Research Council/National Academy of Sciences, Boulder, CO, Westview Press, 1984.

Warren, S.D., W.H. Blackburn, and C.A. Taylor, "Soil Hydrologic Response of Number of Pastures and Stocking Density under Intensive Rotation Grazing," Journal of Range Management, 39:500-504, 1986.

Weltz, M., and M.K. Wood, "Short-Duration Grazing in Central New Mexico: Effects on Sediment Production," Journal of Soil and Water Conservation, 41:262-267, 1986.

Wood, M.K., and W.H. Blackburn, "Grazing Systems: Their Influence on Infiltration Rates in the Rolling Plains of Texas," Journal of Range Management, 34: 331-335, 1981a.

Wood, M.K. and W.H. Blackburn, "Sediment Production as Influenced by Livestock Grazing in the Texas Rolling Plains," Journal of Range Management, 34: 228-231, 1981b.

Wood, James C. and M. Karl Wood, "Infiltration and Water Quality on Range Sites at Fort Stanton, New Mexico," Water Resources Bulletin, Volume 24, No. 2, April 1988.