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Livestock Grazing Management And Water Quality Protection

(State of the Art Reference Document)

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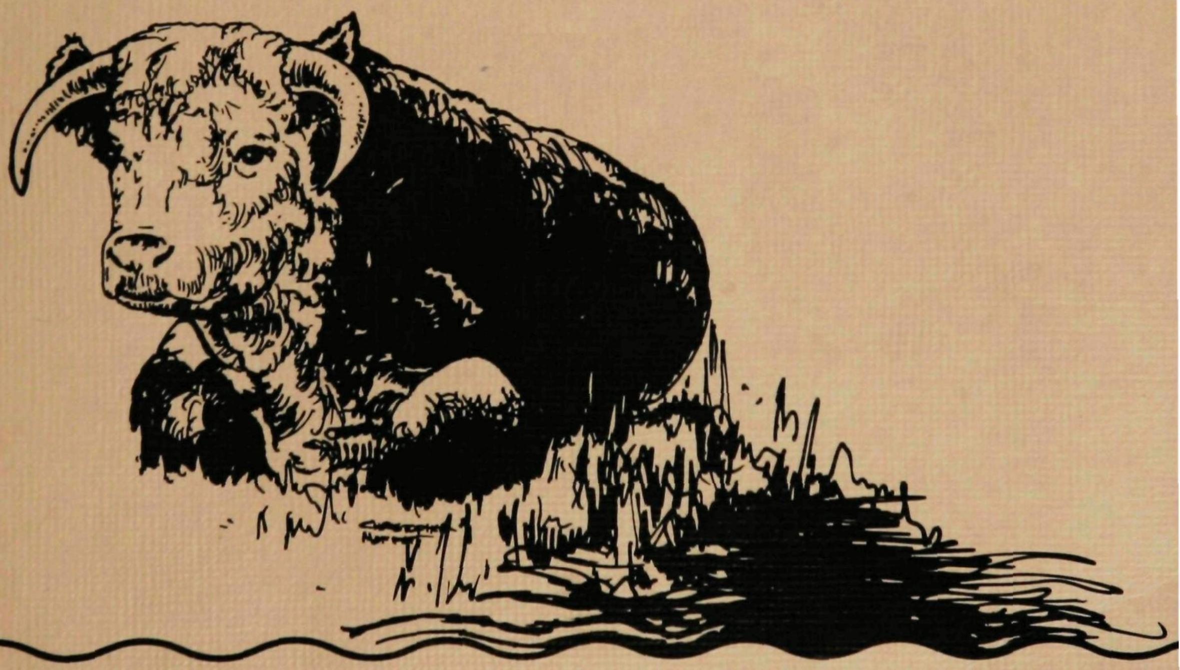

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LIVESTOCK GRAZING MANAGEMENT AND WATER QUALITY PROTECTION (STATE OF THE ART REFERENCE DOCUMENT)

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The National Association of Conservation Districts (NACD) accepted a small contract from EPA to coordinate a Technical Advisory Committee to provide input and assistance to the Project Team. The Technical Advisory Committee (TAC) met three times and reviewed drafts prior to the development of this document. The members of the Technical Advisory Committee were:

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INTRODUCTION

Purpose

The Bureau of Land Management (BLM) and Environmental Protection Agency (EPA) have prepared this document intended to inform and assist state, federal, Section 208 planning and management agencies, rangeland and other land managers and the public in understanding the potential water quality impacts associated with grazing, and practices and techniques for minimizing adverse impacts. The document is specifically intended to assist in: (1) the identification of existing and potential hazards to water quality; (2) selection of procedures, practices or methods suitable for preventing, minimizing, or correcting water pollution problems and; (3) providing several procedural alternatives for assessment of the rangeland management component of a rangeland watershed's total runoff and pollutant production. Alternatives are related to the man-caused rather than natural or geological phenomena. It is also a reference source to other publications, information and materials, and it provides a prespective on the subject for the eleven western states.

The Clean Water Act of 1977 Public Law 95-217, set a national goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife and which provides for recreation in and on the waters to be achieved by July 1, 1983. The Clean Water Act mandates that pollution caused by runoff from agricultural activities including land used for livestock production, as well as other nonpoint sources (silviculture, mining, hydromodification, etc.), be controlled in addition to the control of point sources in order to achieve the national goal of water quality.

The Clean Water Act requires water quality management plans to be developed on all lands that will "include a process to (1) identify, if appropriate, agriculturally related nonpoint sources of pollution, including runoff from land used for livestock production and (2) set forth procedures and methods to control to the extent feasible such sources" (Sec. 208). Section 304(e) directs EPA to address the nature, source and extent of nonpoint sources of pollutants and processes, procedures and methods to control such sources.

The Federal Land Policy and Management Act of 1976 requires

> (1) " An inventory to be prepared and maintained on a continuing basis of all public lands and their resource and other values (including, but not limited to, outdoor recreation and scenic values), giving priority to areas of critical environmental concern. This inventory shall be kept current so as to reflect changes in conditions and to identify new and emerging resource and other values. The preparation and maintenance of such inventory or the identification of such areas shall not, of itself, change or prevent change of the management or use of public lands."

(2) "Land Use Planning with public involvement and consistent with the terms and conditions of this Act, to develop, maintain, and, when appropriate, revise land use plans which provide by tracts or areas for the use of the public lands."

Land use plans shall be developed for the public lands regardless of whether such lands previously have been classified, withdrawn, set aside, or otherwise designated for one or more uses.

(3) "In the development and revision of land use plans, agencies shall (a) use and observe the principles of multiple use and sustained yield set forth in this and other applicable laws; (b) use a systematic interdisciplinary approach to achieve integrated consideration of physical, biological, economic, and other sciences; (c) give priority to the designation and protection of areas of critical environmental concern; (d) rely, to the extent it is available, on the inventory of the public lands, their resources, and other values; (e) consider present and potential uses of the public lands; (f) consider the relative scarcity of the values involved and the availability of alternative means (including recycling) and sites for realization of those values; (g) weigh long-term benefits to the public against short-term benefits; (h) provide for compliance with applicable pollution control laws, including State and Federal air water, noise, or other pollution standards or implementation plans; and (i) to the extent consistent with the laws governing the administration of the public lands, coordinate the land use inventory, planning, and management activities of or for such lands with the land use planning and management programs of other Federal departments and agencies and of the States and local governments within which the lands are located."

(4) "Any classification of public lands or any land use plan in effect on the date of enactment of this law is subject to review in the land use planning process conducted under this section, and all public lands, regardless of classification, are subject to inclusion in any land use plan developed."

Scope

The document emphasizes summarization of research, prevention and control techniques, and criteria for preventing or minimizing water pollution. It presents an overview of rangeland utilization and treatment related to water quality and selected management practices and techniques for the protection of water quality in rangeland management. The document is intended to be an aid for dealing with nonpoint source pollution control. It is designed to form the technical basis to assist managers in making rangeland decisions that minimize impacts on water quality. It is also intended to serve as a first step in developing a definitive basis for water quality management planning for this important nonpoint source of water pollution.

Nonpoint sources of water pollution are characterized by three elements. First, the pollutants are conveyed by water, the source is uncontrolled by any person; that is, the water pollution results from precipitation, natural flooding or snowmelt. Second, the pollution is not traceable to a discrete, identifiable source such as a facility. Because this runoff may be channeled into a ditch or drain before entering navigable waters does not make natural surface runoff a discharge from a point source. Third, the control of nonpoint source water pollution is generally best achieved by implemenation planning and management techniques rather than by collection and treatment of pollutants (Permit Regulations for Agricultural Activities Federal Register Vol. 41, No. 36, February 23, 1976).

Wildlife populations are extensive on much of the rangeland of the west. Where concentrated and poorly managed, they can impact water quality similarly to livestock. Some of the principles and techniques identified in the document may be useful in reducing water quality impacts from wild ungulate populations. However, the major emphasis of the report is on livestock grazing, rangeland treatment and water quality protection.

The Environmental Protection Agency has already prepared a report entitled "Methods and Practices for Controlling Water Pollution from Agircultural Nonpoint Sources" (EPA 1973). The report covers all agricultural activities and is national in scope. Consequently, it is of a very general nature. In contrast, this report deals specifically with one important aspect of agricultural activities for the west.

Animal grazing is a major land use in the western United States that can impact water quality. Grazing activities are used in a broad context; and covers the actions and results of range rehabilitation, livestock grazing, grazing systems and range management planning. These activities are interrelated in may instances and it is difficult to idependently evaluate the potential water quality impact. Therefore, combinations of activities must be considered to adequately judge potential water quality significance.

Throughout the west there are significant potentials for adverse water quality impacts from many facets of grazing activities. The most significant of these potential impacts are related to erosion and sedimentation but in some areas pathogens and salts are significant potential problems. Fertilizers and pesticides are potential site specific problems. However, overall in the area of grazing land management, they are of less severity than sediment, salt and pathogens.

There are wide variations in the applicability of the techniques and methods presented in this report. This results from the varying significance from one sub-region to another of physical and biological factors such as temperature regime, soils/hydrologic characteristics, geology, fisheries, precipitation patterns, range sites, and range condition.

Significant advances in water quality protection can be made through on-site planning. Depending upon the complexity and degree of water quality impact risk, this may involve interdisciplinary input, use of predictive or impact models, expanded utilization of specialized grazing systems, and technical guidelines which have been developed for the specific area of consideration.

Throughout the west, there are widespread differences in the availability of resources of management expertise, field personnel, use of various grazing systems, and in field control from one land manager to another. These differences influence the level and degree to which water quality management goals are achieved. This suggests the need for different types and levels of management approaches. This is particularly apparent when related to grazing activities on public land in contrast to private lands. Where intensive planning (such as allotment management planning) is done and field control is adequate, specific water quality prescriptions or plans can be developed on a site specific basis.

The eleven western states shown in Figure 1 is the specific area of concern for the compilation of this document. Much of the published state-of-the-art information was gathered by workers within the west where livestock grazing is the major land use in many areas. An effort was made to evaluate and assess concepts, approaches and practices on a broad basis rather than being site specific.

The literature review was as comprehensive as practical. It was made after an assessment and utilization of several national data banks. The Bibliography Retrieval Services (NTIS and CAIN data resources), Bio Sciences Information Services (Biological Abstracts data sources), Water Resources Abstracts and S.D.C.'s International Search Service were the computer searches used. Limited manual library and literature reviews were also made. Some significant data sources may have been overlooked in the effort.

FIGURE 1 PROJECT AREA

SUMMMARY OF BEST MANAGEMENT PRACTICES FOR MINIMIZING OR PREVENTING ADVERSE WATER QUALITY IMPACTS

General

"Best Management Practices (BMP's)" means a practice or combination of practices, that is determined by a state (or designated areawide planning agency) after problem assessment, examination of alternative practices, and appropriate public participation to be the most effective, practicable (including technological, economic, and institutional considerations) means of preventing or reducing the amount of pollution generated by nonpoint sources to a level compatible with water quality goals (Federal Register Vol. 40, No. 230, November 28, 1975). BMP's also refer to a broader process of identifying practices and techniques that may be used to reduce water quality impacts. It is the latter concept that is used in summarizing state-of-the-art techniques and practices.

The major emphasis in identifying BMP's was on technical adequacy of practices to reduce water quality impacts. Limited emphasis was placed on economic and institutional acceptability.

Best Management Practices may involve single practices or combinations of practices, selected for specific soils, climates or problem areas. Selection of BMP's to be applied should normally be made by the land manager from the appropriate suitable alternatives based on site characteristics, management objectives and water quality requirements.

Current knowledge of BMP's is primarily based on soil erosion control practices that were developed to reduce soil loss and maintain productivity. The inference is made that if soil erosion is minimized, the technique or practice will be effective in substantially reducing water quality impacts if sediment is the problem. For some of the BMP's there are limited research data to validate this inference. Monitoring the effectiveness of practices is a continuing need for land and water quality management agencies.

Some of the principles that should be recognized in selecting BMP's to reduce water quality impacts from grazing and rangeland treatment are:

1. In many instances, there will be several technically adequate alternatives that may be applied to minimize water quality impacts when problems occur.

2. Exclusion of livestock use because of watershed and site conditions may be the BMP in some instances to minimize water quality impacts.

3. Selection of adequate BMP's may require the expertise of interdisciplinary resource specialists.

4. The most effective protection techniques must be based on site specific conditions such as soils, vegetation, geology, climate, proximity to water bodies and management objectives.

5. BMP's may prevent as well as mitigate water quality problems.

6. BMP's reflect the concept that a system or combination of practices may be needed on a particular site or planning area.

7. The frequency of storm events may have an impact on the ability of BMP's to mitigate water quality impacts. BMP's are more effective in controlling frequent storm events than in controlling the unusual storm climate events. The net effect of BMP's will be some reduction in the total volume of sediment produced, with a large reduction in the concentration during more frequent flows.

BMP's are summarized to emphasize their importance in water quality management planning. Rationale for many of the techniques is presented in the document. Some of the techniques identified in the summary represent inferences based on the state-of-the-art assessment and literature review by the Project Team that prepared the document.

Livestock Management

1. Reducing Impacts from Grazing

a. To implement effective livestock grazing management, basic principles of grazing, vegetation, soils, wildlife, cultural and other uses and resources and their relationships must be understood and used. Although exceptions occur, some important concepts and guiding criteria are:

(1) Livestock graze selectively. Palatability of different plant species varies during the year. Livestock graze many of the same plants repeatedly year after year. They tend to graze a greater variety of plants around a water source and readily accessible areas.

(2) In the design or selection of any grazing system, long term benefits must be considered. Watershed protection must be the first consideration. Watershed protection cannot be sustained on deteriorating rangeland vegetation. The selection for management, and response to grazing, of key plant species is very important since they reflect the health of the total plant community. Key species must be selected for management to meet several objectives, one of which is watershed protection, keeping in mind that the amount, type, and timing of grazing is the key to resource protection and management.

(3) All uses and resources that affect livestock grazing or that livestock grazing affects must be evaluated. Objectives for each should be determined and conflicts resolved. For

example, where wildlife and livestock compete for the same forage, careful planning is necessary to keep a balance between all grazing animals and the forage produced.

b. Management practices, such as changing season of use or rate of stocking; implementing a system of grazing; or obtaining better distribution of livestock may, singly or in combination, improve the range and minimize adverse water quality impacts. However, any such practices must be integrated into a well planned and implemented livestock management program. This is essential to the success of obtaining the most efficient use of the range without significantly adversely impacting water quality and other rangeland resources.

c. Flexibility in livestock herd management (numbers) is absolutely essential to keep forage in balance with livestock needs. This is especially true during years of low forage production. Maintain an animal stocking density that will sustain the vegetation under normal conditions. Site characteristics, including soils, vegetation, water uses and season of use, will affect the animal-acre ratio. Adequate vegetative cover should be maintained to control runoff and reduce erosion.

d. It is difficult to develop a grazing management system that is entirely satisfactory on a deteriorated overgrazed range. Two simultaneous actions must be initiated. Adjust stocking rates to meet forage production and apply management that will provide deferment of grazing for key forage species on key grazing areas. The adjustment and the period of deferment will be governed by the species present, the desired and attainable rate of improvement, watershed characteristics and potential for water quality impacts.

e. From the standpoint of achieving livestock management objectives and minimizing soil, vegetation and water quality impacts, grazing management plans will vary. There is no set formula that will identify the type of grazing system or management plan that will be best for any livestock operation or allotment. Water quality impact will be closely related to soil erosion and sedimentation, associated with vegetation cover and concentration of livestock grazing. The grazing system must be designed on the basis of soil and vegetation capabilities, water quality considerations and livestock and wildlife requirements.

f. Ground cover and size of bare soil openings have the greatest influence on overland flow, soil erosion, and pollutant transport. Research has documented that seventy percent (70%) or above plant cover (standing live and dead vegetation) is an optimum density to reduce erosion, runoff, and water quality impacts from rangelands. From a water quality standpoint, vegetative cover can be manipulated within a range of 70 to 100 percent to maximize forage production and use without a significant effect on water quality. Some semiarid and most arid rangelands of the west do not support a seventy percent vegetative cover, but are not necessarily high producers of sediment because of the nature of the soil, gravel pavements that have developed, and the lack of runoff-producing preciptiation.

g. In summary, BMP's include adjusting numbers of livestock to balance with normal average forage supply but maintain options to be flexible in numbers as forage production varies from year-to-year; practices or combinations of livestock management practices which may be applied to mitigate specific water quality problems include (in addition to adjusting rate of stocking) season of use, fencing, herding, placement of salt and supplements, class of livestock and providing alternative sources of water; the ultimate goal should be to incorporate all feasible management practices in a well-designed and coordinated livestock management plan with specific management objectives, one of which must be to provide the optimum vegetation ground cover to protect the watershed from runoff and erosion.

h. Land use plans and allotment management plans will identify the amount of vegetation necessary to provide adequate watershed protection under grazing use to insure perpetuation of the vegetation, maintain and enhance plant vigor, and assure soil stability. Specific techniques used to mitigate the impact of grazing animals on sensitive watersheds may include:

(1) Fencing and applying rotation grazing management.

(2) Providing water diversions and alternate water sources to attract grazing animals away from streams, reservoirs, lakes, etc.

(3) Periodic herding to redistribute livestock.

(4) Placing salt or food supplements or providing shade away from water.

(5) Improving rangeland condition including revegetation, fertilization, prescribed burning, and other rangeland treatment practices.

2. Reducing Impacts from Animal Concentrations

a. Livestock access in the riparian or streamside management zone should be restricted for sufficient periods to allow vegetative recovery and maintenance. Livestock exclusions are primarily important in areas where water uses to be protected include fisheries production, wildlife, primary contact recreation and human consumption. Pathogen concentrations may not be directly affected by livestock exclusions.

b. Livestock exclusion criteria are included in many public agencies technical guides and handbooks for land management. Some of the major considerations are summarized below:

(1) Purpose - to protect, maintain or improve the quantity and quality of the plant and animal resouces; to maintain enough cover to protect the soil, and to minimize water quality impacts.

(2) Where applicable - where soil hydrologic values, existing vegetation, fish and wildlife production and recreation are prevented or damaged by livestock.

(3) Livestock should generally be excluded from: (1) overgrazed areas where water uses are important, (2) areas of high susceptibility to critical erosion and (3) critical watersheds used for municipal and domestic water supply.

c. Locate supplemental feed and salting stations reasonable distances from streams and water courses. They should be moved about to avoid excessive trampling and can be a means of encouraging better grazing distriubtion. Shading facilities (when needed) either natural or constructed should be incorporated into the planning. They are normally permanent in nature but, like salt and supplements, do not need to be adjacent to watering sources.

Rangeland Treatments

1. Reducing Impacts from Mechanical Treatments

a. The major objective of most mechanical rangeland treatments is to improve vegetative production by increasing moisture storage and reducing soil erosion. This objective is usually consistent with minimizing water quality impacts on a long term basis or after improved vegetation establishment.

b. Soil characteristics (texture, structure, consistency, and moisture holding capacity), climate, type of vegetation, and implements used are the principal variables that determine water quality impacts of any treatment. An understanding of these variables is essential to evaluate the potential for or to minimize the water quality impacts from any rangeland mechanical treatment.

c. The most consistent beneficial response to rangeland mechanical treatment in terms of vegetation production and reduction of runoff and erosion in cited research occurred on medium (very fine sandy loam, loam, silt loam and silt) to fine (sandy clay, silty clay and clay) textured soils.

d. With severe soil disturbance resulting from many rangeland mechanical treatments, it is essential that sites be conducive to vegetation establishment with seeding after the treatment is completed. Since the life of most rangeland mechanical treatments is relatively short, it is essential to minimize water quality impacts from sediment that a desirable vegetation cover be established and maintained.

2. Reducing Impacts from Prescribed Burning

a. Carry out all burns in accordance with a prescribed burning plan. An adequate plan considers those factors which have the potential to adversely affect water quality and incorporates actions to avoid or minimize these impacts.

b. The following site and watershed characteristics should be evaluated and addressed in the preparation of prescribed burning plans: litter accumulations, availability of fuel, soil type, stability and moisture content, susceptability of soil to water repellancy, annual precipitation, topography, type of vegetation, recovery potential, and proximity of treatment area to streams and lakes. Season of year and wind conditions are also important factors to consider.

c. Exclude grazing from the burned area for the length of time identified in the prescribed burning plan.

d. Monitoring for potential pollutants should be a planned activity when water uses indicate there is a need.

e. Prescribed burning plans must be consistent with local, state and federal air quality regulations to avoid adverse impacts on air quality.

3. Reducing Impacts from Chemicals

a. Use of pesticides should be consistent with manufacture's label. Over use can lead to unnecessary contamination and under use will detract from full effectiveness.

b. Disposal of excess pesticides and empty containers must be consistent with federal, state and local regulations.

c. Use pesticides only when other control methods are ineffective or are not economically feasible.

Feral Horse and Burro Management

The key to managing wild horse or burro populations and their habitat, is a determination of the number of animals to be managed in any particular area. This determination must be based upon the ability of the land to produce forage and cover for all animal species, including horses or burros, plus the compatibility of use by horses or burros with other animal species and/or resource values. In some cases trade-offs may be necessary for best multiple use management. Once the number of horses or burros to be managed on each area has been determined, the first management action undertaken is actual reduction or addition of animals to obtain the "desirable number".

BMP's include horse and burro numbers at levels proportionate to the forage supply to prevent overgrazing and subsequent runoff and erosion and which mitigate adverse water quality impacts; minimum fencing of water sources for protection, but care must be exercised that the law or biological requirements of the animals are not violated; and development of alternative water sources to protect higher value riparian/aquatic ecosystems.

Summary

It is essential to have a good water quality assessment of an area or watershed to assist in making a selection of BMPs to solve existing problems. In many instances, it is not necessary nor appropriate to apply Best Management Practices across the board or throughout a watershed. The emphasis in selection and application of BMP's should be on recognized or potential water quality problem areas. Coordinated interdisciplinary resource planning involving State, Federal and private rangeland managers is an effective tool for minimizing impacts from grazing animal management.

GRAZING AND WATER QUALITY

General

McElroy et al. (1976) state that pollution from nonpoint sources can be attributed to the following types of activities: (1) agriculture - cropland, pastures, rangeland, woodlands and "small" livestock and poultry feeding operations; (2) silviculture - forest growing stock, logging, and forest road building; (3) construction - urban or commercial development and highway construction; (4) surface mining; (5) terrestrial disposal of agricultural, industrial, commercial and municipal wastes and wastewaters; and (5) stormwater drainage from urban areas.

Several attempts have been made to place numerical ratings on several land types and use classifications. For example, Stewart (1975) as cited in Dixon et al., 1977 computed forest land at 0.53 percent and agricultural cropland at 89.6 percent of total nonpoint source production. Several disturbance types were rated at intermediate percentages, including grassed rangeland (5.87 percent). The above example allocates the problem once location, physiography, and a land use mix are set. In reality, local soil, vegetation, aquatic relations, geology, slope, aspect and hydrology along with land use will determine the erosion, runoff and water quality effects.

Land distrubances vary in their water quality impacts. It is at this variation that the U.S. Environmental Protection Agency's (1973) areal erosion rate index system is aimed. In this scheme, high impact relatively non-extensive uses (mining, road construction) receive high, adverse dimensionless scores, whereas the more extensive lower impact activities such as grazing are rated more favorably. It is widely accepted that the major nonpoint pollution problem in the Western United States is sediment (EPA, 1973). This chapter focuses on the sediment yield responses associated with various livestock grazing systems and rangeland treatments.

"Nutrients" as used in this document include major pollutants such as nitrogen and phosphorus. The pollution potential from cow-calf operations and cattle wintering (confinement to a barnyard area near a farm homesite) in particular, would appear to be in the form of sediment, nitrogen, phosphorus, organic compounds, and fecal coliform bacteria, although the limited current data indicate nitrogen and phosphorus contributions will be small (Dixon et al,, 1977).

Various pollutants have variable effects on rangeland streams. Nitrogen and phosphorus are essential nutrients for plant growth. Aquatic vegetation of the free-floating type, such as algae, depends on dissolved nitrogen and phosphorus compounds for a nutrient supply. When periodic flushes of nutrients are injected into rangeland streams, dense, rapidly multiplying algal blooms may occur. Often such growths of algae are undesireable to water users and may interfere with other forms of aquatic life. The enrichment of a water body is called eutrophication and can be an adverse result of excessive nutrient loading.

Biochemical oxygen demand (BOD) is also of great importance to aquatic ecosystems and can be affected by range managemet actions. Data concernir the impact of open rangeland grazing systems and range improvement practices on stream water quality are very deficient. The most important face of this problem is that land characteristics (edaphic, geologic, vegetative), natural wildlife populations, local hydrology and present and past climatic conditions all tend to interact to influence and confound the effects of grazing management operations on nonpoint source loading and pollutant transport and effects.

"Dissolved solids and total dissolved solids (TDS) are terms generally associated with freshwater systems and consist of inorganic salts, small amounts of organic matter, and dissolved materials. Principal inorganic anions dissolved in water are the carbonates, chlorides, sulfates and nitrates. The principal cations are sodium, potassium, calcium and magnesium, (EPA 1976). Excess dissolved solids are objectionable in drinking water because of possible physiological effects, corrosion and water treatment expense.

Agricultural uses of water are limited by excessive TDS concentrations, particularly where the amount of sodium cation is high in relation to others present. In this instance, osmotic pressures may become excessivel high, and soil structure, infiltration and permeability problems may result.

The term "suspended and settleable solids" is descriptive of the inorganic particulate matter in water. It includes suspended sediment and bedload. Suspended solids produce turbid water. Both turbidity and suspended solids are of concern in municipal and industrial water supplies. The less turbid water becomes, the more desirable it is for swimming and other water contact sports. Fish and aquatic life requirements concerning solids in suspension can be divided into effects brought on by a turbid water column (impact on the compensation point for photosynthetic activity and effects resulting from sedimentation of the bottom of a stream or pond (blocking of gravel spawning beds, removal of dissolved oxygen from overlying waters, smothering of bottom invertebrates). In addition, the discharge of sediment (suspended inorganic particulate material) into a stream creates an energy demand upon the kinetic energy of streamflow which may result in a change in channel erosion and deposition processes.

The presence of fecal coliforms in streams is not in itself proof that domestic livestock are the source, as is demonstrated by a study of three pristine watersheds of northern Utah (Doty and Hookano, 1974). Because fecal coliform generally do not multiply outside the intestines of warm blooded animals, and have a short life span, the high densities of fecal coliform reported for Halfway, Corduroy, and Whipple Creeks following a 3.16 inch rainfall event in 8 hours (August, 1977) are indicative of relatively recent pollution, presumably from wildlife populations. All three basins have been protected from fire, domestic grazing, and silvicultural operations for the previous 45 years.

Coliform organisms are used as an indicator of bacterial water pollution. An appreciable count is considered to indicate a disease producing potential in the water sample. Members of the coliform bacteria group may come from soil, water, vegetation and feces.

Infiltration Relationships

The infiltration of water into a soil determines the amount that becomes soil water. The balance either evaporates, is transported by plants, or becomes surface or overland flow. Infiltration rates limit the occurrence, as well as the quantity and timing, of runoff when rainfall intensity is between initial and final infiltration rates.

Many factors influence the rate at which rainfall can enter a soil. Table 1, (modified from Branson et. al., 1978), presents these factors by like groupings. Of those listed, litter, biotic, and some of the physical soil characteristics are the ones which livestock grazing and rangeland treatments most directly affect. While runoff does cause erosion and provide pollutant transport, infiltration can also cause nutrient transport (particularly nitrates). In general, nitrates will move with water with little regard for erosion control. If the water infiltrates, the nitrates will migrate downward.

Grazing and browsing animals remove protective plant material and compact the soil surface (Branson et al., 1978). Reduction of live plant cover (plus litter) and compaction of the soil surface both reduce infiltration rates. When this happens runoff potential is increased in sediment and attendant chemical and nutrient pollutants, and microorganism transport.

While increasing grazing intensities and grazing as an activity have been shown to reduce infiltration rates in many studies, recovery of infiltration rates after reduced grazing pressures or nonuse has also occurred in a number of studies. Some two dozen studies on a variety of range conditions and under a wide variation in grazing intensity have assessed the time length of reduced grazing intensity or nonuse necessary for soil water infiltration rates to recover up to some pre-treatment level (inches per hour water intake rate through the soil surface). A summary by Branson et al., (1978) shows three to thirteen years of nonuse or reduced grazing is required for complete restoration of infiltration rate.

TABLE 1
FACTORS AFFECTING INFILTRATION RATES

Groupings	Factors
1. Litter/Stone Cover	Percent litter, small stone, large stone
2. Biotic	Vegetal canopy coverage, successiona stage and age of vegetation, micro-biolgical activity
3. Physical Soil Characteristics	Shrinking and swelling of colloids, soil temperature, degree of aggregation, surface crusting, quantity of coarse material in soil surface, soi structure and texture, bulk density, moisture content, capillary force patterns, parent material
4. Chemical Soil Factors	Exchangeable ions present, degree of dispersion of surface soil by sodium coatings, percent organic matter, parent material
5. Climatic Conditions	Season of year, rainfall energy, win action, air and water temperature
6. Topography	Slope, aspect, exposure

Runoff and Ground Cover Relationships

The kinetic energy of raindrop impact at the soil surface is the primary force responsible for initiating soil movement at the land surface. Surface runoff is the dominant force for transportation offsite of the detached soil particle. Runoff begins when water occupies all available surface detention storage (soil depressions plus plant interception storage) and when rainfall intensity exceeds the instantaneous soil water infiltration rate.

Factors affecting the timing of runoff and the volume from individual storms for a given watershed include type of precipitation, rainfall intensity and duration, rainfall distribution, watershed topography, geology, soil characteristics, watershed cover characteristics, and antecedent soil moisture conditions. Of these, soil and watershed cover characteristics are the ones affected by livestock grazing and land treatment practices. Evaporation and transpiration reduce the reservoir of available soil water. The most active region of the soil-plant water regime extends from a few centimeters in the soil to the top of the plant canopy (Lorenz, 1974). Hence any disturbance or alteration of the components of this region influences the water balance of the entire system, which in turn influences surface runoff and water quality.

Livestock grazing removes protective vegetation and trampling compacts surface soils. These effects cause a reduction in infiltration rates which may result in increased surface runoff. As pointed out earlier, increased surface runoff may result in water quality degradation becuase of increases in suspended matter and attendant pollutants.

Ground cover components of live vegetation and litter (mulch of dead vegetation) play a large part in controlling surface runoff from rainstorms. Stuidies in Colorado and New Mexico found that storm and annual runoff varied with the amount of bare soil or the amount of vegetation plus mulch (Branson et al. 1978). Runoff increased as vegetation and mulch decreased, or bare soil increased. Studies in Idaho and Utah found that 65-70 percent ground cover (basal area of live plants plus mulch) was required to maintain minimum surface runoff and erosion (Packer, 1961). These studies also found that to maintain minimum runoff and erosion, ground cover had to be increased when trampling associated with grazing increased.

A study of three contiguous watersheds in New Mexico (Aldon, 1964) reported runoff before and after implementation of a summer-deferred grazing system was about the same, as was annual average precipitation, although sediment production decreased when the season-long system was converted to deferred. Changes in sedimentation were thought to be attributable to the decrease in grazing intensity during treatment.

Numerous investigators (Packer, 1953; Elwell and Stocking, 1974 and Gifford, 1976) have reported consistently that about 70 percent plant cover (aerial projected) is a critical value in terms of the stability of the hydrologic environment. Above 70 percent cover, changes in land use which simply alter the amount of plant cover, have little effect on runoff. Packer's (1953) work emphasized that the rule of thumb is only applicable on western mountain rangelands where site potentials of 70 percent or greater are biolgically feasible. Gifford (1978) interprets this breakpoint to mean that as cover on a site is reduced below the range of 65-75 percent, soil factors become increasingly important over vegetation as determinants of runoff regime.

The significance and physical meaning of the percent figure must be cautiously considered. The figure is not a universal breakpoint for water quality effects, such as bacterial pollution or nutrient loading, however it is a fairly reliable guide for sediment. Also, it is important to note that all sites with 70 percent cover will not respond the same. The figure seems to be applicable over a wide area, but the degrees of soil stability between sites are dependent in large part on local factors. While 70 percent may result in less sediment production from numerous mountain rangeland sites, these minimums have a large amount of scatter rather than strongly approaching any single value. The guide should not be applied to arid and semiarid rangeland watersheds where site productivity cannot support 70 percent cover. Therefore, from a water control and erosion standpoint, plant cover theoretically can be manipulated within the spread of 70 to 100 percent so as to maximize livestock production functions without much effect on runoff and erosion relations.

It must be understood that in practicality, cover changes seldom would occur without simultaneous changes in other important system variables (infiltration rates, soil water depletion patterns). This would obviously influence a measured response in erosion, water quality or streamflow.

Grazing Animal Management Effects

Infiltration Rates

Several studies have shown that moderate to heavy grazing by livestock can decrease infiltration rates, increase surface runoff, increase soil compaction, and increase erosion and sediment yields (Dortignac and Love, 1961; Lusby, et al. 1971; Tromble et al., 1974; Thompson, 1968, Rauzi, 1956; Dunford, 1949; Aldon, 1964). Some of these studies also show that reduction of grazing intensities, change from yearlong to seasonal (nongrowing period) grazing, or elimination of grazing can result in improved watershed conditions.

Wherever livestock grazing and soil or water response has been assessed, the observed changes in runoff, infiltration, soil compaction and sediment yield have been due to not only the livestock grazing activity but also wildlife utilization. The latter has never been successfully independently quantified.

Data relating grazing intensity to infiltration rates are available, however, distinct limitations to the data have recently been pointed out by Gifford and Hawkins (1978). It is emphasized that only the infiltration process has been examined in a degree of detail which allows for a preliminary quantitative analysis.

Gifford and Hawkins (1976) concluded that intensity is by far the most common expression of grazing activity. Figure 2 from Gifford and Hawkins (1978) show simple linear regression models fitted to measured final or constant (f_c) infiltration rates as associated with varying degrees of grazing intensitiy.

The conclusions drawn by the authors based on the regression analysis and considerable paired student's "t tests" are as follows:

a. There is an influence of grazing on final water infiltration rates. Ungrazed rates are statistically different from grazed (at any intensity) at the alpha level of 10 percent.

b. It is difficult to differentiate between the influences of moderate and light grazing.

c. There is a significant effect of heavy grazing intensity on final infiltration rates.

d. At the lower range of water infiltration rates (generally less than 0.8 inches per hour) there is an apparent positive improvement (increase) in the final rate as a result of any level of grazing intensity. This may reflect a soil wetability problem or hoof chiseling of an impermeable sealed soil surface. This phenomena is reflected by data of Branson et al., 1962; Johnston, (1962); Dortignac and Love, (1961); Thompson, (1968); Rauzi, (1955).

The Gifford and Hawkins review demonstrates with quantitative analysis that data relative to range condition are insufficient for proper evaluation of hydrologic change. Their recommendation for research which will allow for more systemmatic hydrologic assessment is a detailed definition of the long term effects of grazing (by year and season) on infiltration rates as a function of range site and condition, and grazing intensity.

Infiltration rates were found to be slightly higher on grazed than ungrazed plots for the last 20 minutes of infiltration runs at Badger Wash in western Colorado (Lusby et al., 1971). This indicates that under certain conditions grazing has no appreciable effect on infiltration during the latter stages of extended rains. However, the initial quantity of water infiltrated before runoff began on ungrazed plots was significantly higher than on grazed plots (Thompson, 1968). In Colorado, protection from cattle grazing resulted in increased infiltration rates; the recovery period extended 6 years on ponderosa pine-grass sites and 13 years on grassland sites. Infiltration rates of soils in grassland and pine-grass

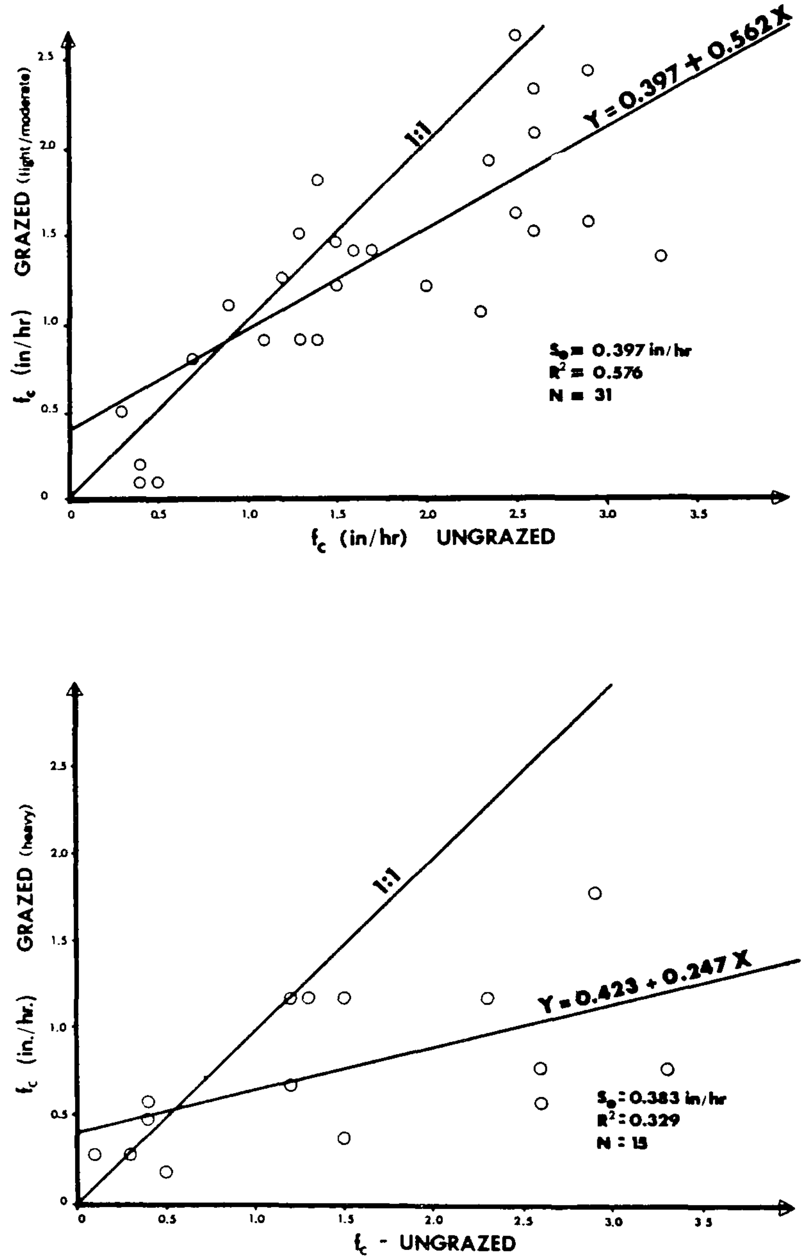

FIGURE 2 REGRESSION RELATIONSHIPS OF FINAL INFILTRATION RATES UNDER LIGHT/MODERATE GRAZING INTENSITY (Y) AND UNGRAZED (X) RATES (GIFFORD AND HAWKINS, 1978)

sites could be estimated by measuring the quantity of dead organic material and non-capillary pores in the surface soil (Dortignac and Love, 1961).

In northeastern Colorado on blue grama and buffalo grass short-grass prairie, heavy grazing (1.79 acres per yearling heifer per month) significantly decreased infiltration rates on an Ascalon sandy loam site, on a Nunn loam site, but not on a Shingle sandy loam site (Rauzi and Smith, 1973). This research was conducted at the Central Plains Experimental Range. During the first 10 minutes of the infiltration process, only the effects of soil was found significant. After an additional 5 minutes, grazing intensity effects on infiltration rates were statistically discernible. By 30 minutes, the interaction of soil type and grazing appeared important. The implication for shortgrass types is that for high intensity, short duration (less than 10 to 15 minutes) thunderstorm events, grazing system effects may have no effect; soil type and characteristics may be the controlling factors.

Work in Oklahoma (Hanson et al., 1970) has indicated that grazing intensity makes little difference on total runoff during large storms which are preceded by wet periods.

Trampling

The disturbance of litter and soil caused by trampling associated with livestock grazing has long been recognized as an important factor contributing to accelerated erosion and storm runoff on western forest and range watersheds. Because of a shortage of useful information on the tolerable limits of trampling, Packer (1953) initiated a simulated trampling disturbance study at two intermixed types of foothill spring-fall range (Agropyron inerme and Bromus tectorum) on steeply sloping, granitic slopes of the Boise River Watershed. Each of five degrees of simulated mechanical trampling was randomly applied to trial plots. All levels of trampling disturbance (10, 20, 40, and 60 percent of the plot surface) reduced ground cover and increased interspace size on both range types. A similar response was observed in amount of overland flow and soil movements, with undisturbed sites as the reference level. Packer (1953) stressed that the findings of the Boise River trampling study had some important management implications for the wheatgrass and cheatgrass covered granitic rangelands of southwestern Idaho as follows: "It appears that such ranges having less than 70 percent ground cover are probably not in a satisfactory watershed condition and should be improved. It also appears that where these ranges have from 70 to 80 percent ground cover, light grazing use is indicated for maintenance of protective conditions. On range having ground cover on the order of 90 precent or more, trampling is apparently not too serious a consideration."

Work later by Packer (1963) on the Gallatin elk winter range of south central Montana further demonstrated the importance of maintaining a 70 percent ground cover density with maintenance and restoration of soil stability being the land management objectives. As rainfall intensities increased, so did soil erosion under all conditions of ground cover, however the erosion increases were relatively large on sites having less than 70 percent cover.

Packer's (1953, 1963) studies support 70 percent cover as a critical value. The Boise River work also emphasized that the 70 percent figure becomes academic where precipitation, site potential or repeated heavy disturbance prevents plant cover from reaching this relatively high cover percentage. Quantitative relations between grazing intensity (numbers of animals, or acres per animal unit month), utilization, trampling and changing infiltration rates remain undetermined for all soil-plant community complexes, 25 years after Packer first conducted his steel hoof disturbance studies.

Effects on Runoff

Runoff from plots in a Colorado study was greatest for those heavily grazed, while the least runoff was from protected plots. While the results from the study showed an increase in runoff from moderately grazed plots, this increase was not accompanied by increased soil loss. The investigators concluded that moderate grazing was permissible if the resulting loss of water did not cause a critical shortage of soil moisture for plant development (Dunford, 1949). A study in western Colorado found 30 percent less runoff from ungrazed watersheds than from those with two years of winter-spring grazing by cattle and sheep (Lusby, 1970). In Arizona, Rich and Reynolds (1963) found that spring and fall grazing by horses and cattle on porous granite soils, at intensities of 40 percent and 80 percent, removal of perennial grasses did not increase runoff.

Rainfall-runoff relationships may be influenced by management of grazing animals, although various grazing systems (especially rest rotation systems) have not been studied from the standpoint of hydrologic impacts (Gifford and Hawkins, 1976). Improved grazing management (a change from yearlong to winter grazing, and grazing controlled to attain 55 percent use of key species) on three experimental watersheds in New Mexico (Aldon 1964) resulted in improved watershed conditions over a three-year period.

Average ground cover for the three watersheds doubled, bare ground decreased, and there were marked reductions in sediment yields and runoff. Hanson et al. (1970) found that heavily grazed watersheds produced runoff from short intense storms as well as from storms of long duration, whereas lightly grazed watersheds produced runoff mainly from long duration storms that followed wet periods (Table 2). However, when long duration storms follow a wet period, runoff from lightly grazed watersheds may be as much as from heavily or moderately grazed watersheds. Leithead (1959) found that western Texas rangeland in good condition absorbs moisture five to six times faster than poor condition range, and thus, greatly reduces surface runoff amounts. Generally a good grass cover, moderately grazed, sufficiently retards runoff and erosion while providing a forage resource as well (Smeins, 1975). Gifford (1978) goes further: "Maintaining a cover of 70 percent (if possible) in conjunction with moderate or light grazing will minimize erosion and infiltration will most likely still be 75 percent of the undisturbed values at worst."

Grazing system effects on water quality

Chemical constituents considered in this section are total dissolved solids (mineral matter in solution) and nutrients (phosphates, nitrogen). Physical parameters addressed are alkalinity and suspended sediment. Bacteriological parameters are total and fecal coliform, and fecal streptococcus organisms. Most of the early rangeland and watershed studies neglected water quality. Often suspended sediment was the only water quality parameter addressed.

There is little published research on grazing system effects on runoff or water quality. Work conducted at Badger Wash, Colorado by the U.S. Geological Survey (Lusby et al., 1971) did focus upon a relatively unspecialized grazing system. However, due to management changes over the twenty year period, consistency within and between treatments was a problem. The Colorado work thus leaves many questions unanswered. Work performed at the Reynolds Creek Experimental Watershed, Idaho (Dixon et al., 1977, Stephenson and Streeter, 1977) in the early 1970's investigated the bacteriological, sedimentation and chemical aspects of deferred grazing systems on a portion of the 23,390 hectare basin. The most comprehensive information on grazing system - water quality relationships has been collected at Reynolds Creek, however the allotments studied were small, and results have limited potential for extrapolation even within the Columbia Plateau region.

"Grazing system" as defined by the Society for Range Management (Kothmann, 1974), is considered to be a "specialization of grazing management which defines systemmatically recurring periods of grazing and deferment (from grazing) for two or more pastures or management units." Badger Wash, Colorado is one of only a few instances where a grazing system (although relatively simple deferred) has been studied from the watershed hydrology aspect. There are several locations where riparian sections of specialized grazing systems have been researched for aquatic biology and water quality effects. However, the upland hydrology of slope source areas has not been accounted for by these fishery studies.

Reports are available on the effects of continuous or season long nonrotational grazing superimposed over some previous rangeland treatment. For example, Buckhouse and Gifford (1976) examined a southeastern Utah pinyon-juniper site, which had been chained and windrowed. A stocking rate of 2 hectares per AUM was maintained for two weeks. No significant changes were noted in fecal pollution. The experiment was designed to be comparable to rates used by the Bureau of Land Management on well established crested wheatgrass seedings in the vicinity.

TABLE 2

RUNOFF FROM DIFFERENTIALLY GRAZED WATERSHEDS

	Watersheds by grazing treatment[1/]					
	Heavy[2/]		Moderate[3/]		Light[4/]	
Year	Precipitation	Runoff	Precipitation	Runoff	Precipitation	Runoff
1963	30.8	4.6	30.5	4.0	32.0	3.5
1964	21.8	1.7	21.8	0.7	19.7	0.1
1965	27.5	0.3	28.1	0.4	27.7	0.3
1966	23.9	0.4	23.3	0.0	24.0	0.0
1967	27.9	3.1	28.4	2.0	27.7	1.4
Mean	26.4	2.0	26.4	1.4	26.2	1.1

1/ Four 0.8-hectare watersheds with each grazing intensity

2/ Forage utilization 55%

3/ Forage utilization 35 to 55%

4/ Forage utilization 35%

Stephenson and Street (1977) indicated that typical rangeland cattle operations in Idaho will probably result in coliform bacterial pollution along various reaches of rangeland streams, with bacterial concentrations dependent upon the number of cattle and their access to streams. In addition, the Idaho studies performed at Reynolds Creek demonstrate the importance of physical and hydrologic characteristics, and climatic conditions on the total bacterial effect of livestock operations.

In three mountain streams of the Bear River Range in northern Utah, Darling and Coltharp (1973) have reported statistically siginficant increases in the total coliform, fecal coliform, and fecal streptococcus counts at locations along streams just below the areas grazed by cattle and sheep. No statistically significant increase could be demonstrated for temperature, pH, turbidity, nitrates or phosphates. Because of incongruity between watershed and allotment boundaries, and no data on relative allotment and study watershed acreages, it is not known what stocking levels or grazing intensities produced this impact on bacteriological water quality.

Incremental damages to water quality from bacteriological, chemical, and nutrient loading associated with various kinds of grazing systems and intensitities all have relative importance depending on soil salinities, proximity to perennial stream channels, runoff regimes, frequencies, and other factors.

Summary

Infiltration rates and the interaction of changes associated with livestock grazing are a complex phenomena. It is apparent based on over a dozen studies that light and moderate intensities of grazing will not damage infiltration rates during unsaturated soil conditions. However, a concentration of livestock brought about by any phase of a grazing system which encourages heavy intensity grazing is likely to produce significant decreases in the maximum potential rate at which rainfall or snowmelt can infiltrate into the soil. Adverse impacts on sheet and rill erosion and water quality constituents are an outcome of these changes. The phenomena of heavy trampling damage to infiltration rates may be an insignificant problem on fine-textured high clay content soils where undisturbed rates are less than one inch per hour.

It is well documented that periods of nonuse from livestock grazing, however built into the grazing system, allow certain natural processes to progressively improve soil water infiltration rates to predisturbance levels. These processes include freeze-thaw cycles, buildup and decay of plant litter, etc. Somewhat a function of season and clearly a function of rest length, deferment of use is an important facet of any intensive livestock management system and can be used not only as a technique for hydrologic condition restoration, but also to achieve froage production and maintenance goals.

On rangelands such as those in western Montana, where aerial projected plant cover is 70 percent or greater, a relatively high resistance to long-term damage from livestock trampling is assured. On such sites having a cover of 90 percent or greater, trampling associated with even heavy grazing is not too serious, unless significant declines occur in water infiltration rates.

The amount and peak flow of rainfall runoff appears postively correlated with degree of grazing intensity. Heavy grazed rangelands (all other variables being equal) will produce greater runoff in a shorter time than ungrazed or lightly grazed rangelands. Each range site will produce run-off in a quantity and rate which has no bearing on the kind of grazing system in effect, depending upon rainfall intensity and atecendent soil moisture. Some storm intensities may be considered acts of nature and of an infrequency for which land managers simply accept risk and consequences. In general, range management which maximizes plant cover and infiltration rates, enhances channel roughness and assures well engineered water control structures will minimize adverse effects of high intensity storms.

Maximizing water quality of rangeland streams and at the same time maintaining a proper balance with domestic livestock production is a great challenge to the land manager and a source of numerous research hypotheses for the scientific community. For some time to come, until much more specific findings on the subject are available, agencies and operators must act on the general premise that actions which minimize adverse changes in the stormflow and snowmelt runoff processes will simultaneously minimize adverse water quality impacts.

This generalization is most valid for the water quality constituents of sediment, nutrients, and salts and less valid for those constituents with source areas in the riparian zone (bacteria, water temperature). For all water quality characteristics it can be generally inferred that, allotments with steep slopes and relatively large perennial stream networks provide more potential for water quality impacts from grazing. Also length of use, given a uniform grazing intensity will increase the opportunity for pollutant loading, as will clustered and concentrated centers of animal feeding and watering. A watershed with a potential for a fishery, contact recreation, drinking water supply and open to close public scrutiny of site conditions, requires very careful selection of a grazing management system designed to improve hydrologic conditions.

Rangeland Treatment Effects

Though hydrologic impacts of range improvement practices have been of interest for many years, there are still practices and physiographic regions with relatively little information for assessing potential impacts. Effects of range improvements on hydrologic conditions may be either beneficial or detrimental depending on land management objectives, local uses of water, physical and biological factors.

Infiltration rates may change when plowing and chaining practices (for reduction of undesirable plant species and/or seedbed preparation for desirable species) are applied to rangeland sites. Gifford and Skau (1967) looked at first-year impacts of plowing (moldboard plow) with drilling and plowing with contour deep furrow drilling on infiltration rates and potential sediment production on two big sagebrush sites in Neveda. They found that infiltration rates, in general, for the two plowing treatments were significantly less than rates measured on undisturbed sites. Sediment production on the plowed treatments, however were not significantly different from the natural sagebrush community.

In another study on silty loam soils in southern Idaho, Gifford (1972) and Gifford and Busby (1974) conducted intensive infiltrometer studies on a plowed big sagebrush range over a four-year period. Results of this study indicated there was a natural decay in absorptive capabilities of surface soils due to the plowing treatment.

Meeuwig (1965), working in central Utah on subalpine range, reported that seven years after disking and seeding to grass, the main effects were decreased organic matter and capillary porosity in the surface soil, greater bulk density, and decreased plant and litter cover. Although seeding did not significantly affect infiltration rates or soil stability, grazing during the previous four years did.

Blackburn and Skau (1974) studied two plowed and seeded big sagebrush communities in Nevada. They found that infiltration rates for sandy loam soils were not significantly different from their undisturbed counterparts. Studies by Gifford (1975a) showed that infiltration rates had only been slightly affected when comparing chained sites to undisturbed pinyon-juniper woodland.

Infiltration is generally decreased where burning (fire) is of high intensity and the organic covering of the soil is completely consumed (Gifford 1975b). Three studies in California on different soils showed no decrease in infiltration rates as a result of burning while a fourth found that repeated burning in chaparral reduced average infiltration by ninety-five percent (95%) (Gifford 1975b).

Runoff from high intensity rainfall on chained pinyon-juniper sites with debris left in place is less than runoff from natural woodland sites (Gifford 1975a). However, runoff from pinyon-juniper sites chained with debris windrowed can be expected to exceed that from natural sites.

Rehabilitation of damaged rangelands at Cornfield Wash, New Mexico (Burkham, 1966) was tested using various land treatment practices; reservoirs, gully control sturctures, wire sediment barriers and rangeland pitting. Some improvements could not be evaluated because of inadequate data, however, the reservoirs were effective in reducing sediment accretion upstream. In addition, the advance of abrupt headcuts below the structures was stopped and flood peaks reduced.

In Arizona, several small experimental watersheds were established in chaparral on the Tonto and Prescott National Forests. Brush cover was eradicated by various techniques including herbicides and fire -- the effects on streamflow, erosion, and other values were studied (Hibbert, et al, 1975). Based upon this research, the average increase which could be expected at downstream reservoirs or points of use is 2.4 inches of water per acre treated. Initially, nitrate concentrations in streamflow increased from 0.2 to as high as 56 ppm (Hibbert et al., 1975), and then gradually declined to near pretreatment levels during dry periods. Herbicides used in brush control were detected in low to moderate concentrations in streamflow immediately below the treated watersheds (picloram, fenuron).

In the oak woodlands of the California annual grasslands Lewis (1968) chemically treated dense oak and brush to increase forage. Steamflow increased and evapotranspiration decreased 4.5 and 5 inches/year, respectively.

Conversion of woodland types to grass may result in minor changes in runoff. In the pinyon-juniper type in Arizona, Collings and Myrick (1966) found a slight increase in runoff from the treated watershed compared to the untreated control basin but concluded that the increase could have been due entirely to chance. Replacing Utah juniper with grass at Beaver Creek, Arizona resulted in a 10 percent increase in runoff; however, this was not a statistically significant increase (Wilm 1966).

Rangeland treatments which change the vegetal subtype or modify the plant cover on a watershed may result in a corresponding change in rainfall-runoff relationships. These treatments include burning, chaining, and other types of vegetation conversion. When annual precipitation is less than 40 centimeters (16 inches), increase in water yield resulting from a treatment is likely to be less than 5 centimeters (2 inches). However, the efficiency of vegetation conversion for increasing mean annual runoff improves with increased mean annual rainfall, at least up to 86.7 centimeters (34 inches) (Hibbert et al., 1975). (Figure 3).

Mechanical treatments of soil which are designed to enhance soil water by reducing surface runoff also change rainfall-runoff relationships. Such treatments include ripping, contour furrowing, contour trenching, pitting and other cultural practices. Effects of such practices are usually greatest immediately following application but tend to decrease with time. Hickey and Dortignac (1964) found that surface pitting on easily eroded shale-derived soils in New Mexico caused reductions of 12 to 24 precent of surface runoff and 16 percent in erosion the first year after treatment. At the end of 3 years, surface runoff was reduced only 10 percent and erosion was about the same from treated and untreated plots. Dortignac and Hickey (1963) and Hickey and Dortignac (1964) found that ripping of shale-derived soils in New Mexico reduced surface runoff 96 percent and erosion 85 percent the first year after treatment. Three years after treatment, reductions were 85 and 31 percent, respectively for runoff and erosion. Contour furrowing was found to be effective in reducing runoff and increasing perennial grass yields (Branson, Miller and McQueen, 1966). Furrow effectiveness decreases over time but studies in Montana and Wyoming found an effective life of 35 years (Branson et al., 1978).

In arid and semi-arid rangeland, the major factor influencing sediment, bacteriological and nutrient loading from the soil surface is volume and timing of overland flow. It is through this link that rangeland management affects wildland water quality.

Gifford's (1957b) review on some aspects of range improvement practices showed that such measures are not all beneficial from a runoff and sedimentation standpoint. Some measures which often result in an increase of erosion and sediment yield are chaining of pinyon-juniper, plowing and improper burning practices. Most investigators that have assessed the hydrologic impact of rangeland improvement practices looked at only sediment as a water quality barometer.

Summary

The process of water infiltration generally is decreased or unaffected by rangeland treatments. Severe mechanical disturbance will generally adversely affect infiltration rates. The question of whether or not an improvement practice will produce more runoff depends upon the composite of such responses as infiltration, soil water depletion patterns, plant interception and storage changes. It is impossible to generalize on the runoff changes expected.

Contour trenching and furrowing may be expected to cause decreases in water yield, as measured by watershed runoff. Runoff response to vegetal conversion will depend on community type and structure, plant cover and the rainfall regime. The efficiency of vegetation conversion for increasing mean annual runoff improves with mean annual runoff, as seen in Figure 3. Conversion of deep rooted plants to shallow rooted plants also increases runoff.

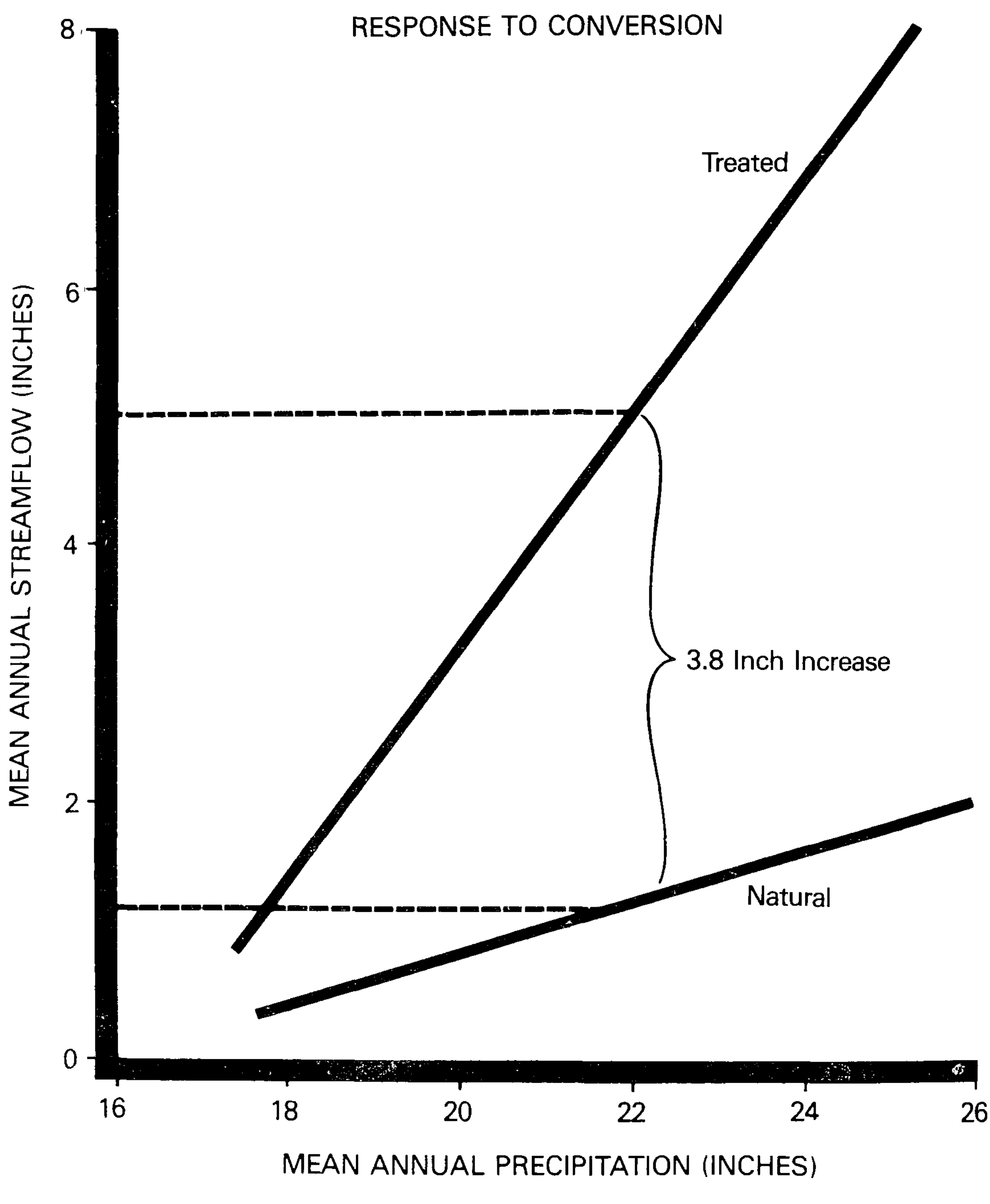

FIGURE 3 AVERAGE WATER YIELD FROM NATURAL AND CONVERTED CHAPARRAL AS A FUNCTION OF PRECIPITATION. DIFFERENCE IS ATTRIBUTED TO TREATMENT. (HUBERT, DAVIS, AND BROWN, 1975)

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GRAZING MANAGEMENT AND AQUATIC HABITAT

General

Many researchers over the past few decades have addressed the livestock grazing/fishery/wildlife resource problem. Impacts on spawning and general habitat have been related to livestock grazing and other sources of disruption by Behnke and Zarn (1976), Borovicka, Culbertson and Jeppson (1975), Duff (1977), Gunderson (1968), Lewis (1969), Marcuson (1977), Page and Collins (1974), Platts (1977), and the BLM Nevada study (1975). Impacts on food type and abundance have been studied by Duff (1977), Haugen (1977), Platts (1977), and others. Impacts on water quality and quantity have received study from Claire and Storch (1977), Cordone and Kelley (1961), Duff (1977), Meiman and Kunkle (1967), and Page and Collins (1974). Grazing impact evaluation and prediction techniques have been explored by Duff and Cooper (1976) and Cooper (1977) and are discussed in more detail in the chapter on problem assessment. Platts (1977) presents an excellent review of the above referenced literature plus additional references.

Armour (1977) summarized the concerns of fisheries biologists regarding fishery habitat loss resulting from "improper" livestock management. Some biologists also express concern over rest-rotation grazing systems. For example, Platts and Rountree (1972), Behnke (1976) and Johnson (1976) view one year rest-rotation grazing systems as insufficient to protect or restore woody and herbaceous riparian vegetation. Studies by Duff (1977), Glinski (1977), Marcuson (1977), Winegar (1977) and others substantiate need for a rest period approaching five years--and even this appears somewhat optimistic in many cases.

Carothers et al. (1974), established the strong relationship between riparian vegetation removal and breeding bird use. Hubbard (1971), Johnson and Simpson (1971), and Anderson and Ohmart (1977) have documented the inordinately high use by various avian groups of this particular habitat type. In addition to the above, many other researchers have documented the riparian habitat importance to avian and mammalian organisms in the publication, "Importance, Preservation and Management of Riparian Habitat", USDA, Forest Service (1977).

In addition to the above references specifically oriented to livestock grazing and riparian zone resource problems, other literature from such activities as forest harvest and roadbuilding also identifies impacts on the aquatic habitat due to siltation and loss of streamside cover.

Tagart (1976) demonstrated a strong negative correlation between salmonid survival-to-emergence and gravel permeability in gravels with a high percentage of particle composition less than 0.850 mm in size.

Shelton and Pollock (1966) demonstrated salmon egg mortalities of 85 percent when 15 to 30 percent of spawning gravel voids were filled with sediment. Koski (1966) also demonstrated that the percentage of fine sediments in spawning gravel had a strong inverse relationship to salmonid egg and fry survival. Phillips (1971) listed effects of suspended and settleable solids (sediment) as determined by field research. Fine sediments not only produced anoxic conditions and interference with removal of metabolites (carbon dioxide and ammonia), but also reduced escape cover and available food supply required for survival of emerging fry. Gammon (1970) observed that both fish and macroinvertebrate standing crops were severely depressed in response to increased sediment loadings. Moring (1975) demonstrated a direct relationship between reduced salmonid populations and various altered environmental parameters including elevated summer water temperatures and depressed intragravel dissolved oxygen levels in a stream where riparian vegetation had been removed during clearcutting. A significant increase in sedimentation was also observed. Burns (1972) observed a water temperature increase of 20°F following riparian canopy removal during road construction. Chapman and Bjornn (1969) also observed that many young salmonids overwinter in the stream substrate when temperatures fall below about 5°C and that riparian vegetative cover (insulative protection) is therefore extremely vital to survival. McNeil (1966, 1968) in studying reproductive success of salmonids, observed that certain spawning bed environments effected by logging activities caused significant spawning-to-emergence mortality. Low streamflows in summer caused depressed intragravel dissolved oxygen and winter fluctuating flows caused mortality due to freezing. Sheridan (1961) also concluded that riparian vegetative cover could be instrumental in preventing freezing of intragravel eggs during cold "open" winters, i.e., with little snow cover insulation.

Skovlin and Meehan are three years into a five-year study entitled "The Influence of Grazing on Riparian and Aquatic Habitats in the Central Blue Mountains," in northeast Oregon (personal communication - Skovlin). One of the principal elements will be the evaluation of the effects of grazing management strategies on fish populations. In addition to studies on watershed and soils characteristics and water quality and quantity, the project also addresses impacts by big-game, benthic fauna density and diversity, streambed sedimentation, and herbaceous and woody vegetation production and utilization. Results should be directly applicable to selection and evaluation of BMP's.

A study being initiated by the BLM in Utah will inventory riparian vegetation and aquatic biota and establish a grazing system/exclosure monitoring program in conjunction with the Hot Desert Environmental Statement (ES) in SW Utah. The proposed three pasture rest-rotation system will be monitored utilizing riparian zones along with some vegetation recovery/exclosure studies and fisheries/water quality studies in selected riparian reaches (personal communication - Duff).

Thomas, Maser and Rodiek point out in a draft report entitled "Riparian Zones" that the riparian zone is the most critical wildlife habitat in southeastern Oregon and that, of the 350 terrestrial wildlife species occurring in the area, 281 are directly or significantly dependent on this zone (personal communication - Thomas).

The Rocky Mountain Forest and Range Experiment Station, Tempe, Arizona, is one year into a three-year study addressing management and stewardship problems of riparian habitat in southwestern national forests. "Reducing the impacts of cattle grazing...", "classification, restoration and management...", and "habitat requirements, biology and distribution of native...trouts" within/of the riparian zone are the principal study areas (personal communication -Clark).

A cooperative ten-year study involving private (Saval Ranch), BLM and Forest Service lands is scheduled to begin this year in Nevada (personal communication - Platts). Nevada Fish and Game will initiate the wildlife inventories this summer. The Science and Education Administration* will conduct hydrologic studies and soil and vegetation inventories in 1979. Exclosures, both upland and riparian zone, will also be constructed. In 1980, after study and evaluation of the data and conducted inventories, a grazing management system will be designed and implemented and the methodology prescribed for measurement of grazing effects.

The principal conclusions derived from review of state-of-the-art references are that:

1) Severe damage to riparian wildlife and fisheries habitat often results from riparian zone activities such as livestock grazing.

2) The riparian zone is a critical habitat during some life stage for a very high percentage of the species inhabiting a given geographic area.

3) In most cases good livestock management alone is not adequate to protect riparian fisheries and wildlife habitat from severe damage.

4) Of the livestock grazing management techniques available for riparian habitat protection, only riparian zone fencing appears capable of certain protection.

5) It is not economically feasible to fence all riparian habitat on livestock grazing lands.

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*previously the "Agricultural Research Service"

6) Riparian habitat protection, the inventorying of critical riparian habitat types and prioritization of specific streams and/or stream reaches to be protected must be accelerated.

7) Streams and/or stream reaches characterized by unstable soils and a fragile but diverse vegetative community should receive urgent consideration for fencing.

8) Streams and/or stream reaches characterized by comparatively stable soils and vegetation should initially receive protection via BMP's other than fencing - with follow-up by a strong monitoring and BMP evaluation effort.

There are many ongoing research efforts that should yield guidance, recommendations and conclusions leading to a resolution of the riparian zone problem. The following recommendations are supplemental to current research. Some of these recommendations are in part being implemented, or are ongoing under various state or federal agencies.

Recommendations Supplemental to Current Research

1. Establish rankings on riparian reaches based on vegetative, wildlife and fishery/macroinvertebrate potential for the purpose of identifying BMP's and prioritizing their implementation.

An important first step in prescribing and defending riparian management decisions is the development of a system for describing and classifying riparian habitat and site potentials. "Recognizing the site potential prior to developing the management program will aid in achieving desired streamside goals and focus efforts on areas where maximum results can be obtained" is suggested by Claire and Storch (1977).

If all streams within a given area were ranked based on a) aquatic insect/fishery potential b) vegetation recovery and establishment potential, or c) wildlife potential it is conceivable that high, medium and low protection priority streams could be designated and receive protection based on the above resource potential. Complicating factors within the drainage such as competing water use (irrigation diversion, subsurface withdrawal, flow regulation), timber harvest, mining activities, etc., must be considered if a valid ranking of riparian habitat potential is to be achieved.

Until the vegetative, wildlife, or fishery/macroinvertebrate potential of streams are determined and ranked throughout an area the implementation of riparian protection BMP's will be questioned and open to unnecessary criticism.

Where undisturbed "control" streams, wilderness streams, National Park streams, etc., are not available to demonstrate or establish riparian zone biological potential, stream exclosures should be used. The potential must be identified to accurately predict and assess the benefits from the improvement program.

2. Initiate the planning and implementation of density and diversity benchmark inventories of vegetation, wildlife and instream fauna to facilitate evaluation of selected BMP's.

Most range managers, specialists, and researchers agree that each grazing allotment must receive site specific evaluation and prescription of BMP's, i.e., combinations of grazing systems and range improvements, etc., and that no BMP will handle all situations. Controversy arises when considering how widely applicable a largely research derived BMP should be. The BMP's proposed initially may be an interagency cooperative effort "best shot". It will then be up to the resource agencies' physical and biological scientists to evaluate and recommend change as needed. Benchmarks of present riparian flora and fauna and critical habitat are essential and must be a first priority before implementation of BMP's. BMP's cannot be rationally evaluated or justified unless based on a benchmark biological inventory.

The determination as to which inventory parameter or combination of parameters should be benchmarked, will be largely dependent on the projected highest and best use of the riparian zone in question. If the highest and best use is determined to be fishery then either the fishery or aquatic macroinvertebrates should be selected. If wildlife, avian use is determined to be highest and best use then a vegetation benchmark should be considered. The vegetation benchmark should also be used when livestock grazing is determined to be the highest and best use. The classification of riparian vegetation in the southwest is being refined by Pase and Layser (1977), Pase (1977), Dick-Peddie and Hubbard (1977) and others such as Brown and Lowe (1974) and Pfister and Arno (1977). The classification may be modified for use in many areas.

The State of Arizona is producing a riparian habitat inventory and mapping process through multiple agency efforts in delineation of perennial stream and wetland resources (Brown, Carmony and Turner, 1977).

3. Establish an information and data center oriented to grazing/riparian biota research completed, current and proposed. Archive, catalogue, and track research and field studies and supply requested information.

Many universities, state agencies, interest groups, etc., are realizing the benefits from central data and information efforts. A few of the benefits are 1) greatly reduced duplication of effort, 2) improved intra- and inter-disciplinary communications, 3) the creation of a forum through which projects and concepts can be supported, 4) the creation of a unified, cohesive interest group or body of experts which carries considerably greater political and professional impact, and 5) providing a mechanism by which future research could be directed or ongoing research redirected.

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WATER QUALITY PROBLEM IDENTIFICATION AND ASSESSMENT

Problem Identification

One of the major problems of assessing water quality impacts from grazing and other nonpoint sources of pollution is the lack of adequate criteria. As indicated in the Introduction, the Federal Water Pollution Control Act, as amended, established a national goal wherever attainable of water quality that provides for the protection and propagation of fish, shellfish and wildlife and provides for recreation in and on the waters by July 1, 1983. Therefore, the basic framework for problem identification is established. However, the national goal has not been quantified in terms of water quality criteria.

Considerable information is available on criteria and techniques for evaluating soil erosion problems and impacts on vegetation from grazing. Soil surveys, various watershed evaluation and rating systems and several range condition survey techinques are used to evaluate soil and vegetation conditions on rangelands. The relationship of this information to water quality is often by subjective inference without any cause and effect or statistical basis.

The purpose of this section is to present the considerations that should be built into water quality assessments related to grazing, and to summarize the documented water quality assessment techniques related to aspects of range management.

Water quality impacts of grazing are associated with amount, duration and timing of runoff, erosion and sedimentation. All these factors are associated with vegetative cover. Sediment, turbidity, pathogens and nutrients are the major water quality parameters associated with range management. Water temperature changes associated with riparian vegetation, dissolved solids and the use of chemicals may also impact water quality. These types of impacts tend to be much more specific to channel and drainage area than runoff or suspended sediment. Sediment, pathogens and nutrient related problems are summarized in Chapter III.

It is difficult to determine and quantify beneficial and detrimental influences of grazing on runoff and erosion as related to water quality because of the complex interaction of many associated variables. Some of the inter-relationships involved in assessing grazing related impacts were illustrated by Smeins (1975). His concept is broadened to include water quality and is shown in Figure 4. Some of these inter-relationships may reduce the application of generalizations related to potential water quality impacts. This diagram is not all inclusive. Conservation programs or the application of Best Management Practices would reduce the water quality impacts.

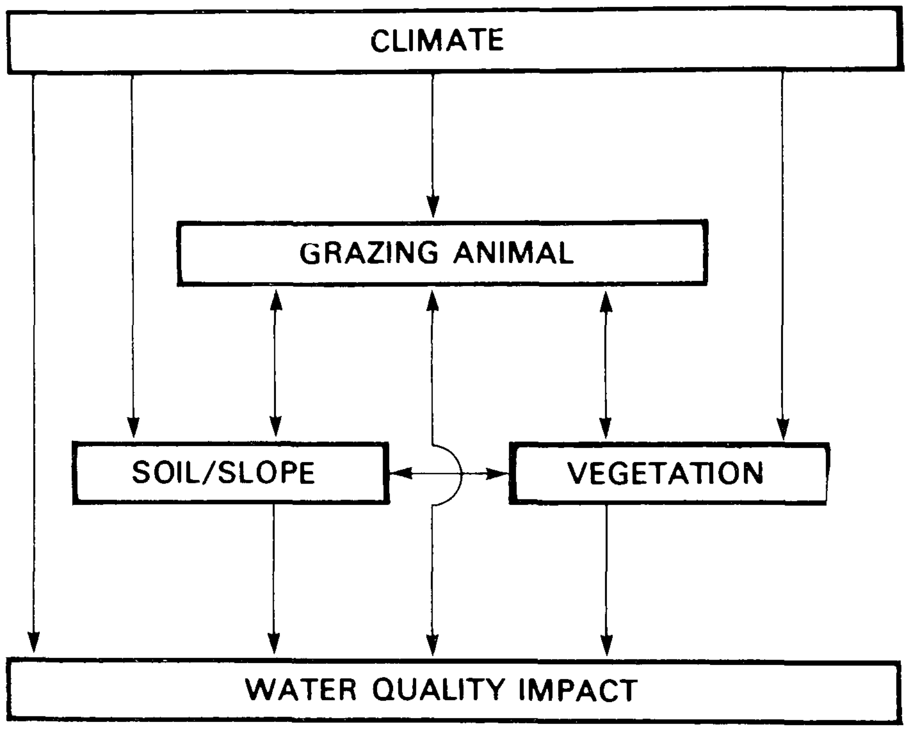
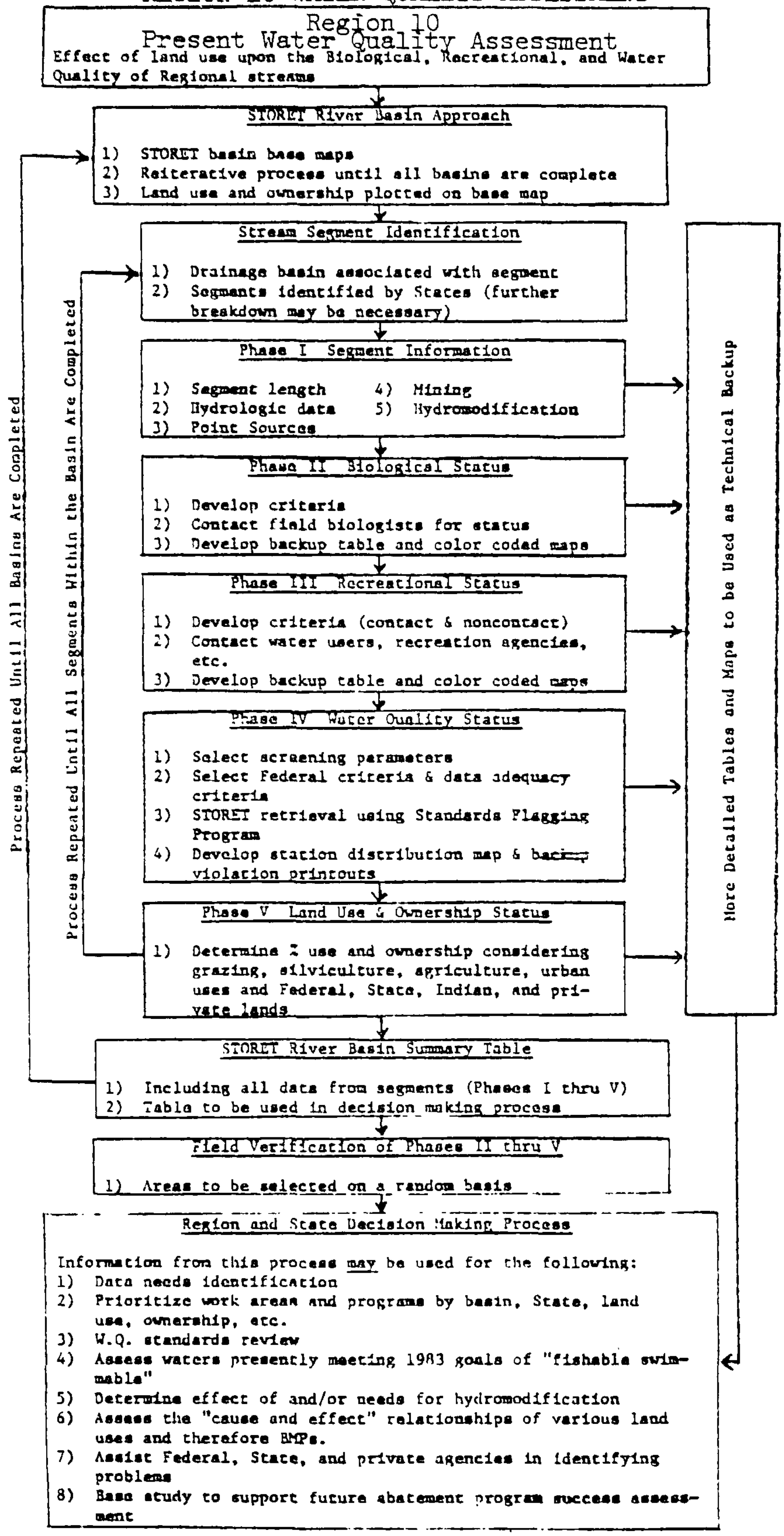


FIGURE 4 VARIABLES THAT INFLUENCE RUNOFF AND EROSION (MODIFIED FROM SMEINS, 1975)

FIGURE 5

REGION 10 WATER QUALITY ASSESSMENT



The field biologist utilizes the following evaluation matrix in determining stream segment status classification.

BIOLOGICAL EVALUATION CRITERIA

TABLE 4

CRITERIA FOR BIOLOGICAL EVALUATION / TIME & SEVERITY FACTORS	Duration of Adverse Condition			Severity of Adverse Condition			Period of Biological Activity	
	NEVER	INTERMITTENT	CONTINUOUS	LOW		HIGH	NON-CRITICAL	CRITICAL
I. Destruction of habitat for indigenous species - passage, spawning, rearing.	Blue →		Red	Blue →		Red	Blue/Yellow	Red
II. Interuption of total food chain	Blue →		Red	Blue →		Red	Yellow	Red
III. Interference with the well being of indigenous species of fish or food chain organisms.	Blue →	Red	Red	Yellow →		Red	Red	Red

NOTE: The color-code (blue, yellow, and red) is used on the maps (see slides).

On the summary tables, a pattern-code was used to allow for easier duplication.

Therefore:

Blue corresponds to:

Yellow corresponds to:

Red corresponds to:

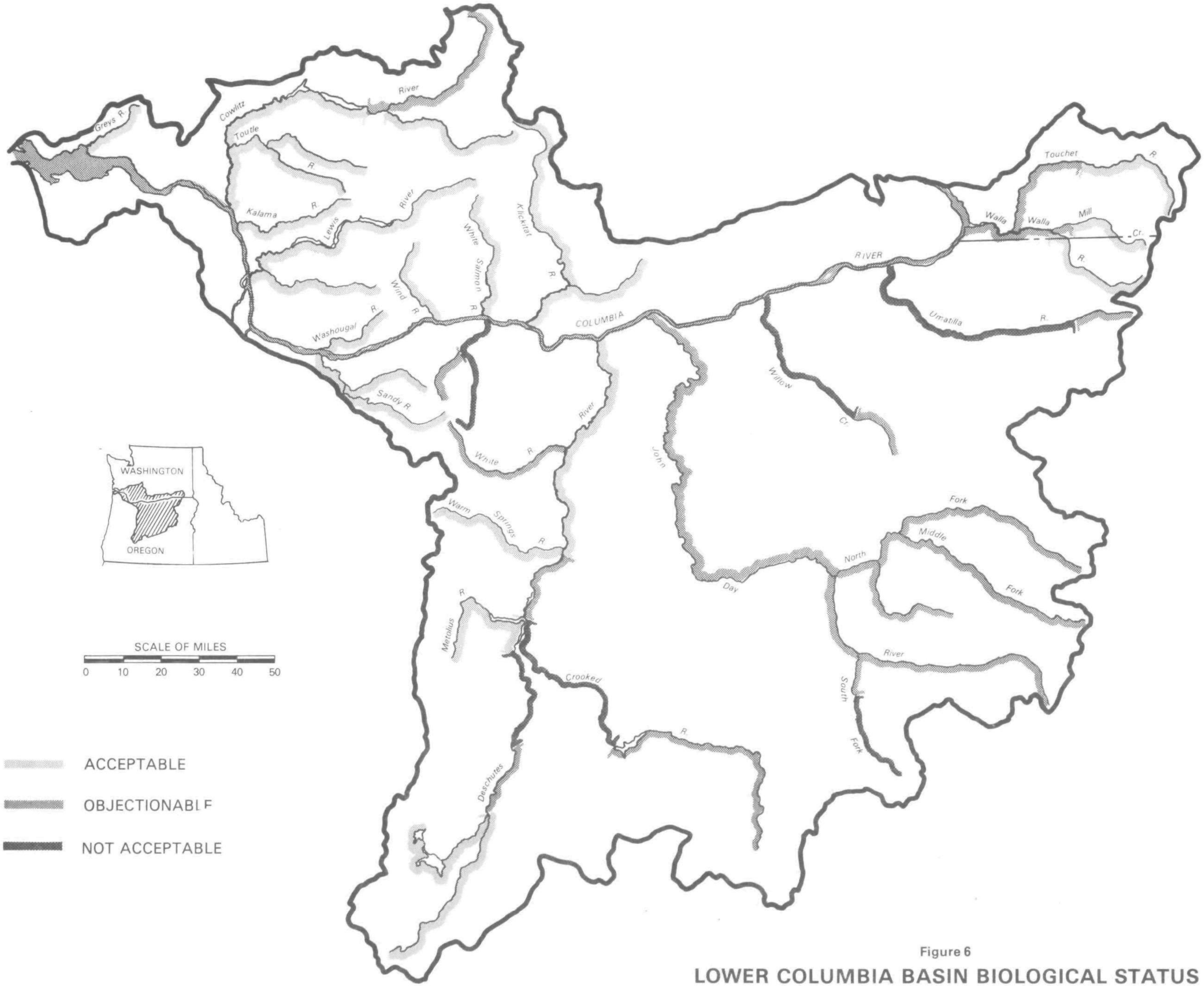


Figure 6

LOWER COLUMBIA BASIN BIOLOGICAL STATUS

(GENERALIZED)

TABLE 5
BIOLOGICAL STATUS
River Basin Name Columbia River

Contact: Errol Claire, Oregon Fisheries & Wildlife Commission, Canyon City

Recorder R.A. Wagner Date 8/23/76

STREAM NAME	STREAM REACH (River Mile)	SEG#	BIOLOGICAL CRITERIA: Destruction of Habitat – Duration	Destruction of Habitat – Severity	Destruction of Habitat – Importance of factor	Interruption of Food Chain – Duration	Interruption of Food Chain – Severity	Interference with Species Well Being – Duration	Interference with Species Well Being – Severity	BIOLOGICAL PROBLEM	BIOLOGICAL EFFECTS	STAT
Streams north of Columbia River in Washington from Kennewick to Goodnoe Hills	Various	14-31 -01	C	H	Yes	C	H	I	H	Overgrazing, poor logging and land management practices, road construction, intermittent, uncontrolled runoff. Eurythermal oligotrophic streams. (No Biological Activity – Natural Condition)	Habitat loss, niche quality reduced. Adverse effects to biota because of scouring, temperature, silt, sediment, turbidity, and riparian loss due to bank erosion.	Obj
M.F. John Day source to mouth (confluence with N.F.)	32.3/ 76.2-0	JD-26 -01	C	H	Yes	C	H	C	H	Overgrazing; poor logging, water and land management practices; road construction; and intermittent uncontrolled runoff. Bank loss, scouring effects to stream bed in spring, low flow and high temperatures August thru September. Coarse fish buildup.	Same as above including drastic reduction for fish passage, spawning, and rearing.	Obj

S = Seldom
I = Intermittent
C = Continuous

L = Low
M = Medium
H = High

Acc = Acceptable
Obj = Objectionable
N.A.= Not Acceptable

Off-Site Impacts

The potential for water quality impacts from grazing managements and rangeland treatments are dependent upon storm characteristics and local hydrologic characteristics and conditions. Many grazing allotments of the West are drained by ephemeral streams with a few perennial drainages. Numerous small watershed studies have shown runoff events frequency to be of small amount and very irregular in the western portion of the United States. This is due primarily to low annual precipitation and flow losses in the normally dry streambeds. Porous soils, small scale storms, stream alluvium and very large evaporation deficits also contribute to the scarcity of streamflow. In many large watersheds, runoff is produced from only a portion of the area, in response to a high intensity, limited areal extent convective thunderstorm. Snowmelt runoff does not normally contribute an appreciable fraction of the runoff originating from lower elevations on semi-arid rangelands.

Forest land hydrologic response research, as it relates to vegetative manipulation, has been incorrectly extrapolated by some in the past to substantiate claims that vegetative manipulation of the lower elevation, more xeric rangeland communities will produce significant "improvements" in water yield and quality. Great dangers exist in transferring research findings from forested watersheds to lower elevation areas where storms, soil water depletion patters, climate and hydrology are much different than in the winter snowpack zones.

Generally it can be said, and has been frequently pointed out by Gifford (1975b), that the critical hydrologic concern on rangeland watersheds of the West is more efficient utilization of precipitation and soil water on-site, rather than any off-site or downstream concerns.

Where runoff has low potential to leave a site, land management treatments should be aimed at increasing water use efficiency. Follow-up monitoring should be along plot study, rather than small watershed lines, in these instances. Extremely large storms (50 year recurrence interval and greater) will be an exception. However, under such conditions storm characteristics dominate all local watershed and hydrology characteristics, and most generalizations become academic.

A very small portion of western grazing lands do have the potential for generating runoff from the more typical storms and transmitting them to a location where this is cause for concern. This sometimes occurs in areas which have been designated Critical Community Watersheds[1] by the Bureau of Land Management, because annual precipitation and snowmelt runoff is large. Steeper, shorter slopes and closer proximity to perennial streams is often characteristic.

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1 Considered by USDI , Bureau of Land Management , to be any basin which contributes 10 percent or more of a community water supply from public lands. Also qualifies if the basin has produces flood and sediment damages in excess of $1,000 per year in community damages.

Water Quality Standards

The water quality standards of the states in the west are related to water use classifications. The designated uses for which waters of the states are to be protected include, but are not necessarily limited to, domestic and industrial supplies, irrigation and stock watering, fish and wildlife, recreation and aesthetic qualities. The states have general and special standards for specifically designated waters. The designations may include lakes, streams, segments of streams, or river basins. Various classes related to uses such as AA, A, B and C are frequently used to identify specific bodies of water.

The criteria in water quality standards are related to classes. An example of some of the key criteria from state standards that may be affected by range management and livestock grazing are illustrated in Table 3.

Sediment and Turbidity. Sediment and turbidity are important parameters in municipal and industrial water supplies.

Turbid water interferes with recreational use and aesthetic enjoyment. Fish and other aquatic life requirements related to suspended solids can be divided into, those whose effect occurs in the water column, and those whose effect occurs following sedimentation to the bottom of the water body (EPA 1976a). Both effects impact water uses.

None of the existing water quality standards in the western U.S. include a sediment criterion. With sediment being the principal pollutant related to lifestock grazing and other nonpoint sources, the current standards are not adequate measures of water quality impacts from nonpoint sources.

Turbidity criteria are used in the state standards, some of the limitations of using turbidity as a measure of water quality impacts are (1) it does not relate to sediment concentrations the same for all streams, and is not a quantitative value, (making it difficult to relate it to erosion, per unit area or time); (2) it does not identify a particular size of water body of applicability; i.e., a first order stream has the same "limit value" as the Columbia River, etc.; (3) a uniform blanket criterion on some streams is too restrictive and on others, allows a significant adverse impact on water quality.

The suggested criterion (EPA 1976a) for solids and turbidity is that "settleable and suspended solids should not reduce the depth of the compensation point for photosynthetic activity by more than 10 percent from the seasonally established norm." The compensation point is the level at which incident light penetration is sufficient for plankton to produce enough oxygen to balance their respiration requirements. This suggested criterion is very difficult to use as a practical tool in water quality management.

Some of the major needs in developing useful water quality standards related to grazing and other nonpoint source pollution control programs are: (1) natural sediment production rates on ungrazed areas should be established for different plant communities on major soils, (2) plant communities must be better understood in relation to potential of soil loss and its effect on water quality, (3) a better definition of impacts due to grazing, associated with various plant communities and soil loss is necessary, and (4) establishment of sediment criterion for standards based on water uses.

Solids (Dissolved) and Salinity. Dissolved solids consist of inorganic salts, small amounts of organic matter, and dissolved materials. For most purposes, total dissolved salt content and salinity are equivalent. The principal inorganic anions dissolved in water include the carbonates, chlorides, sulfates and nitrates. The principal cations are sodium, potassium, calcium, and magnesium. Excess dissolved solids are objectionable in domestic and livestock drinking water because of possible physiological effects, unpalatable mineral taste and cost for treatment.

The suggested criterion (EPA 1976a) for dissolved solids in domestic water supplies is 250 mg/l for chlorides and sulfates. Studies (Soiseth, 1975, EPA 1976a) have indicated that cattle and sheep can survive on saline waters up to 15,000 mg/l of salts of sodoum and calcium combined with bicarbonates, chlorides and sulfates but only 10,000 mg/l of corresponding salts of potassium and magnesium. The approximate limit for highly alkaline waters containing sodium and calcium carbonates is 5,000 mg/l. Water uses as irrigation and industrial consumption have specific salt limitations.

Fecal Coliform Bacteria. Microbiological indicators have been used to determine the safety of water for drinking, swimming, and shellfish harvesting. As knowledge concerning microbiology has increased, so has the understanding of the complex interrelationships of the various organisms with diseases (EPA 1976a).

Bacteria of the coliform group are considered the primary indicators of water quality. The coliform group is made up of a number of bacteria, and have been associated with feces of warmblooded animals and with soil.

The suggested criterion for bathing waters for fecal coliform is "based on a minimum of five samples over a 30 day period, the bacterial level should not exceed a log mean of 200 per 100/ml, nor should more than 10 percent of the total samples taken during any 30-day period exceed 400 per 100 ml." Total coliform is not recommended as a quality criterion for water because of the difficulty of relating it to a source (EPA 1976a).

Many of the criteria in existing state standards are currently being revised as a result of the mandate of P.L. 95-217, Section 303(c)1. The states shall from time to time (but at least once each three years beginning in 1972) hold public hearings for the purpose of reviewing applicable water quality standards and, as appropriate, modifying and adopting standards.

TABLE 3

SELECTED PARAMETERS FROM STATE WATER QUALITY STANDARDS

State	Turbidity	Total Dissolved Solids mg/l	Fecal Coliforms #100ml
Arizona	10 JTU	quantitative/ambient level	1000
California	0-5 JTU 50-100 JTU[1] 20% above nat. NTU 10 JTU	quantitative/ambient level	50-200
Colorado	10 JTU/net/backgrd		200
Idaho	5 JTU above nat.		50[1]
Montana	10 JTU		200
Nevada	10 JTU max inc.	quantitative/ambient	200-1000[1]
New Mexico	10-50 FTU	1500-20,000	100-1000
Oregon	10% above nat.	500 mg/l max.	1000
Utah	-	-	2000
Washington	25 NTU increase/backgrd.	-	240-1000[1]
Wyoming	10 JTU max increase/backgrd.		200

Footnote
1 - Depends on body of water

Water quality criteria and standards are not synonymous. Criteria are constituent concentrations associated with a level of environmental effect upon which scientific judgments may be based. Criteria usually refer to designated concentrations of constituents that, when not exceeded, will protect an organism or water use. Standards are legally enforceable requirements for water dischargers. Water quality standards may be based on stream reaches or effluent levels. Standards may differ from criteria because of local natural conditions, economic considerations or the degree of protection desired for water uses. The objective of revision of current standards is to update them to reflect new knowledge or considerations related to water uses

Predicting Impacts

Monitoring Nonpoint Sources of Pollution

Water quality monitoring of various types of nonpoint source activities as forestry, agriculture and livestock grazing are increasingly becoming an activity and responsibility of resource managers. Better water quality data is needed on range management practices such as quantification of impacts associated with various seasons of use, intensities of grazing, cattle distribution, range condition and range improvements.

This section presents an overview of some important aspects of water quality monitoring relative to nonpoint sources of pollution. The emphasis is on rangeland practices; however, many of the concepts presented apply to other nonpoint sources of pollution. The discussion is not intended to develop a how to do it approach, or solve the many contemporary problems associatd with various aspects of water quality monitoring. It is intended to emphasize some to the fundamentals and complexities involved in monitoring related to such nonpoint sources of pollution as livestock grazing and rangeland treatments. The EPA (1976b) document outlines the details for establishing a water monitoring program.

Some to the common needs for water quality monitoring are to: (a) evaluate the presence of pollution; (b) define causes or sources of pollution; (c) evaluate data for development of assessment of preventative measures; (d) determine the natural background quality of water in the watershed, and to be able to distinguish between natural and man-caused sediment, bacteria and other water quality parameters in a system of extreme variablility; and (e) document or enforce the application of BMP's as designed by state or areawide 208 plans.

Livestock grazing has short-term impacts during and immediately following use of an area and generally decreasing long-term impacts if grazing is not continuous. The major pollutants are eroded mineral sediments, associated salts , and bacteria. Significant localized pollution problems can be caused by pesticides and nutrient elements (principally nitrogen and phosphorus) from soils, plant and animal matter, and fertilizers.

Some important aspects of nonpoint source monitoring that must be recognized in developing a monitoring system are: First, that sediment is the most significant pollutant from nonpoint sources on rangelands in the Western States and secondly, that stream systems naturally produce sediment during certain periods.

Biological monitoring may be especially appropriate and useful in assessing impacts from grazing related activites. The protection and continued propagation of aquatic life is a good indication of water quality. This was recognized in the declaration of goals and policy, 101(a) of P.L. 92-500, which stresses the need to restore and maintain the biological integrity of the nation's waters. Aquatic organisms are very efficient pollution monitors, because they integrate the effects of water quality over periods of time and reflect impacts that may not be detected by using only chemical parameters in monitoring.

Biological monitoring is defined in Section 502(15) of P.L. 95-217 as "the determination of the effects on aquatic life, including accumulation of pollutants in tissue, in receiving waters due to discharge of pollutants." The requirements for a basic minimal ambient biological monitoring program are outlined in a document by EPA (1976b).

The principal communities of aquatic organisms used in biological monitoring are identified and described in the EPA (1976b) reference. It is emphasized that the properties useful in determining the condition of aquatic communities include: (1) abundance (count and biomass), (2) species composition and diversity, and (3) metabolic activity. The basic biological monitoring program described below is designed to provide information on (1) the trophic status of lakes, reservoirs, and estuaries, through the use of plankton chlorophyll as an algal biomass (productivity) index, (2) the biomass (productivity) and taxonomic composition of the periphyton, which is a lower-food-chain-level producer community, (3) the abundance and species composition of the macroinvertebrates, which form an intermediate-food- chain-level consumer community, and (4) accumulation of toxic substances in fish and shellfish, which are upper-food-chain-level organisms.

The parameter list, sampling season, frequency and method for each hydrologic area, and the rationale for measuring various parameters are outlined in EPA (1976b). Much of the above discussion indicates the limited value of general prescription approaches to monitoring nonpoint sources. Monitoring activities should be designed for predefined purpose.

Monitoring should normally be limited to those parameters most likely to be significantly affected by grazing and related practices. As indicated, the most significant parameters may be sediment, salts and bacteria. Temperature, nutrients, and chemicals such as pesticides and fertilizers may require monitoring in special situations. Stream flow should also be measured to assist in interpreting water quality data.

The sampling frequency for chemical, physical or biological monitoring must be carefully established so that all the ranges of water quality experienced from grazing and related practices are observed. Monitoring schemes must be built on knowledge of how and when the pollutant is likely to be produced. For example, it is known that sediment enters streams primarily during storm events. It is also documented that bacteria has the greatest potential for entering streams during and immediately after rainfall and runoff. The first major rainfall runoff event of the "season" will generally contain the highest number of bacteria. For water temperature monitoring, the sampling should be geared to diurnal variations, as well as seasonal and annual variations.

Sampling Approaches

Among those factors which should be assessed in selection of sampling approach are: expected water quality effects; desired accuracy and precision; laboratory expense and certification requirements; area hydrology; climatology; seasonal variations; and state water quality standards.

Long-Term Monitoring. This type of monitoring is designed to establish representative water quality and document seasonal and year-to-year fluctuations. The monitoring stations should be on major drainages within a watershed to adequately represent the combined effects of all activities within a drainage. The information will give an overview of the quality of water within the source area.

Many long-term monitoring stations already exist and are operated by the EPA, U.S. Geological Survey, U.S. Forest Service, Science and Education Administration, State agencies and universities. In special interest areas such as municipal watersheds or water bodies used for primary contact recreation, if grazing occurs over a period of time, it may be desirable to establish long-term stations to document water quality impacts. The information may be used in developing preventative and corrective measures.

Project Monitoring. This type is designed to monitor project activities before implementation (to establish a calibration), during implementation (to establish the effect of the activity on quality) and after implementation (to establish time frames for return to pre-disturbance conditions).

These short-term monitoring stations should be located near activities to be assessed. The paired-station approach, one station upstream and one station downstream, is the most convenient and conventional. It is appropriate for monitoring practices such as mechanical land treatments, and grazing in riparian areas. The shortest possible time should occur between sampling the two monitoring stations.

The potential limitations of the paired-station approach are (a) in-situ changes in pollutant concentration due to past natural--or--man caused activities; (b) locating downstream stations to insure adequate mixing, yet avoiding unrelated pollutants from instream areas; (c) the approach does not indicate the frequency of changes or their meaning at water use points; (d) in order to achieve any degree of statistical significance in the sampling procedure a number of samples will be required. In addition, it may not be possible to utilize this technique in certain instances. Many small watersheds, where monitoring is desirable, occupy a position in the upper reaches of a drainage system. It may not be possible to establish a station upstream and downstream of an activity in such a situation where a stream originated within the activity area.

It is essential to understand the limitations and applications of any monitoring approach prior to its use. Recognizing its limitations, the paired station approach is still appropriate for monitoring livestock grazing and related practices in many instances.

The technique of paired watershed analysis may also be used in monitoring livestock grazing activities. This method entails concurrent climatological and hydrologic measurements on two similar (but not necessarily identical) small "experimental" watersheds for pretreatment and post-treatment periods. Five years is often cited as the minimum length of the pretreatment calibration period. This time is necessary to show that differences in evaporation, storage changes, and leakage between the two basins are constant, but not necessarily equal. Following treatment, runoff levels on the treated basin are computed based upon the control watershed's mearsured runoff, and observed differences in precipitation, and the constant sum of evaporation, storage and leakage differences. This estimation then allows a series of statistical hypothesis testing on the differences between the treated watershed's observed vs predicted response values. Thus, the control element of the pair is employed to estimate what the true runoff would have been on the treated basin in the absence of the treatment, and in consideration of any differences between the two in precipitation, storage changes, evaporative and leakage losses.

This method has received criticism over the years by university and agency researchers. However, the alternatives proposed (e.g., modeling) are often aids rather than substitutes for watershed experiments, as pointed out by Hewlett, Lull and Reinhart in 1969. The technique is more applicable to assessing water quantity rather than quality conditions.

The effects of land uses such as grazing and rangeland treatments on water quality may be approaced via several analytical techinques. These include: similar area comparisons, "before and after" analysis, "above and below" analysis and graphical plotting techniques.

Good information can provide a more defensible basis of identifying problems and assessing the effectiveness of various water pollution control measures, including the application of Best Management Practices for range management.

Hydrologic and Water Quality Modeling

The nature of the problem associated with impact predicting from nonpoint sources is illustrated by the following quote from a recent report funded by EPA (1976c) on Loading Functions for Assessment of Water Pollution from Nonpoint Sources. "The rates and magnitude of discharges of pollutants from nonpoint sources do not relate simply to source characteristics or source-related parameters. Evaluation of the severity of this problem is hampered by lack of tools to quantify pollutant loads, and scarce and imprecise data on the interrelationships between control measures and pollutants loads. This is also a deterrent for formulation of control or regulatory strategies." This is one of the principal limitations in developing a sound control program for range management practices.

The Loading Function Handbook presents a number of mathematical expressions that may be used to calculate the discharge of a pollutant from a nonpoint source into surface waterways. The document also presents some of the needed data and suggest methods of acquiring data when available data are inadequate. The document covers a variety of nonpoint sources with many of the functions having limited or no application to predicting impacts from range management.

Present concern for quantitative approximations of what happens to the precipitation which falls on rangeland watersheds cannot be totally addressed by monitoring and field data collection. Very often constraints dictate a computational approcach which is dependent upon a mathematical conceptualization of the actual rengeland environment; i.e., a model. The whole area of modelling is reviewed in detail in other sources, for example Riley and Hawkins (1976), Lombardo (1973), Grimsrud et al (1976), Branson et al (1978) and U.S. Forest Service and EPA (1977).

Before nutrient, sediment and other pollutant transport processes and outputs from rangeland watersheds can be realistically simulated, the basic watershed hydrology must be understood and accounted for. A water quality model which fails to account for these hydrologic processes (precipitation input, infiltration, slope runoff, deep percolation) is not sound. These basic hydrologic processes determine the streamflow response from a source area. Streamflow is the prime carrier of pollutants from rangelands and is often highly correlated with concentrations and total discharge of pollutants.

A state-of-the-art document on Nonpoint Water Quality Modeling in Wildland Management (USFS, EPA 1977) indicates that although surface erosion models exist, most have originated from the approaches of Musgrave (1947) or the Universal Soil Loss Equation (USLE) of Wischmeir and Smith (1965) developed for cropland. These basic equations with modifications have been used to predict erosion of forest and rangelands (Anderson 1969 and Dissmeyer 1973). The techniques are most useful in comparing before and after conditions rather than the absolute values obtained.

Phillippi and McCool (1978) have developed a range ecosystem evaluation method based on the universal soil loss equation (USLE). Modifications of the "R" factor (rainfall and runoff) and LS (topographic effect) were necessary to apply the USLE to northwestern rangelands. The USLE has been applied to rangeland watersheds as a management tool. Results have been good according to the author's evaluation, but they indicate a need for further evaluation and research. Research currently in progress should improve the validation of the USLE for predicting soil loss from rangeland ecosystems.

No modelling technique, regardless of type, should be applied until serious consideration is given to the evaluation objectives, the quality of data and the model(s) assumptions and limitations. Many users find a need to modify segments to better correlate output required with available input data. Users should constantly "tune" the potentially usable model in view of new research results, new concepts and techniques. A big advantage to the use of models in rangeland evaluations is their diagnostic value.

Usable models are very scarce. Many are unrealistic, have large calibration data requirements, and associated problems. Almost any new modelling effort on chemical, sedimentation, and bacteriological characteristics of runoff waters from grazing system trials or rangeland improvements would be useful, providing that the work is based on a sound integrated approach to predicting water quality changes associated with rangeland practices.

Three basic steps for evaluating the impacts of livestock grazing on water yield and quality have been proposed by Green (1977). The steps which involve several applications of modelling are:

1. Determine the distribution of livestock within the watershed or allotment of interest (by acres in given grazing intensity classes and vegetative types). Grazing intensity is found as a function of forage production minus utilization biomass. Next, a regression model is needed which estimates livestock grazing intensity for all pastures within any grazing system.

2. The second step is to evaluate the statistical relationships of grazing intensity to infiltration and sediment production within homogeneous phase of soil series and vegetative units. The model used in this step would have a physical component (rainfall simulator) and various statistical components designed to evaluate probability distributions.

3. Step three is evaluation of the off-site hydrology, based on the on-site hydrology process analysis of the previous step. This requires a precipitation-infiltration-runoff model (deterministic).

In summary, the state-of-the-art for using models in range management suggest: (1) there is a need for baseline data in model development and validation; (2) the normally high variablity or "noise"in the system may completely mask any measurable statistical impacts that grazing may have;

(3) models should be validated under field conditions; (4) model accuracy, even with proper validation, may be off by from five to one hundred percent or more, depending on the time scale and input data; and (5) the user of any model must be familiar with the assumptions and conditions under which the model was derived.

Water Quality Assessment Approaches

There are a number of techniques available for assessing resource problems related to range management. As indicated, most techniques are related to soil and vegetation conditions. Three water quality assessment approaches are summarized that may be used in relating livestock grazing and land treatment to water quality management. The approaches are: (1) EPA Region X's procedure; (2) Panhandle National Forest's Method; and (3) BLM's Hydrologic Evaluation system.

1. Assessment Approach 1 - EPA Region 10's Water Quality Assessment

One of the difficulties in developing control programs for nonpoint sources that meet water quality goals is the lack of quantification or qualification of the fishable-swimmable concept. Region 10 of EPA developed a water quality assessment approach to assist EPA planners, land management agencies, state and local agencies in identifying probable nonpoint sources of pollution and assessing their general effects upon the fishable-swimmable aspect of regional streams.

The approach is based on displaying existing information related to biological, recreational and water quality status of regional streams. This information is related to land use, land ownership, hydromodification, flows and point source discharges. The information is systematically organized on a summary table for use. A flow chart outlining the assessment procedure is presented in Figure 5.

STORET basin maps are used as base maps for all evaluations. Biological status information is obtained from field biologists representing state and federal fish and game agencies. Their assessment is based upon the criteria shown in Table 4. The biological and recreational status are shown in Figures 6 and 7. Recreational status is obtained from field biologist, recreational specialist, fishermen and swimmers utilizing the criteria in Table 5.

Water quality station locations in each segment are also displayed during the assessment. The STORET data system was used as a basis for all water quality information. Most state and federal agencies and many local agencies and universities store data in the system in Region X. Data were retrieved utilizing the STORET standards flagging program with EPA's Water Quality Criteria (EPA 1976a) as the threshold levels.

Figures 8 and 9 show land use and land ownership of the basin. This information is from an inventory by the Pacific Northwest River Basin Commission. All information is summarized on River Basin tables as illustrated in Table 6. Information is arranged by segments in an upstream to downstream order beginning at the upper end of each basin.

While the approach in not category specific for assessing only impacts of grazing, it may be used as a first approximation of problem identification. The information obtained and compiled using this procedure is general. However, it suggests probable cause and effect relationships related to land use and ownership. The background information for tables, figures, STORET printouts and maps allows more detailed evaluations. However, more specific information gathering investigations in problem areas would be necessary for a definitive cause and effect assessment.

The assessment may be used as a first step for more refined approaches to problem indntification, measuring the effectiveness of management practices, and developing control programs. The advantages and limitations of various approaches must be recognized and kept in perspective. The biological and recreational adequacy of water bodies should be a major component in water quality assessments. They are the barometers for assessing the progress toward achieving the fishable-swimmable goal of PL 95-217.

Some of the advantages and disadvantages of the Region X approach are summarized below:

Advantages

1. It provides a basin-wide perspective of nonpoint source problems for major basins, based on the best data in the STORET system.

2. The greatest potential use of the approach is in broad scale planning as opposed to site specific planning. This is primarily due to water quality data being from larger streams. With adequate water quality data the concept would be applicable to smaller geographical areas.

3. Water quality problem significance is based on uses including biological and recreational status.

4. Available water quality data is assessed on the basis of EPA's water quality criteria (EPA 1976a).

5. It illustrates water quality data relationships to percent of land use and ownership for segments.

6. It may be used to develop more specific programs for: (1) identifying monitoring needs, (2) working with such nonpoint source categories as grazing or land use, in terms of significance and control program development, and (3) working with classes of land owners such as federal, state and private in terms of problem significance.

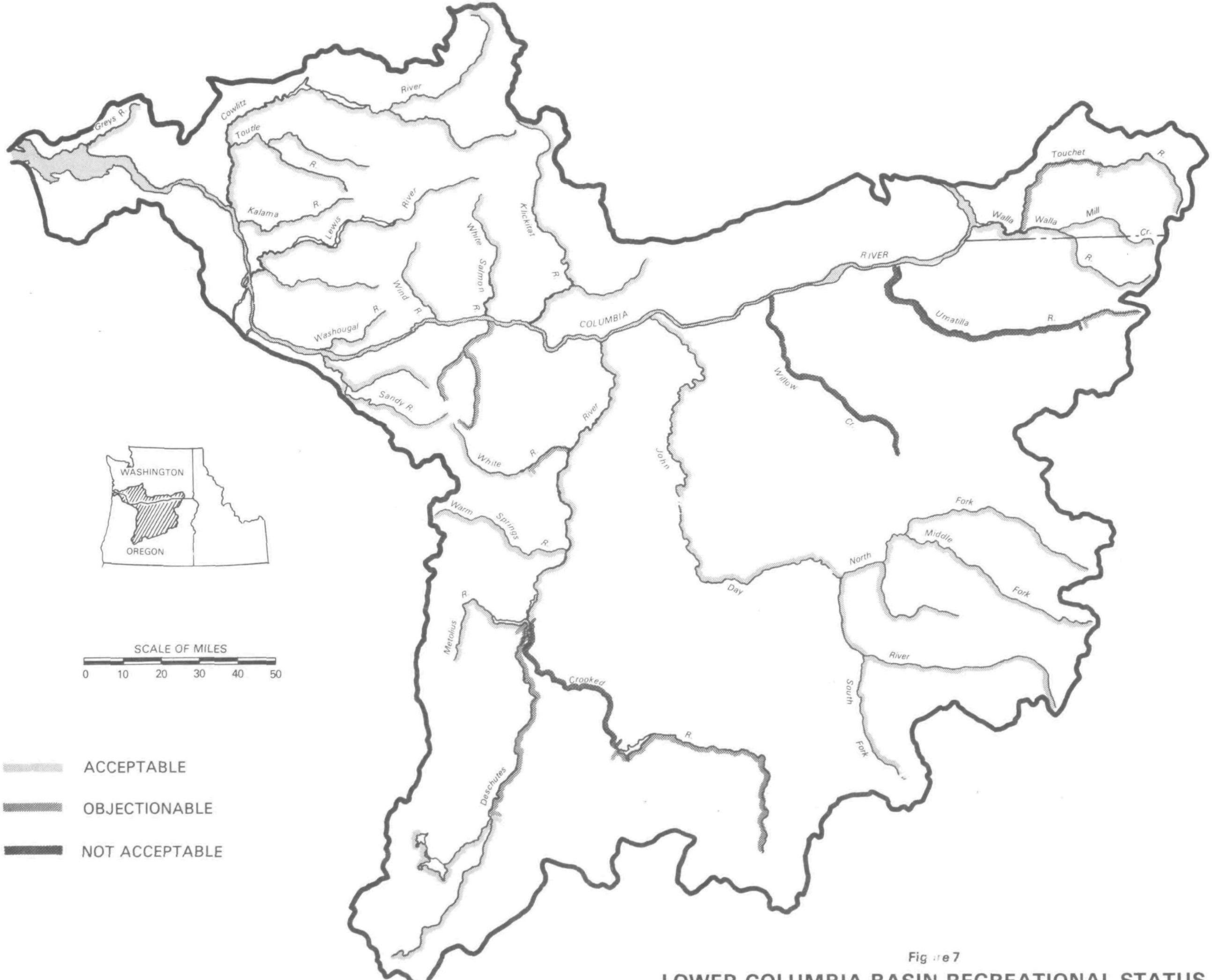

Figure 7

LOWER COLUMBIA BASIN RECREATIONAL STATUS

(GENERALIZED)

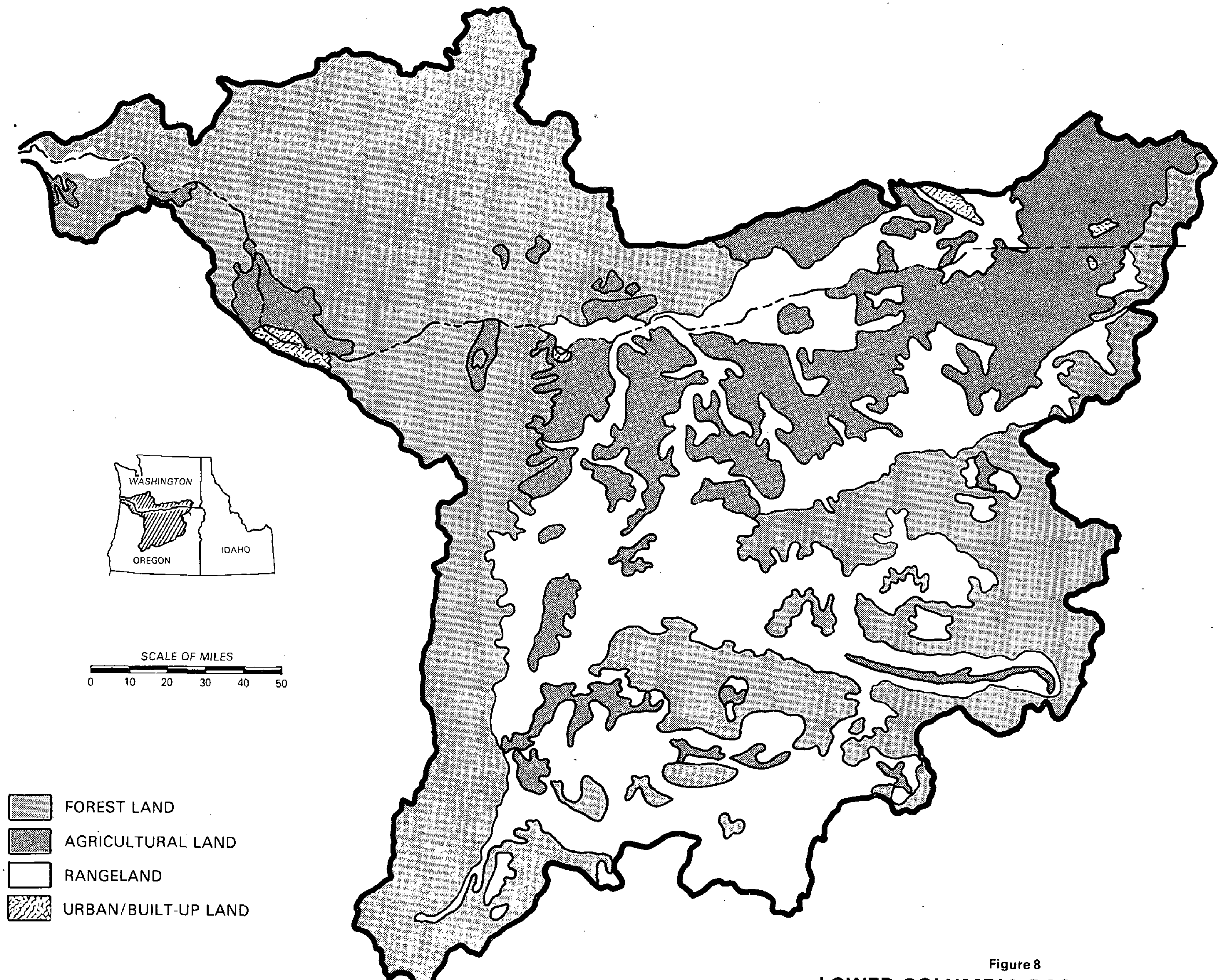

Figure 8
LOWER COLUMBIA BASIN LAND USE
(GENERALIZED)

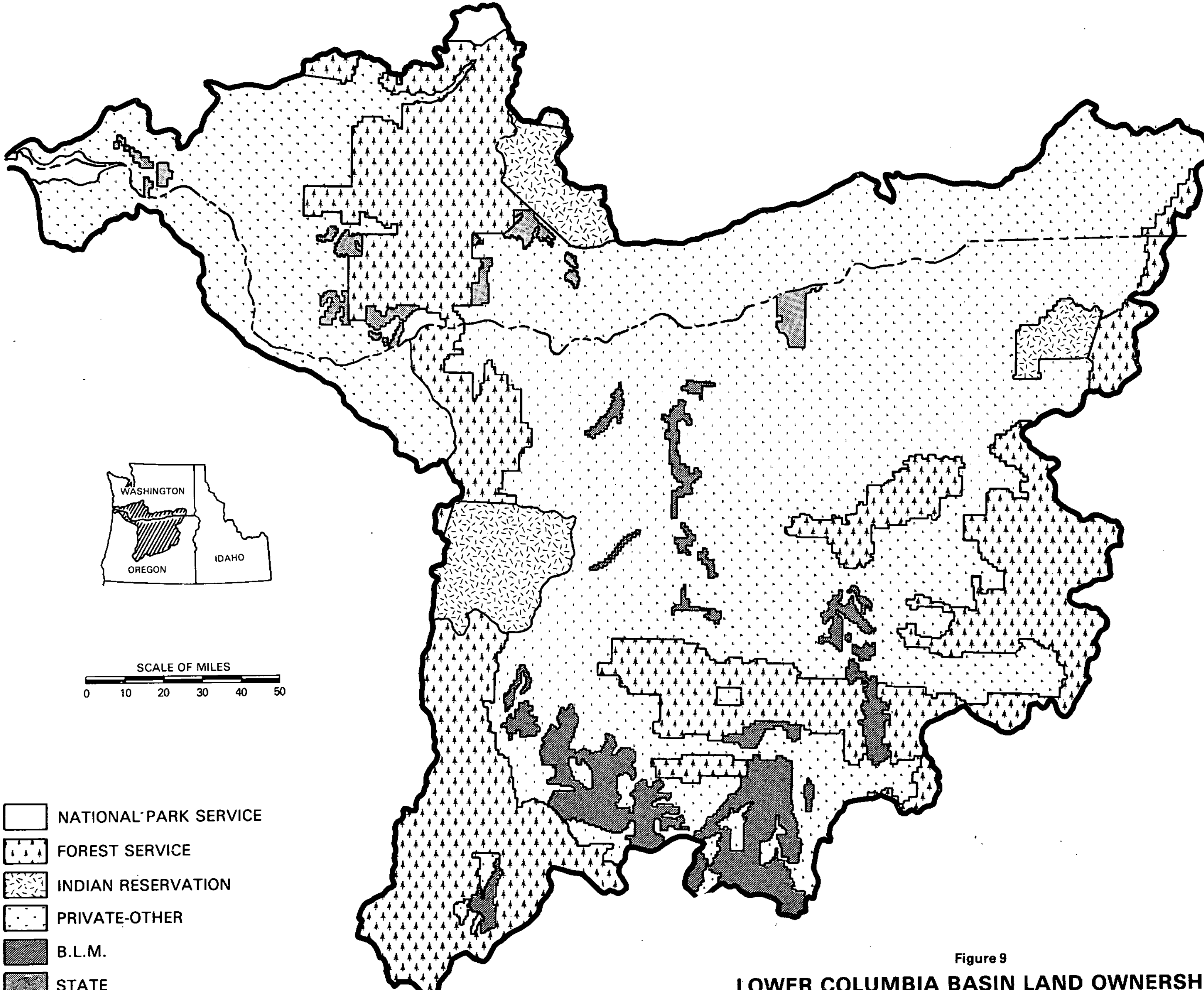

Figure 9
LOWER COLUMBIA BASIN LAND OWNERSHIP
(GENERALIZED)

TABLE 6

LOWER COLUMBIA **RIVER BASIN** DECEMBER **YEAR - 1976**

Sub-basin Information							Environmental Information									% Land Ownership					% Land Use								
Sub-basin	River	Seg #	Drain Area m^2	cfs Flow $x10^3$	R M Range	Seg Length	Sig. Disch M	Sig. Disch I	Hydro-mod	Mining	Water Use	# Sta.	# Smp/yr	Data Adequacy	USFS	BLM	Indian	State	Private	Urban	Agric	Range	Forest	Water	Wetland	Barren	Tundra	Snow & Ice
	Streams north of Columbia	14-31-01	1730						I+ C	N	Ag	0		-		1		5	94	3	36	44	17					
John Day	J. DAY src. to S. Fk. conf.	JD-26-02	1070	.24 1.14 .02	218/ 285- 211.8	73			I+ C	N	Ag Mun Rec F+W	0		-	45	6		1	48		9	36	55					
	S. FK. J. DAY src. to mainstm	JD-26-03	680		211.8/ 60.7- 0	61			I C	N	Ag Rec F+W	0		-	52	19		1	28		6	40	54					
	MID. FK J. DAY src. to N. Fk.	JD-26-01	820	.33 2.3 .02	32.3/ 76.2- 0	76			I		Ag Mun Rec F+W	1	12	-	60	1		1	38		4	29	67					
	N. FK. J. DAY src. to mainstm	JD-26-04	1860	1.44 9.68 .09	184.7/ 112.5- 0	113			I C	A N	Ag Mun Rec F+W	19	272	-	62	2		1	35		4	25	71					
	J. DAY S.F. to Butte Creek	JD-26-05	2100	2.13 12.9 .12	218/ 211.8- 97.3	115			I+ C		Ag Rec F+W	0		-	10	9		1	80		10	64	26					
	J. DAY Butte Cr. to Col. R.	JD-26-06	1820	2.31 13.5 .08	218/ 97.3- 0	97			I+ C		Ag Mun Rec F+W	2	19	-	2	5		1	92		47	43	10					

WATER QUALITY: dotted = acceptable; hatched = objectionable; solid = not acceptable

Bio Sta | Rec Sta | parameters: T, DO, TDG, pH, Turb, Phos, N, NH3, Bact, Met, Cond, OTox

Disadvantages

1. Data are inadequate for many of the segments.

2. There is no sound rationale for relating biological and recreational status (qualitative) to parameter (quantitative) information. For example, there is no procedure for estimating how much turbidity or sediment results in how much destruction of habitat, interruption of food chain and interference with indigenous species.

3. Much of the water quality data for monitoring stations in STORET does not include sediment which is one of the major nonpoint source pollutants.

4. Much of the data have not been adequately validated in the field, especially water uses, biological and recreational information.

5. Data in STORET is taken from many sources with limited quality control of sampling and laboratory procedures.

6. STORET data does not differentiate "natural" conditions from man caused effects.

Assessment Approach 2 - Panhandle National Forest's Technique

The technique is based on a procedure developed by the Northern Region of the Forest Service for evaluating impacts of increased water yields in stream bank and channel stability (Pfankuch 1975). With minor modifications the channel stability assessment has been used to evaluate and predict the impact of grazing on bank and channel stability. Good correlations were found between bank channel stability and ungulate damage. The technique is presented in detail by Cooper (1977). Field data from Wyoming and Idaho was used to validate the method.

The ungulate damage factor or percent of linear bank damage was estimated by observer and added to the form for each stream segment evaluated. Ungulate damage was defined as mass wasting of the upper bank or lower bank cutting that could be attributed to ungulates. Hoof marks, trail and excessive trampling were used in estimating damage.

Rating forms are completed during stream surveys. Information is obtained for the length of the segment. When items rated on the form change classes, an additional rating is determined. The items rated and found to be most directly related to grazing impacts are upper bank slope, mass wasting debris, vegetation cover, lower bank rock content and cutting.

In the areas evaluated bank vegetation and rock content interacted to reduce grazing damage. The data suggested that by combining the two variables, a maximum rating figure may be obtained to determine sensitive areas. For areas evaluated, bank vegetation must rate less than 6 to have measurable interaction with rock content for preventing significant damage. Sensitive banks in northerm Idaho rated 11 points or more and 10 or more for Wyoming foothills, as illustrated in Figure 10.

Advantages

1. The technique provides a quick method for evaluating the impact or potential impact of grazing on stream bank stability.

2. The technique may be useful in predicting impacts of various levels of grazing management on bank and channel stability and fish biomass.

3. By reversing the technique, recovery rates for excessively damaged stream channels can be predicted. For example, a 90 percent ungulate damaged stream would have a stability rating of approximately 45. By removing grazing or otherwise protecting stream banks, it would be probable that in a few seasons the rating would improve to about 25. A 20 point change can be significant in Northern Idaho (Cooper, 1977).

Disadvantages

1. The method is based on visual estimates of items rated rather than quantitative data, especially for ungulate damage. Cooper emphasizes the need for field training for prospective users before attempting use.

2. The technique is based on relatively limited field evaluations for validation with data from Northern Idaho and Wyoming.

3. There is not a good correlation of ungulate damage and water quality impact.

Assessment Approach 3 BLM's Hydrologic Evaluation System

Range management proposals (new intensive grazing systems, range improvements, exclusion of grazing, vegetative manipulation) are made by the Bureau of Land Management and other public land management agencies. This approach outlines a comprehensive method for hydrologic evaluations related to livestock grazing.

An analysis involving eight phases of expected effects of range management in the study area may be used. The successful completion of these tasks will depend upon the efforts of a well qualified vegetation scientist range specialist, soil scientist and water quality hydrologist working in close consultation with each other.

The first phase of the effort should be a literature review of the published papers and reports available on the subject with specific emphasis on the application to the area of study. It should be primarily oriented to locating resource descriptions and interpretive studies (research results, experiments, cause-effect studies) rather than basic data files (e.g., USGS streamflow and water quality observations). Locating basic data will occur later, emphasis will be given to conclusive interpretative studies of the processes involved in this phase. Particular

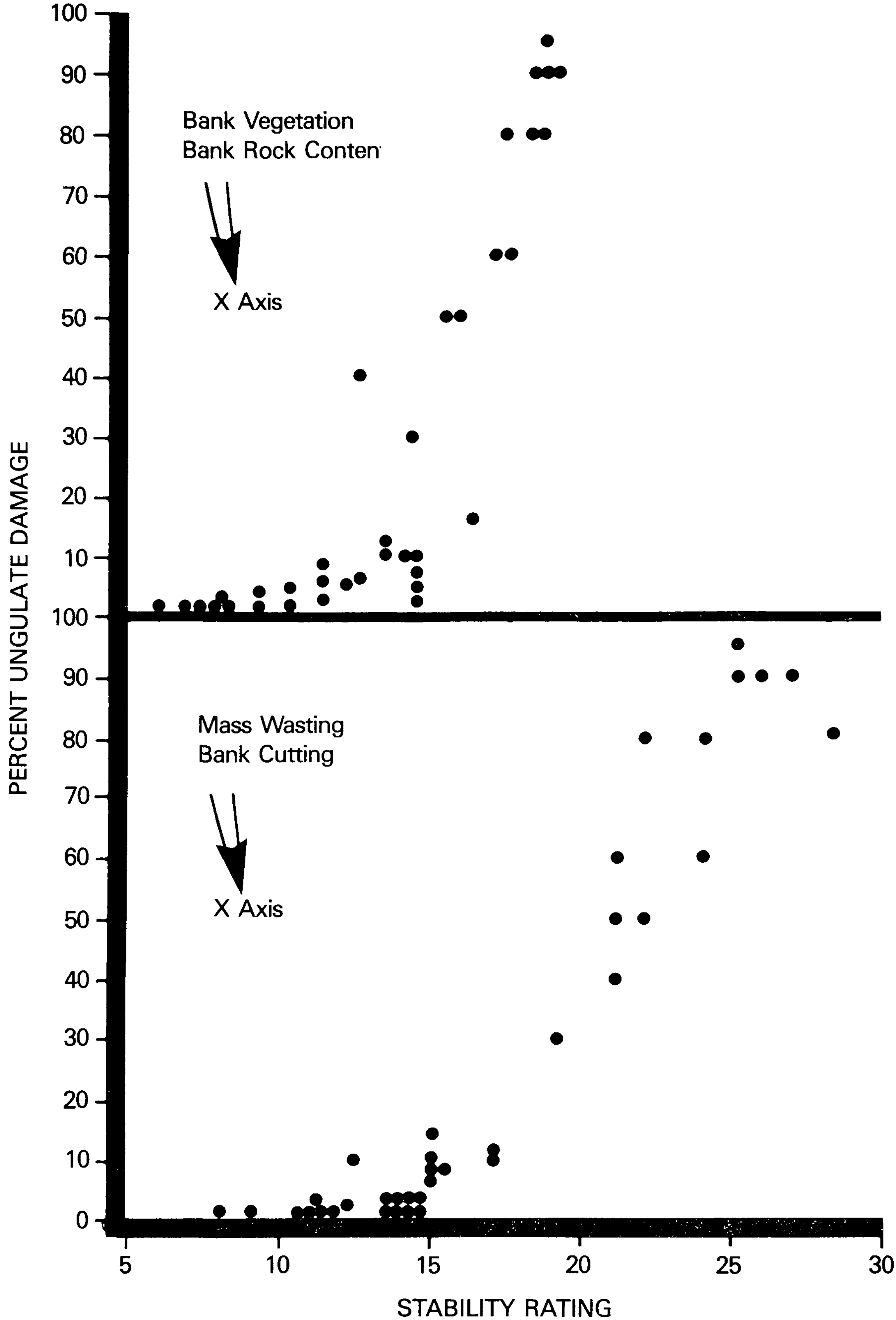

FIGURE 10 MASS WASTING — BANK CUTTING AND BANK VEGETATION — BANK ROCK CONTENT. STABILITY DECREASES FROM LEFT TO RIGHT. (COOPER, 1977)

attention to research of the universities in the study area, Departments of the Fish and Game, U.S. Forest Service, Science and Education Administration and others.

Forage modeling should be the second phase. This is an extension of the information contained in the allotment management plans. The range science professional is an essential collaborator. They translate the vegetative resource allocation plan. Basically, the allotment management plan (AMP) calls for the utilization of the vegetative resource by a certain class (or classes) of domestic livestock, over certain pasture areas, in particular sequence of utilization and rest. The vegetation data of the AMP implementation period, a quantitative scheme must be developed or modified to allow this type of prediction. Modeling predictions should be based on the best research knowledge available.

Phase three, climatological analysis, overlaps with forage modeling because of the obvious presence of climate as a dominant factor in vegetation productivity. This phase initially should focus on a descriptive narrative and statistical presentation of the climate of the study area and nearby region as measured by the nearest National Weather Service climatological stations. The variables of principal interest are: precipitation totals, monthly average and variation; snowfall totals, monthly and variation; windspeed and direction; daily shortwave total solar radiation, air temperature on a mean monthly minimum and maximum basis, pan evaporation on a monthly basis. In a synthesis of the above, climatological characteristics should be discussed in terms of how they relate to such biotic factors as rangeland vegetation. This phase also requires the development of requisite input (precipitation and/or temperature) to the plant cover and production model. Simulation of a stochastic series of precipitation events is an example of the type of information that may be necessary.

Regional hydrologic assessment constitutes phase four. For the study area involved, this means taking a close look at streamflow, water quality and stream channel characteristics of the area. The data should be evaluated from all aspects. Discharge relations compared to suspended sediment and dissolved solid transport should be examined. Flood frequencies of stream should be assessed. The precipitation and elevation regression for the basin should be identified if possible. It is desirable to compare the variations in total runoff from year to year, the variations of daily rates throughout the year, and seasonal variation. Basin shape, geology, and climatic exposure should be understood in data interpretation. These influences should be compared to land management activities. For distinguishing between overland flow and natural ground water discharges to the river, consider hydrograph separation techniques. The principal emphasis at this state of regional analysis should be to obtain a better understanding of the regional system, so that a more realistic and accurate model of the smaller tributary basins can be constructed during phase six.

Phase five should be less involved than phase four, because its focus should be upon the stream receiving most of the "off-site" impacts of land management practices in the study area. Data availability may be a limitation in this phase, but the techniques of regional analysis should again be applied to the extent possible. In some instances, water quality data of the state, U.S.G.S. or EPA may be available for streams within the study area. These sources should be contacted for information.

The next phase, six, evaluates the on-site, slope hydrology effects of management. This is a stage where quantitative effects of all proposed actions are tied down in the best possible fashion. Basically, AMP's propose some change in livestock distribution and forage utilization in time and space. This may create direct impacts on vegetal cover and soil water infiltration rates, and as such, needs to be assessed on an areal basis. There are three basic processes which must be evaluated on the areal basis. First, the grazing systems for the study area must be expressed as grazing intensity (per acre AUM's) (predicted) for any point, as a function of season of use, class of stock, grazing system, water distribution, slope, and vegetative type. Second, grazing (AC/AUM) intensity must be mathematically related to infiltration rate by season. During this process runoff, infiltration, suspended sediment, total dissolved solids and coliform bacteria counts per 100 ml must also be interrelated. The infiltration rate recovery function for rest periods must also be established or assumed based upon literature reviews. Finally, the information and relationships above, within phase six, must be all brought together in an infiltration-runoff-sedimentation computation which computes runoff and sediment response for certain conditions and design storms.

Phase six requires compartmentalization on the basis of pastures, vegetation-soil complexes and often, other factors. Each cell then becomes a more homogeneous hydrologic response unit, which is analyzed independently and then at the end, integrated into a watershed response. Compartments are established on a certain number of "representative watersheds," recognizing that certain uniformity occurs in soils, vegetation and climate in most resource areas, and that resource constraints are always severe in public land management.

The seventh phase should be that of establishing the upland hydrology effects on soil water depletion and soil water levels. The soil water analysis connot be done before the upland hydrology work is complete. It is not always possible to assess, nor is it always relevant, depending upon the upland hydrology. Techniques for assessment of soil water are less well established than surface runoff routing. Other techniques based on tracking available waterholding capacity are available. These effects should be assessed on a point basis for the major soil taxonomic units. The time period will generally be biweekly or monthly, as opposed to the overland flow routing which is in response to some assumed precipitation input.

Phase eight should be an interpretive task of relating results from phases four through seven, in narrative form to existing uses of water, normal meteoroligic events, stormflow frequencies, existing state water quality standards, and value of fisheries. Perspective is to be placed in this section on all previous computations, estimates, assumptions, and limitations.

A desk top calculator or computer is desirable to do a comprehensive job of completing the evaluation phases outlined. The phases may be done step by step concentrating on representative watersheds. Many of the concepts outlined in the hydrologic evaluation system have their greatest potential applicability to public lands; however in many instances they may also be useful for range management planning on private lands.

Advantages

1. It provides a comprehensive system for evaluating the hydrology of a watershed.

2. It incorporates existing information into a logical format for use in resource assessments.

Disadvantages

1. A computer is required for best results in using the system. This limits its utility for many resource managers.

2. Necessary data for the various phases are usually limited. This usually results in extrapolations, inferences, etc., that increase the noise or variability in projected results.

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RESOURCE PLANNING TO PROTECT WATER QUALITY

Water Quality Management Plans

Implementation of land and water management plans (developed on sound principles of conservation) is the best approach to reduce water quality impacts from grazing animal management. As indicated in the Introduction and other parts of the document, the basic framework for land and water management planning and implementation are established by Federal legislation. Much information is available on good land use planning related to range management. Agencies' manuals and handbooks discussed in subsequent parts of this chapter provide much detail for developing a good range management plan.

The purpose of this section is to present some of the concepts and components of good water quality management and allotment management plans that are essential to reduce impacts from grazing management. The importance of coordinated resource planning on western rangelands is also emphasized.

Water Quality Management Plans

The Environmental Protection Agency promulgated regulations specifying procedural and other requirements for the preparation of water quality management plans to achieve the fishable and swimmable goal of the Act. Water quality management plans and implementing programs are to be prepared and established by state planning agencies pursuant to Section 208 and 303(e) of the Act and by designated areawide planning agencies.

The water quality management plans will be developed for all lands within a state. The primary objective of water quality management plans will be to achieve the 1983 national water quality goal of the Act, where attainable. The plans will identify the controls, regulatory programs and the established best managment practices.

"A water quality management plan is a management document which identifies the water quality problems of a particular approved state planning area or designated areawide planning area and sets forth an effective management program to alleviate those problems and to achieve and preserve water quality for all intended uses. The value of the water quality plan lies in its utility in providing a basis for making sound water quality management decisions and in establishing and implementing effective control programs. To achieve this objective, the details of the water quality management plan(s) should provide the necessary analysis and information for management decisions. Moreover, there must be a flexible revision mechanism to reflect changing conditions in the area of consideration . A water quality management plan should be a dynamic management tool, rather than a rigid, static compilation of data and material. In addition, the plan should be as concise as possible, thereby minimizing unnecessary paperwork. A water quality management plan will provide for orderly water quality management by (1) identifying problems, (2) assessing needs/establishing priorities, (3) scheduling actions, (4) defining control programs, (5) defining management agency responsibilities, and (6) coordinating planning and management". (40 CFR 131.1(c) and (d)).

The designated areas aspect of the 208 program emphasizes planning by local governments in a particular planning area. The objective is for these groups to work together to find and implement solutions to their common water quality management problems. It gives local planning agencies a means of solving their problems.

Runoff from land used for livestock production should be part of the water quality management plan in areas where it is related to water quality impacts. Each category of nonpoint sources of pollutants should be considered in any specific area as established in the State/EPA agreement. Identification and evaluation of all measures necessary to produce the desired level of control through application of best management practices (recognizing that the application of best management practices may vary from area to area depending upon the extent of water quality problems) should be utilized in planning and implementation.

The nonpoint source evaluation shall include an assessment of nonpoint source control measures applied thus far, the period of time required to achieve the desired controls, the proposed programs to achieve the controls, the management agencies needed to achieve the controls, and the costs by agency and activity, presented by 5-year increments, to achieve the desired controls, and a description of the proposed actions necessary to achieve such controls. With the large ownership of Federal lands used for livestock grazing in the West, and the potential water quality impacts from these lands, it is essential that Federal land management agencies be an integral part of the water quality management planning process. The rules and regulations for the planning process (40 CFR, Part 130.35(b) contemplate that Federal agencies shall cooperate and give support to state or designated areawide planning agencies in the formulation and implementation of water quality management plans relating to Federal properties, facilities or activities and land areas contiguous with Federally-owned lands.

Roles and Responsibilities in 208 Planning

a. States and local Agencies

- o Development and mangement of 208 plans is the responsibility of governor designated state and areawide agencies. The designated state agency acts as the planning agency for all portions of the state not covered by areawide planning.

- o In the western states, state water quality agencies (SWQA) are responsible for assuring that each element of the approved planning process is achieved for grazing management activities.

- SWQA may delegate the accomplishment of state plans or tasks under 208 to other Federal or state agencies or any entity it determines to be qualified (40 CFR §130.14(a). In some areas state water quality and land management agencies have negotiated cooperative planning agreements, with the land management agencies having primary responsibilities relative to BMP development and implementation.

b. Federal land management agencies

Federal land management agencies are required to cooperative with and support the state or state designated agency in the formulation and implementation of 208 water quality management plans for lands they administer or that relate to Federal properties, facilities, or activities and land areas contiguous with federally-owned lands. Moreover, the Clean Water Act of 1977 (PL 95-217) makes it mandatory for the Federal agencies to meet the official substantive and procedural pollution abatement requirements of the state.

c. Environmental Protection Agency (EPA)

The EPA has the responsibility of administering funds appropriated to support the 208 planning process, approving completed plans based on adequacy for meeting water quality goals, and assisting the state in its relationship with Federal land managers. The deadline for the initial submittal of statewide water quality mangement plans was November 1, 1978.

Necessary Parts of an Approvable Livestock Grazing Management Pollution Control Program.

a. Section 208 plans for grazing practices should cover the following elements:

- identification of which water quality problems exist now or need to be prevented in the future (activity related or geographic).

- identification of the sources of those problems (including natural causes).

- identification of problems and control priorities and geographic area(s) to be covered.

- description of the technical solution(s) to be implemented for each problem.

- identification of the action schedule for implementation of control measures.

- description of the extent to which carrying out identified controls is expected to eliminate or reduce water quality problems (the concept of maximum allowable loading).

- estimation of the costs of implementing the proposed controls consistent with a continuing water quality management planning process.

- identification of each responsible management agency and its management relationship with the SWQA in tracking implementation of control measures.

- description of existing (or needed) legal authorities the management agency will use to implement each control requirement, including conditions and situations in which the law or regulation applies; timing of regulation, notice, hearings; legal form of regulation, contracts, permits, and legal authority for regulation.

- description of how the implementation program will be financed.

- description of how the implementation program will be managed, i.e., (1) the level of staff resources which will be committed to inspection, technical assistance, administration, education and training, and enforcement; (2) how the program will be administered-technical assistance, initiation of inspection, enforcement, etc.; and (3) the institutional arrangements with other agencies or levels of government which are or will be established as necessary to fully implement the control program.

- description of how effectiveness of individual control practices will be monitored or evaluated in relation to instream water quality and a description of the continuing process for upgrading pollution abatement measures, modifying implementation procedures, and updating the water quality management plan.

b. Public participation.

Public participation in water pollution control program development is required. The major objectives of such participation include greater responsiveness of governmental actions to public concerns and priorities, and improved understanding of official programs and actions.

c. Implementation statement and designation of management agency by governor.

A completed 208 water quality management plan must contain an implementation statement prepared jointly and signed by the planning agency and the proposed management agency. The implementation statement should contain a description of specific responsibilities and of tasks to be performed by each agency in sufficient detail that all parties have a thorough understanding of the actions expected of each of the parties to the agreement.

The governor designates appropriate agencies to carry out the management responsibilities of the plan. This action is straightforward if the proposed management agency is a state or local agency. If it is a Federal agency, the governor's designation must be based on an interagency agreement that adequately addresses the implementation elements of the plan.

d. BMP implementation and modification.

o Controls are to focus first on identified priority problems impeding attainment and maintenance of water quality goals.

BMP's will be implemented through regulatory programs where those are determined to be the most practicable method assuring effective implementation.

o BMP's will be assessed as to their effectiveness with the use of water quality standards in the same manner that standards are used to assess water quality. The measurement of BMP's involve two monitoring approaches: (1) compliance monitoring to establish the adequacy and effectiveness of implemented control practices, and (2) instream pollution impacts monitoring. Monitoring concepts and approaches are discussed in other parts of this document. Monitoring procedures need to be spelled out in interagency agreements. These procedures should result in data, inspection, and records suitable for periodic formal evaluation to guide decision making on needed BMP modifications.

o BMP's must be reviewed annually and modified to improve their effectiveness where nonpoint sources of pollution continue to impede the achievement of the water quality goals (BMP identified in the planning process will continue to apply during the course of revision).

o BMP's must otherwise insure that all feasible steps are being taken to achieve water quality goals.

e. Administration and financing.

The process of monitoring, evaluating, and upgrading specific BMP's for water quality is a continuing process. The planning and management agencies must jointly work together throughout this process to assure coming up with implementable and effective pollution control programs irrespective of land ownership. Institutional arrangements and agreements must be periodically reviewed and formally reaffirmed to facilitate this required upgrading process. Controls will usually be administered by state or local agencies on state and private land and by the Federal agencies on Federal lands.

Both the state water quality and the fish and game agencies have a major role in developing and reviewing water quality management plans and monitoring water quality. Implementation of controls on Federal lands will be strengthened by Federal agency administration of special clauses in grazing leases as appropriate, special use permits, and water quality monitoring. State and Federal efforts to montior water quality are to be coordinated to assure consistency in methodology, control compliance and the mutual understanding of control needs and priorities. States will assure that adequate administration of controls is taking place through periodic compliance inspections on all lands.

States and Federal agencies are expected to finance the management process. Section 304(k) funds under PL 95-217 ($100 million per year for five years) has been authorized by Congress, but not yet appropriated. This could help to accelerate Federal agency technical and training programs to support the development of state and local 208 control programs and to implement priority pollution control projects on Federal lands consistent with water quality management plans.

Section 208(j) of the Clean Water Act of 1977 (PL 95-217) established a program for financial assistance to private owners and operators of rural lands for the purpose of installing and maintaining best management practices. The BMP's must be to control nonpoint sources of pollution for improved water quality in states or areas that have an approved 208 plan. The legislation authorized $200 million for fiscal year 1979 and $400 million for fiscal year 1980 to carry out the statutory mandate. The USDA will be the implementing agency for the program. Rules and regulations for administering the program are developed. This program should provide some economic incentives to range managers to apply best management practices.

In summary, water quality management plans should be the broad umbrella under which othertypes of land use planning with water quality implications fall. It is recognized that many aspects of the planning discussion are most applicable and appropriate for Federal, state and local units of government involved in land mangement or planning. However, basic range conservation plans developed in water quality problem areas for individual land owners and operators should be prepared with an awareness of Federal, state and local water quality requirements and goals. It is essential that broad scale planning such as allotment management planning of Federal land management agencies be consistent with the water quality management plan for their areas.

Allotment Management Plans

Policy and management direction is well established under the Federal Land Policy and Management Act (1976) which mandates resource planning, including domestic livestock grazing, for the Bureau of Land Management and Forest Service the two principle Federal land and resource management agencies. Management planning is accomplished with the Allotment Management Plan (AMP) for livestock grazing on these public lands. The Act states:

"An allotment management plan means a document prepared in consultation with the lessees or permittees involved, which applies to livestock operations on the public lands or on lands within National Forests in the eleven contiguous Western States and which:

(1) prescribes the manner in, and extent to, which livestock operations will be conducted in order to meet the multiple-use, sustained-yield, economic and other needs and objectives as determined for the lands by the Secretary concerned; and

(2) decribes the type, location, ownership, and general specifications for the range improvements to be installed and maintained on the lands to meet the livestock grazing and other objectives of land mangement; and

(3) contains such other provisions relating to livestock grazing and other objectives found by the Secretary concerned to be consistent with the provisions of this Act and other applicable laws."

Although some variations may occur, an AMP normally contains:

1. General Information concerning an analysis of the present resource values and uses, including problems and conflicts;

2. Identification of objectives to be achieved which are specific and quantifiable and which resolve or mitigate resource problems and conflicts;

3. Design of a grazing system which will achieve the objectives;

4. Necessary range improvements to implement the grazing plan; and

5. Methods and techniques to monitor and evaluate whether the objectives are being achieved.

Forest Service guidelines and policy for preparation of Allotment Management Plans are provided in the Range Environmental Analysis Handbooks issued by the Regional Offices in conformance with the Forest Service Manual 2212. The Rocky Mountain Regional Handbook (Forest Service, 1968) states--"Range analysis is a program concerned with the systematic collection, evaluation and mapping of data on range resources; the end result is a workable management plan in operation on each indivdually mapped allotment. The analysis includes: the classification and mapping of range types, determination of range suitability and condition, and the periodic measurement of trends in range condition. It also provides for collection of information on production and utilization, range improvements, range readiness, season of use, and their combinations into an updated management plan. The system of management used should: (1) ensure the optimum use of the range resource, (2) maintain ranges in good condition, and (3) improve ranges in fair and poor condition. The action resulting from the program described shall conform with the multiple-use principle."

The Bureau of Land Management guidelines and policies for preparation of allotment management plans are provided within the Bureau Range Management Practices Manual 4112.15 (BLM, 1968a). The Bureau manual may be supplemented by each of the respective State Offices to provide more specific details for local situations. Allotment Management Plans are the livestock grazing activity plans developed with the objectives, guidelines, and constraints as determined through the Bureau's Management Framework Planning Manual 1608 (BLM, 1975). Objectives of specific AMP's generally are to establish a grazing management program which obtains and sustains stable soil and watershed conditions, maintains or improves wildlife habitat, and provides a dependable supply of forage in balance with other multiple uses. However, each AMP has specific quantifiable objectives tailored to each individual allotment. Allotment Management Plans provide continuity to the range management program. The long term objective is to complete allotment management plans on BLM lands to be retained for management.

The Soil Conservation Service includes livestock grazing management with the Resource Conservation Plan. These plans are developed for private lands of Soil Conservation District Cooperators. The National Range Handbook (SCS, 1976) provides guidelines and policy for planning, implementation and evaluation. Conservation plans for native grazing land include decisions for establishing and maintaining a cover of vegetation to protect the soil and permit efficient use of available moisture. Major planning objectives are proper grazing use and maintenance of sufficient cover to keep soil loss below the tolerable limits specified in local technical guides. This cover provides forage for livestock and wildlife; enhances watershed conditions; and provides shade, ornamental and esthetic or screening facilities. When properly implemented, conservation plans for ranches and farms benefit the individual operator, community, and the nation. Well-managed native grazing land, along with the livestock and wildlife it supports, makes a major contribution to the natural beauty of the landscape and the maintenance of a quality environment.

Other Federal and State agencies, such as Fish and Wildlife Service, Bureau of Reclamation, Department of Defense, National Park Service, State Departments of Fish and Game, etc., also manage grazing use on substantial acreages of rangelands. These agencies also apply basic principles of range management in the administration of livestock grazing on the lands to comply with appropriate laws cited previously in this document, such as FWPCA.

Most of the western states have operational allotment management plans, many of which, when properly designed and followed, show remarkable effective- ness of scientific grazing management planning. Many examples exist of successful operating coordinated plans in many combinations of private, state, and Federal agency cooperation. A viewpoint was expressed by Fulcher (1973) that properly designed grazing systems, developed in conjunction with the agency's overall action plans for an area, are the least cost alternative of meeting the major objectives and responsibilities of government agencies in managing public rangeland resources.

There are several examples of the resource management benefits of good allotment management planning throughout the West. Coordination and cooperation between involved public agencies and the allottee(s) is essential for success in allotment planning. A good example of effective allotment planning and implementation is the Middle Mesa AMP in New Mexico (BLM, 1968). The Plan was developed with the BLM and New Mexico Department of Fish and Game as public agencies working with the land users. It involved considerable land treatment (pinyon-juniper chaining and seeding) as well as livestock management planning.

The objectives of the AMP were to (1) develop a grazing system, (2) comply with the inter-agency agreement, (3) improve the vigor and increase the density of desirable vegetation, (4) stabilize and improve the watershed conditions, and (5) protect archeological sites. The improvement which has taken place since 1968 is impressive but is not unusual when compared to other properly designed grazing management plans with appropriate land treatment practices. Cool season grasses, an important item for deer, have increased primarily from seeding. Cover patterns for deer have improved due to chaining practices so that deer can move through the area for food and water. There is more browse for wildlife primarily released by chaining. The amount of vegetation cover increased, which has resulted in less soil erosion. Many areas are healing. The amount of forage has increased from about 100 pounds per acre to 400 pounds per acre in the seeded areas. The average plant density has increased from fifteen to forty percent. Calf weaning weight has increased about 85 pounds per head and the calf crop has doubled. Periodically, the rancher is allowed to graze additional cattle because of the increase in forage.

This is but one example, typical of others, where coordinated planning and application of grazing management and range improvement practices have been beneficial, to resources involved and the economic well-being of the rancher.

A major precept for allotment management planning is acknowledgment of the fact that the primary basis for sound land use must lie in a determination of the land's capabilities and suitabilities as limited by climate, soil, and topography, and recognition that range is a kind of land producing a multitude of different resource values and subject to a variety of uses (Colbert, 1977). Proper land use is further recognized as a major goal for range management in Range Research (Utah State University, 1977). "Range management really has no product to produce or sell. It is a science, spiced with art, that has as its major goal proper land use, especially for those wildlands grazed by domestic livestock and wild animals."

Putting rangeland (allotment) planning into practice is discussed by Heady (1975). Goals of each rangeland manager differ; some managers may aim for large profits, while others may give first preference to a good life with little concern for accumulating wealth, and still others may aim for protection of the rangeland ecosystem. Good livestock grazing management practices are not in conflict with any of these views. Each range site, pasture, and ranch will respond to several management techniques. Change of animal numbers, fencing and water development to improve distribution of animals, planning of the sequence of grazing and deferment, and altering of the mixture of animal species are some of the major tools for providing beneficial results and mitigating adverse impacts of the animals. Noxious plant control, seeding, and fertilization have many variations and may be combined to supplement livestock grazing plans to expedite range improvement. In essence, each grazing plan and supplementary range improvement practices must be specifically tailored to each unique area of land to resolve problems, to the extent practical and feasible, with planned livestock grazing management.

The concern to include more complete ecological considerations in land management planning was further discussed by Volland (1975). Plant and animal ecology provides a valuable tool in land management if for no other reason than it can provide some order to the complexity of things. Some order is necessary so that we may (1) comprehend the diversity represented within an area, (2) communicate with others, (3) remove variation and improve our predictability. Ecological information provides a basis for management planning and evaluation, but in itself cannot be the only source of input. Management objectives will govern what other information is necessary.

Allotment management plans provide the framework for planning livestock grazing use of rangelands. Stoddart, Smith and Box (1975) indicated: "there are principles of scientific management that can be applied to improve the range resource and insure a sustained yield of goods and services from rangeland. In order to apply these principles, grazing use must be planned and the plan executed. The first consideration in planning range use is to ensure that the basic plant and soil resources are used in such a way that they continue to be productive under the grazing system explored. The selection of a particular system will depend upon the kind of vegetation, the physiography of the range, the kind of animals, and the management objectives. New facts have been uncovered, basic concepts have been refined and tested by experience, and investigative techniques have been perfected. But even more important than the technical changes are the shifts in emphasis among the various rangeland products. Nonconsumptive uses, though not new, have become even more important. With increased human populations and greater demands for rangeland products, the need for clear understanding and greater knowledge of range ecosystems remains as vital as before. Nevertheless, no new conceptual framework differentiates the field of range management now from before. Basically, range management deals with the use of lands of low potential productivity maintained under extensive systems to produce water, red meat, wildlife, timber, and recreational opportunities in such a way that the basic resources, soil and vegetation, remain unimpaired."

Roads on Rangelands

In addition to erosion and sediment directly associated with livestock grazing, many miles of roads have been and are being constructed on rangelands to provide access to grazing lands and to maintain range improvements. These roads may contribute substantially to the production of sediment from rangelands.

An EPA (1975) publication on Logging Roads and Protection of Water Quality discuss many of the principles related to minimizing impacts from roads. Although logging haul roads are the primary focus, most of the principles and techniques described have wider application and can be extended to include all wildland watershed access roads which are similar in standard, but are constructed for different purposes such as mining, fire protection and grazing or for multi-purposes.

Coordinated Resource Planning

In some of the western states, land and other resource management agencies and land users have combined efforts for cooperative planning and implementation. Coordinated planning is based on soils, water quality, wildlife and other resource needs for the area planned. The planning process is based on the concept of addressing and resolving potential resource conflicts by those responsible for plan implementation. Plans are developed by several parties with a commitment by everyone involved to implementing the plan. The coordinated planning process involves both public and private lands.

A good description of effective coordinated planning with some examples was presented in a series of papers at the 27th Annual Meeting of the Society for Range Management in 1974. The process has worked especially well in Oregon. The Bureau of Land Management, Forest Service, Soil Conservation Service, Soil Conservation Districts, State Wildlife Commission, private land owners and permittees on public lands worked together in cooperative resource planning. Coordinated plans dealt with not only grazing aspects of the rancher's economic unit, but also identified management prescriptions for other resources (wildlife, fisheries, and water quality) within the area.

Schlapfer (1974) used the Murderers Creek area in Grant County, Oregon as an example of an effective total resource plan. This plan was completed in March of 1973 and covered an area of approximately 100,000 acres. The overall objective of the plan was to prepare one document from which the cooperating agencies and livestock permittees could operate in harmony.

The specific objective of the Murderers Creek Plan were idenitified as: (1) to improve the quantity and quality of forage and habitat for domestic and wild animals; (2) to offer for harvest the maximum amount of forest products compatible with the other resource values; (3) to offer recreational opportunities and development of a transportation system; (4) to maintain a high quality fisheries habitat; and (5) to provide sanctuary for a herd of 100 free-roaming horses. Land management prescriptions were designed to enhance the resources and land use while providing the maximum protection to resource values. Plans identified in detail what was to be done on the land to meet the management objectives.

Anderson (1975) discussed coordinated resource planning from a historical perspective, emphasizing that it is not a new concept. He points out, it has only recently been effectively used as an operating procedure. Anderson identified some of the principles that have guided and resulted in effective coordinated resource plans. Some of the key concepts are: (1) There is a great need for resource planning to give full consideration to the second and third order of consequences that likely will take place as the result of a planned activity; (2) There is no substitute for a sound ecologically based resource inventory as the foundation for decisions including all major resources of the planned area such as water, wood, wildlife and forage. Their use and management should not be planned independently but coordinated; and (3) A resource management system or combinations of practices or treatments instead of piecemeal applications may be necessary to impact management objectives.

Water quality considerations are an essential part of effective coordinated resource planning. This is especially true in areas with problems or potential problems associated with water uses. The fundamental concept of effective coordinated resource planning is that agencies, groups or land users with resource management responsibilities can be brought into the process as appropriate to offer input and participate in plan devlopment and implementation. Water quality management plans on rangelands discussed earlier should be closely tied to well prepared and implemented coordinated resource plans for the rangeland area.

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APPENDIX I

SELECTED SMALL WATERSHEDS AND EXPERIMENTAL RANGES

Much of the available information on land and water quality management is from small watershed studies. An experimental basin is one that has been chosen and instrumented for the study of hydrological phenomena. A representative basin is one that has been chosen and instrumented to represent a broad area, rather than making measurements in all basins of a comparatively homogeneous region.

The major physiographic regions of the Western United States are illustrated in Figure A-1. The experimental and representative basins for rangeland research are identified in Table A-1 for the physiographic regions.

TABLE A-1

SELECTED SMALL WATERSHEDS AND EXPERIMENTAL RANGES

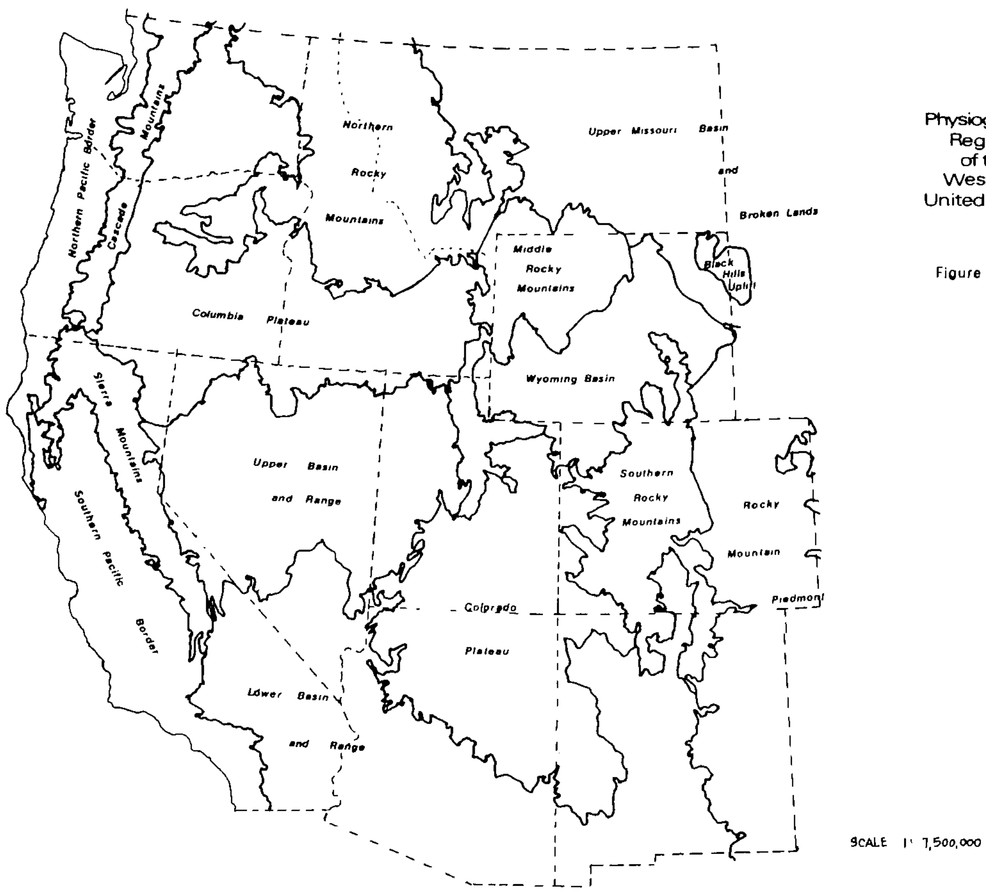
Province	Representative Basins	Experimental Basins	Ranges
Northern Pacific Border		Casper Creek Exp. Basin, CA. (Tilley and Rice, 1977)	
Cascade Mountains	Antioch Watershed, Wenatchee N. F., WA (Johnson 1978)	H. J. Andrews Experimental Forest, OR (Rothacher, Dryness and Fredriksen, 1967)	
	Clackamas River Watershed, Mt. Hood N. F., OR (Johnson 1978)	Coyote Creek Basins, OR (NRC, 1969)	
	Entiat River Watershed, WA (Dortignac and Beattie, 1955)	HI-15 Basins, OR (NRC, 1969)	
	Green River Watershed, Snoqualamie N.F., WA (Dortinac and Beattie, 1965)		
	Upper Sauk River Watershed, WA (Johnson, 1978)		
Southern Pacific Border	Santa Ynez Watershed, Los Padres N. F.	Hopland Watersheds (Burgy, 1958)	San Joaquin

Province	Representative Basins	Experimental Basins	Ranges
		San Dimas Experimental Forest (Hill and Rice, (1963)	
Sierra Mountains	Big Creek Watershed, Sierra N. F. (Dortignac and Beattie, 1965)	Central Sierra Snow (Anderson and Gleason 1960)	Harvey Valley, N.F., CA (Ratliff, Reppert and McConnen, 1972)
		North Fork Watersheds, CA (Rowe, 1941)	
		Teakettle Basins, CA	
		Ward Valley Watershed, CA (Leonard and Coats, 1974)	
		Dog Creek, NV	
Columbia Plateau		Entiat Basins, WA (NRC, 1969)	Starkey Experimental Forest and Range, OR (Skovlin and Harris (1974)
Columbia Plateau	Rock Springs Basin, NV (NRC, 1969)	Reynolds Creek, ID (Johnson and Hanson, 1976)	
Upper Basin and Range	Churchill Canyon, NV (NRC, 1969)	A and B Basins, Great Basin Experimental Range, UT (Meeuwig, 1960)	Desert Experimental Range, UT (Hommgren, 1974)
	Coils Creek, NV (NRC, 1969)		Great Basin Experimental Range, UT (Keck, 1972)

Province	Representative Basins	Experimental Basins	Ranges
	Cow Creek, NV (NRC, 1969)		
	Crane Springs, NV (NRC, 1969)		Tintic Pastures, UT
Upper Basin and Range	Crowley Basin, NV (NRC 1969)		Winnemucca Experiment Station, NV (Dylla and Muckel, 1964)
	Duckwater Basin, NV (NRC, 1969)		
	Eastgate Basin, NV (NRC, 1969)		
	Mill Creek, NV (NRC 1969)		
	Steptoe Watershed, NV (NRC, 1969)		
Lower Basin and Range	Pine and Mathews Canyon, NV (Blackburn and Skau, 1974)	Corduroy Creek Basin AZ (Collings and Myrick, 1966)	Jornada Experimental NM
	Cornfield Wash, NM (Burkham, 1966)		Santa Rita Experimental Range, AZ
	Rio Puerco Watersheds, NM		
	Walnut Gulch, AZ (Renard, 1970)		
Northern Rocky Mountains	Meadow Creek, Nez Perze NF, ID	Priest River, ID (Kline, Haupt and Campbell, 1977)	
Middle Rocky Mountains	South Fork of Smith Creek, Wasatch NF, UT	Davis County Watersheds, UT (Johnston and Doty, 1972)	
	Straight Canyon, Manti La Sal NF, UT		

Province	Representative Basins	Experimental Basins	Ranges
Wyoming Basin	Stratton Study Site, WY (Sturges, 1975)		
	Wayne's Creek Basins, WY (Tabler, 1968)		
Southern Rocky Mountain	Encampment River, Routt NF WY and CO (Johnson, E. A., 1978)	Boco Mountain Watersheds CO (Shown, Lusby and Branson, 1972)	
	Lake Creek Basin, Pike - San Isabel NF, CO (Lonberger, 1965)	Black Mesa, Gunnison NF, CO (Frank, Brown and Thompson, 1975)	
	Little South Fork, Cache La Poudre Basin, CO (Kunkle and Meiman, 1967)	Fraser Experimental Forest CO (Alexander and Watkins, 1977)	
	Tesque Watershed, Santa Fe NF, NM (Gosz, 1977)	Manitou Experimental Forest CO (Dortignac and Love, 1961)	
		Wagon Wheel Gap, Rio Grande NF, CO (Bates and Henry, 1928)	
Colorado Plateau	Black River, AZ. Apache-Sitegreaves NF (Stewart, 1975)	Badger Wash, CO (Lusby Reid and Knipe, 1971)	
	East Fork Sevier River, Dixie NF, UT (Johnson 1978)	Beaver Creek, Coconino SF, AZ (Brown, Baker, Rogers, Clary, Kovner, Larson, Avery and Campbell, 1974)	
		Castle Creek, Apache-Sitgreaves NF, AZ (Rich, 1972)	
		Cibeque Ridge, AZ (Collings, 1966)	
		Cresent Wash. UT (Peterson, 1962)	

Province	Representative Basins	Experimental Basins	Ranges
		Piceance Basin, CO (Frickel, Shown and Patton, 1975)	
		Price River Basins, UT (Ponce et al, 1975)	
Rock Mountain Piedmont		Alamogordo Creek, AZ	Central Experimental Range, CO (Rauzi and Smith, 1973)
		Pawnee Intensive IBP, Pawnee National Grassland, CO (Striffler, 1974)	
		Pole Mountain Basins, NY (Tabler, 1971)	
Upper Missouri Basin		Willow Creek, MT	



Physiographic Regions of the Western United States

Figure A-I

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APPENDIX II

GRAZING MANAGEMENT

Livestock Management

Water quality can be protected and/or enhanced through application of the present knowledge of scientific and technical principles of livestock management on rangelands. Entrapment of pollution particulates is provided by vegetative cover and through soil infiltration (Dixon et al. 1977). Grazing systems prescribed for a specific rangeland area and incorporation of appropriate livestock distribution practices provide the principle means for management of livestock grazing. Single management practices including system of grazing, season of use, rate of stocking, or distribution of livestock, may, when used alone, improve rangelands and minimize water quality impacts. However, it is more appropriate to include all necessary management practices into a well planned, integrated livestock management program to achieve specific management objectives identified for that particular rangeland area. This is essential for success in obtaining the most efficient use of the range without significantly adversely impacting water quality and other rangeland resources.

Grazing Management System

Grazing systems are specialization of grazing management which defines systematically recurring periods of grazing and deferment for two or more pastures or management units (Kothmann, 1974). The type of system selected depends on the resources involved, objectives to be achieved and production requirements, all properly planned and integrated to allow proper management of the land and resources, including water quality. The basic purpose of any grazing system is to promote the most efficient range management practicable which maintains or improves basic resource values, (Driscoll, 1969). Range conditions can often be improved through better distribution of livestock by using several different practices, either singly or in combination, such as salting, water development, fencing, herding, grazing system, etc.

Grazing is either continuous throughout the grazing season, or specialized and intensified by dividing a range area into a number of units and periodically moving livestock during the grazing period. The degree and kind of specialization must be designed specifically for each range area. Some factors to consider in selection include resource values, problems, and objectives to be achieved; phenological development and productive potential of the vegetation; growth and maintenance requirements and grazing habits of the livestock; amount and location of forage; and potential land, resource and water quality impacts.

Although the literature commonly refers to several basic grazing systems such as rotation or alternate grazing, deferred grazing, rest-rotation grazing etc., there are in reality an almost infinite number of specialized grazing systems if each system is individually tailored to a specific area of grazing land. However, all specialized systems are based on concepts of rotation of grazing use and deferment or rest from grazing use.

Advantages and disadvantages of specialized grazing systems were discussed by Driscoll (1969). Besides those of Driscoll (1969), some additional advantages of specialized grazing systems are that use of the same area at the same time in successive years is avoided especially when the grazing season includes all or part of the growing season; vegetation over the entire area being used may be maintained with good plant vigor; excessive soil disturbance with an increase in potential soil erosion and sedimentation is minimized with most specialized grazing systems; opportunity for ripening of seed, seedling development, and establishment of important desirable plants is increased; provides more complete use of the vegetation resource with better livestock distribution; and seeding and control of undesirable species may be integrated into a grazing plan without additional fencing for grazing control. Other advantages may accrue to the livestock resource by better concentration and birth rate, and increased weaning weights resulting from improved vegetation condition and production. Some disadvantages of specialized grazing systems are that investment cost of range improvements such as fencing and water developments increases with number of grazing units used in a livestock operation; many of the specialized systems may require relatively large land areas to have a viable management unit; herding and moving requirements are increased with associated increased labor cost; animals may be forced to graze less palatable, less nutritious forage on some parts of the range when specialized systems are used; and livestock grazing patterns may be disrupted with movement from one area to another that may result in depressing weight gains in the short term.

There has been considerable research done comparing livestock and vegetation responses with continuous grazing versus specialized grazing systems. Driscoll (1969) reviewed fifty reports related to these subjects. This review summary of twenty-nine studies indicated no constant relationship between livestock responses in terms of weight gains and specific grazing systems and particular kinds of vegetation. Site specific factors as quantity and quality of vegetation, management of animals, and the season of use were responsible for differences rather than grazing systems alone. His review of thirty-nine studies that compared the responses of vegetation, measured by increases or decreases of desirable species, under continuous grazing versus some other some indicated: (1) in three studies, vegetation condition improved under continuous grazing, (2) in thirty-one studies, vegetation condition declined under continuous grazing as compared to specialized system, and (3) in five studies, there was no appreciable difference in vegetation condition under continuous as opposed to a specialized grazing system.

Hickey (1966) did a comprehensive review of pertinent literature published between 1895 and 1966 related to grazing management systems. The information wsas compiled into a handbook to provide land managers with easy access to information on grazing management.

Based on the review of available literature, it is evident there is no magic formula that will identify the type of grazing system or management plan that will be the best, from the standpoint of achieving livestock management objectives and minimizing soil, vegetation and water quality impacts. The degree of water quality impact associated with any system wsill be closely related to soil erosion and sedimentation, associated with vegetation density and the concentration of livestock in and near water bodies. The grazing system must be designed on the basis of soil and vegetation capabilities, water quality considerations and livestock requirements.

The design of any grazing system must be based on a comprehensive inventory of the resources available on a particular area of land, and the diligent sue of experience, knowledge, and professional judgment in application of the principles of range management to meet specific management objectives, to provide beneficial results and mitigate adverse impacts. Livestock must have access to water. Although the literature is quite incomplete concerning effects of livestock grazing on riparian/aquatic ecosystems, there are many obserable examples where grazing has appeared to adversely affect stream banks, riparian vegetation, and water quality. There is considerable question whether rotational grrazing schemes will provide the necessary protection to riparian/aquatic ecosystems. In some cases, total exclusion of grazing by fencing water bodies and portions of streams may be necessary, particularly where fishery resources and water use values are high, provided that other grazing animals (wildlife and wild horses and burros) are not duly restricted from obtaining water.

Wild Free-Roaming Horse ane Burro Management

Western rangelands have supported a substantial population of feral horses and burros for several hundred years. Passage of the Taylor Grazing Act in 1934 result in the first broadscale attempts to control oversue and destruction of grazing lands and provide for conservation of the natural resource values inherent in these lands. Well into the second half of the 20th century, undomesticated horses and burros running at large on the range were considered as undesirable tresspass animals subject to partial or complete elimination in the interest of providing more water and forage for livestock and wildlife. They were not recognized as wildlife and were generally considered as estrays or abandoned animals under laws of the various states. The Wild Horse and Burro Act, Public Law 92-195, enacted December 15, 1971, has completely changed past practices. The Act defines wild horses or burros as all unbranded and unclaimed horses and burros on public lands administered by the Secetaries of Agricultural and Interior. The Act also states that "it is the policy of Congress that wild free-roaming horses and burros shall be protected from capture, branding, harassment or death and to accomplish this, they are to be considered in the area where presently found as an integral part of the natural system of the public lands." Cooperative agreements for the protection and management of wild horses and burros are authorized between the Secretaries of the Interior of Agriculture and state and local government agencies and with other landowners (Zarn et al., 1977). The Act was amended by the Federal Land Policy and Management Act (1976) authorizing the use of helicopters and motor vehicles by the authorized officer in administration of the Act.

The management of wild horses and burros presents a new challenge to public land management agencies such as the Bureau of Land Management (BLM) and the Forest Service (FS). Prior to 1971, management responsibilities of these agencies were limited to management of the habitat for animal species rather than actual management of animals. With the enactment of the Wild Horse and Burro Act (1971) the BLM and FS became responsible for managing wild horse andburro populations as well as the habitant on which the animals roam. Both agencies have developed plans for protection, management and control of wild horses. Both agencies have land use planning systems that evaluate the resource and then develop integrated planning and management for all the multiple uses of land area under consideration. These include the vegetative and watersheds conditions, wildlife needs, livestock use, recreational use, and other legitimate demands (Zarn et al., 1977). The Act provides that wild free-roaming horses and burros shall be managed in a manner designed to achieve and maintain a thriving natural ecological balance on the public lands. Thus, land use plans must make provisions for recognized wild free-roaming horse and burro populations as a part of the biological community subject to management under the principle of multiple use. Planning efforts must analyze the competitive impacts of all grazing animals on the rangeland resources and associated ecological condition and resultant water quality.

The key to managing wild horse or burro populations and their habitat, is a determination of the number of animals to be managed in any particular area. This determination must be based upon the ability of the land to produce forage for all animal species, including horses or burros, plus the compatability of use by horses or burros with other animal species and/or resource value. In some cases tradeoffs may be necessary for best multiple use management. Once the number of horses or burros to be managed on each area has been determined through the planning process, the first management action undertaken is actual reduction or addition of animals to obtain the "desirable number". Management of wild horse and burro populations differs from management of big game populations in that they are not huntable as a game species. Shooting of wild horse by persons other than officials of the Bureau of Land Management or Forest Service is prohibited by Federal law and is socially unacceptable. As a result, management of populations at the present time involves the live capture of wild animals. This is usually an expensive and time-consuming process. Captured animals are adopted out to private parties through a cooperative agreement for humane care and maintenance. As of May 1978, approximately 7,600 of these animals had been adopted by private parties. It is not possible within the purview of the Act to transfer title to wild horses and burros. As a result, some are reluctant to maintain wild horses or burros without the customary ownership rights. Animals not accepted for adoption may be destroyed in the most humane manner possible with customary disposal of the remains according to state sanitation standards. It is against Federal law to convert the remains of wild horses or burros into commercial use.

The first step in population management is to analyze those factors which have molded the population into what it is at present. Before management of horse or burro population can begin, the factors of population dynamics (productivity, mortality, sex ratio and age structure) must be collected and understood. These factors can then be analyzed to determine the forces which have shaped the population and to predict the numerical abundance of horses or burros in the future. As a result, a primary objective of wild horse or burro population analysis is to determine if the population is stable increasing or decreasing. The following formula represents one method for determining the stability of a horse or burro population:

A = Estimated number of adults in population (1 year and older)
B = Foal/100 adults (percent)
F = Number of foals
Zf = Mortality of foals (percent)
Nf = Mortality of foals (number)
Za = Mortality of adults (percent)
Na = Mortality of adults (number)
Y = Total population estimate adults and foals
P = Projected population
I = Population increase or decrease

$(A)\ (B) = F$
$(F)\ (ZF) = Nf$
$(A)\ (Za) = Na$

$A + F = Y$
$Y - (Nf + Na) = P$
$P - A = I$ (increase or decrease). If P is less than A, reverse P and A on formula. Values will be decreased in population.

$\frac{I}{P}$ = Population increase where P   A

$\frac{I}{A}$ = Population decrease where P   A

Once the stability of a wild horse or burro population has been determined it is necessary to analyze other population data prior to actual management of the population. For example, if the population is determined to be increasing in total numbers and it is undesirable to maintain such an increase, an analysis can be made as to the ratio of male animals to female animals in the total population. It may be possible to decrease the productivity of wild horses by increasing the number of male animals in relation to the number of female animals. In another example, if the population is determined to be stable, it is important to understand the reasons why. It may be that births are equaling deaths or that the population is on the brink of disaster. In this example, an analysis can be made as to the age structure of the population. If the age structure is balanced (i.e., all age classes adequately represented), it may not be necessary to perform anything additional in the way of management. However, if one or more age classes are lacking or totally missing, it may indicate that the missing age classes must be restored if the population is to survive (Zarn et al., 1977).

The extent, nature and degree of competition between wild horses and other domestic or wild animals for habitat components such as food, water, space and cover or other requirements has not been adequately investigated and a certain amount of controversy has existed over competition between feral horses and burros and other domestic and wild animals. Cook (1968), writing on the nutritive content of range forage for domestic ruminants, state that the most critical period for grazing animals that inhabit seasonal ranges are those months between December and April when inclement weather and perhaps poor range conditions cause animals to lose weight excessively. When range conditions are poor, the degree of utilization of the forage increases and the digestibility and nutrient content decreases because animals are forced to eat the less nutritious parts of the plants. Thus nutritional deficiencies are common on winter ranges of the Intermountain Region. The above would also apply to wild horses and burros in varying degrees over much of their range. It is inevitable that at some point in time, wild horses and burros will occupy the range during the same season as livestock, elk, deer, antelope. If, during these periods, forage is in short supply the various classes of herbivores will compete, and it is likely that the less dominant animals will suffer the most. Hansen (1975) does not think that wild horses compete strongly with mule deer or antelope on most ranges, but he would expect them to compete with cattle since their diets appear to be 60 to 98 percent similar. They may compete moderately with domestic sheep, bighourn sheep and elk.

The most important relationship between wild horse and burro grazing management and water quality is maintenance of population densities at levels which do not adversely affect range condition. Excessive numbers of grazing animals, including wild horses and burros, will have a short-term impact by overgrazing rangelands to the point that runoff is increased and water quality affected. Continued overgrazing will result in long-term deterioration of range condition which likewise affects runoff and associated water quality over a long period of time. As a result, it is imperative that wild horses and burros, as well as other grazing animal, be maintained at levels which do not contribute to overgrazing either in the long or short term.

A key factor in preventing overgrazing by wild horses and burros is the control of excessive numbers. The method most frequently used for wild horse and burro populations has involved a direct reduction in density by live caputre of animals. This control technique is not without complications. The reduction in density occasioned by the control measures leaves the quality of resources intact while increasing the quality available to each remaining animal (Caughley 1977). The result is that survival of the remaining animals is increased and the control program is inadvertently converted into one of sustained yield harvest. In other words, a never-ending cycle of capturing excess animals is created.

As better data is obtained and more experience gained, it is becoming more and more doubtful whether wild horse and burro populations are increasing at the phenomenal rates frequently ascribed to them in previous years. However, it is also highly probable that their rate of increase will be accelerated under programs involving direct reduction of numbers. As a result, it appears inevitable that at some point in time, control measures will have to be initiated which minimize the capture of excess animals. One such program involves the selective manipulation of the population's demographic structure with the objective of reducing productivity and enhancing natural mortality. This could be accomplished by altering sex ratios in favor of male animals and adjusting age structures to favor older animals. The result would be a reduction in foal production and accelerated mortality of older animals thereby minimizing the need for direct harvest of animals.

Additional information is needed in all aspects of wild horse and burro management. However, of particular concern is basic data relative to population dynamics, habitat use and competitive relationships among animal species. Much of this information can be obtained through basic inventory procedures but research is needed for more complex data requirements. An example would be the impact on the soil and vegetative resources and inherent features of water quality in the management of all large herbivores on western rangelands.

The management of wild horse and burro habitat is a controversial subject. Basically, this controversy centers around the question of whether horses and burros should be managed within their habitat similar to wildlife or similar to livestock. One primary question involved is whether wild horses and burros should be cycled through grazing management system in the same sequence as livestock or whether the animals should remain free-roaming as are most wildlife species. If horses or burros are managed similar to livestock, they would have to be manipulated to change their distribution patterns in a manner designed to prevent excessive forage consumption in any one area. If they are managed the same as wildlife, it would be necessary to assure that population levels do not exceed the number required to prevent excessive forage consumption in any one area. It may very well be that the answer to this question is contained in Public Law 92-195 and the regulations which implement that law. These documents contain very little discussion relative to the number of animals to be maintained in any particular area but give considerable emphasis to intensity of management for the animals with particular attention on free-roaming behavior as it relates to both management practices and facilities.

The literature concerning wild horses and burros and water quality relationships is even more deficient that that for livestock grazing effects on the riparian/aquatic ecosystem. Horses and burros, too, require water as part of their habitat needs but it is probably safe to assume that their impacts on the riparian/aquatic ecosystem are different than those of domestic livestock. (And because of their "free-roaming nature" and an "integral part of the natural system" such impacts may be more difficult to mitigate.) Wild horses particularly are generally not as likely to congregate in large herds around water sources and remain or "camp" for long periods of time such as domestic livestock are prone to do. They may consume less than domestic livestock of the woody shrub species which help provide stream bank stability and overhand shade for the water.

Since it is unlikely (and probably illegal) to manage wild horses and burros in specialized grazing systems to provide rest and rejuvination for stream bank vegetation, the most promising method for protecting streams and other water resources is to maintain horse and burro numbers at levels which mitigate adverse impacts to water quality. Another possible method for providing this protection could involve fencing certain segments of streams and other water sources to exclude use of these areas by horses and burros. However, horses are extremely wary animals and depend on keen senses of sight, smell and hearing, and speed of movement to avoid dangers. Protective fencing may not only impede the free-roaming nature of horses and burros, cause uneasiness and insecurity, limit accessibility to traditional water sources, but also may block traditional migratory patterns. A minimum of fencing, strategically and carefully located, might therefore be considedred. Other traditional livestock management techniques such as herding, salting, and grazing systems to protect water quality are clearly out of the question. Alternative water sources might be developed to lure horses and burros away from higher value water sources.

It might be concluded that the literature is woefully deficient concerning impacts of horse and burro grazing on water quality and present research efforts are almost nil. However, with foresight and planning, it should be possible to adequately mitigate adverse impacts on water quality resulting from horse and burro grazing by maintaing horse and burro numbers at appropriate levels, minimal fencing, and developing alternative water sources.

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APPENDIX III

RANGELAND TREATMENTS

Mechanical Rangeland Treatment

Overview

Vallentine (1971) has published a rather comprehensive treatise on rangeland development and improvements. Much of the material to follow has been taken from this book.

A basic premise of rangeland management is that vegetation can be harvested in perpetuity by grazing animals while simultaneously providing society with high quality air, water, open space, recreation, and other resource values and uses. Rangeland improvements are special treatments, developments, and structures used to improve range vegetation resources or to facilitate their forage use by grazing animals. Rangeland seeding, control of undesirable plants, fertilization, and pitting, contour furrowing, and waterspreading are direct means of developing and improving rangeland vegetation and forage resources. Rangeland improvements such as water developments, fences, and roads and trails provide more effective management of grazing and thus indirect improvement and more efficient utilization of the forage resources.

Rangeland improvements must be based on ecological principles of competition and succession. A first step in improving rangeland vegetation and forage resources is providing the desirable forage species with a competitive advantage for water, sunlight, and soil nutrients. The reduction of competition from undesirable plants through biological, mechanical, or herbicidal control induces plant succession in the desirable direction. Man, as part of the complex rangeland ecosystem, has a directing influence capable of manipulating the productivity of the ecosystem to his advantage. Rangeland improvement is principally involved in manipulating factors leading to increased productivity from rangelands.

Numerous reports suggest that the productivity and biological efficiency presently being obtained from rangeland ecosystems can be substantially increased. Rangeland improvement cannot be increased indefinitely because the controlling factors, which man either connot or should not manipulate because of environmental or economic constraints, place ceilings on productivity obtainable from rangeland ecosystems. The rate of induced succession is quite variable and determined by (1) the kind of rangeland ecosystem, (2) its extent of depletion, (3) climatic fluctuations, (4) the improvement plan, and (5) the efficiency of subsequent management of grazing animals (Lewis, 1969). Rangeland improvements are not limited to restoration or rehabilitation of depleted ranges. Fertilization and waterspreading can increase productivity beyond natural climax conditions by modifying controlling factors in rangeland ecosystems.

Rangeland improvements have many management implications. It is imperative that rangeland improvements be an intergral part of the planning and directing of rangeland use rather than being considered separately.

Rangeland improvements are best considered as supplementary aids available for achieving objectives of resource management. For example, only slight improvement can be expected on some brush and woodland-dominated ranges even after prolonged periods of good grazing management unless special brush-control treatments are applied (Pechanec et al., 1965). On the other hand, the full potential benefits expected from rangeland treatments, developments, and structures are realized only when accompanied by good grazing management.

Benefits from Rangeland Improvements

Although one primary objective may be sought in a rangeland improvement program, there are usually one or more secondary benefits to the rangeland resources. For example, a single rangeland improvement practive, such as contour furrowing, may increase water infiltration and forage production but also decrease water runoff, erosion, and sedimentation. Possible benefits from rangeland improvements include:

a. Increased quantity of forage. Problems that increased forage production could solve include balancing seasonal grazing capacity, reducing pressure on overstocked ranges, or replacing grazing capacity lost through land transfer, reduction in Federal grazing privileges, etc. Increased forage production must consider seasonal use. Is increased forage necessary on spring-fall ranges? Or is improvement of winter forage supplies most critical for mule deer?

b. Increased quality of forage. Providing forage of greater palatability, higher nutritive content, or longer green growth period may be desirable. A balance of browse for winter grazing and herbaceous secculent forage for early spring use may be the goal of big game rangeland management.

c. Increased animal production. The primary objective may include increased numbers of animals, increased numbers of offspring, increased weaning weights, increased condition, and reduce death losses. Removal of undersirable brush may reduce wool damage in sheep, and lamb losses from straying and predation.

d. Facilitate handling and caring for range animals. This is accomplished by brush control, fencing, corrals, water development, and trails.

e. Control poisoning of grazing animals by poisonous plants. This is accomplished by selectively removing poisonous plants, replacing existing poisonous species with non-poisonous species, or providing alternative sources of palatabel forage. Injury and associated diseases and parasites can be reduced by removing mechanically injurious plant species.

f. Reducing fire hazard. Possibilities include replacing flammable species, such as big sagebrush and cheatgrass, with less flammable species; and constructing and planting fire guards with plant species which deter fire movement and reduce heat intensity.

g. Increased water yields on watershed by replacing woody species with herbaceous plants. Replacement of chaparral on deep upland soils in California (Bentley, 1967) and on canyon-bottom brush-woodland by gras-

(Hill and Rice, 1963) increased water yields. Brush control often activates springs or increases spring flows (Biswell, 1954). Busby and Schuster (1971) calculated annual use of 43,770 and 7,200 acre-feet of water by saltcedar and mesquite, respectively, on a portion of the Brazos River flood plain in Texas. Several springs began to flow for the first time in memory following conversion of brush to grass on a portion of the Rocky Creek Watershed near San Angelo, Texas (Thomas, 1975).

h. Control of pests and diseases. The primary purpose is the control of insects and plant diseases by replacing host plants with others. An example is the replacement of certain weeds which host the beet leafhopper which is a carrier of curly top, a disease of sugar beets and tomatoes.

i. Control erosion by stabilizing erosive soils. In some cases, soil stabilization may justify restoration with secondary consideration given to forage production for grazing animals.

j. Reduce conflicts amoung multiple uses of range resources. Access roads and trails can provide better distribution and management of livestock as well as proper harvesting of big game animals by hunters. Reseeding denuded watersheds can provide necessary forage for grazing animals and clear water for fishing streams. Williamson and Currier (1971) indicate that applied landscape management enables natural beauty to be retained and even enhanced while accomplishing basic objectives of mechanical brush and woodland control projects.

Selecting Rangeland Improvements

The type of rangeland improvement must be carefully considered and properly located and utilized to provide maximum benefits. Guidelines to consider in selecting and locating rangeland improvements include:

a. Use only proven methods.

b. Rangeland improvements must be compatible with the goals of land ownership.

c. Consider availability of local or contract labor, necessary equipment, and supervisory or consultative assistance needed.

d. Evaluate rangeland improvement practices which can be most effectively utilized in the herd or land management plan.

e. Consider changes in management practices that will be required and maintenance that will be necessary.

f. Analyze cost efficient methods and evaluate cost-benefit ratios.

g. Apply rangeland improvement practices at appropriate time to achieve desired objective but, at the same time, avoid unnecessary disruption to the ecosystem.

h. Amount and character of residual vegetation cover and composition will influence choice of rangeland improvement practice.

i. Locate rangeland developments on areas of greatest potential for increasing range productiviey and/or decreasing soil erosion.

j. Plan animal handling facilities that are practical and beneficial both to the rangeland and to range animals.

k. Carefully evaluate the environmental impacts, both beneficial and adverse, of proposed rangeland improvement practices.

Economic Aspects

Rangeland improvements provide many opportunities for increasing vegetation production, forage, and cover for livestock, wildlife, wild horses and burros; reduction of runoff and sedimentation; protection and improvement of aquatic/riparian ecosystems; and herd management

The economic benefits from rangeland improvements should be carefully evaluated before funds are invested. Expected rates of return, risk of failure, maintenance costs, and availablilty of capital must be considered.

Governmental cost-sharing funds for rangeland improvements on private lands is available through various programs of the U.S. Department of Agriculture to encourage conservation practices on private lands. Since funds, labor, and equipment for rangeland improvements are also limiting factors on public lands, the cost-benefit ratio is equally important here as on private lands. However, non-market public benefits receive more consideration on public lands. Benefits to society, such as maintaining environmental quality, protecting the watershed, providing scenic vistas, are difficult to evaluate in terms of monetary value but are nevertheless real values.

Objectives and Planning

Rangeland treatments include mechanical and chemical means of vegetation control, seeding, soil tillage, contour furrowing, root plowing, earth fill and detention structures, or similar work that is performed to improve rangeland conditions that cannot be effectively corrected by livestock or wildlife herd management alone. Rangeland treatment practices are applied to bring about the most rapid improvement consistent with needs of the site and its potential for improvement. (Practices to be applied must be consistent with management objectives included in the land use plan.) Specific objectives usually are to: (a) control rate of overland and channel flow, water and wind erosion, and resultant soil losses; (b) improve soil development, infiltration rates, and moisture capacity, dilute soluble salts, and provide proper plant nutrients; (c) improve quality and quantity of the renewable vegetative resources; and (d) protect on-site and off-site values from sediment and flood damages.

Selection of treatment practices to meet the site depends on the objectives to be attained, benefits and limitations of individual practices, site suitability, local water quality criteria, and other considerations. The application of more than one practice on the same area often results in the greatest overall improvement. Site conditions may require the use of water control structures in addition to rangeland treatment practices. Most sites require specific analysis on which to base final practice selection and design. Analysis must be made of rangeland sites to determine if conditions exist that can best be corrected or improved by the application of treatment practices.

Physiographic and biological conditions to consider are vegetation and soil associations; erosion, water quality, channeling and water flow evidence; livestock, wildlife, and cultural values needing protection; and downstream values. Consider existing site conditions and proposed practice benefits, limitations, or requirements with respect to the potential of the site. The same items which caused the existing unfavorable site condition(s) or that indicate the need for improvement, may also limit favorable response to treatment, i.e. topography may be too rough to allow any kind of tillage practice, seasonal precipitation may not warrent seeding, or big game concentrations may exist that cannot be controlled.

Current rangeland use is an important factor to consider when selecting site and treatment practices. Temporary elimination or curtailment of uses may be necessary to prevent serious damage to new work and to permit existing vegetation to recover, or for seedings to become established. Areas subject to mining activities, geophysical explorations, oil and gas well drilling, and recreational development are questionable sites for treatment unless required protection can be assured. Special consideration must be given on public lands to areas containing archeological, historical, geological, or scientific sites to provide protection of the site and the natural surroundings.

Livestock grazing and wildlife and wild horse and burro habitat management plans should be completed on all areas proposed for treatment. When management plans are already in operation, treatment practices should complement the plans currently in effect, unless plan revision is appropriate. Deferment from livestock grazing in necessary when increasing vegetation cover is a primary objective of treatment. Deferment periods are based on plant ecological-physiological principles. Soils must be adequately firm and the plants well enough established so that damage does not occur under grazing use. Coordinate plans with other land managers when any part of the treatment will involve their interests in the lands or resources, including Section 208 water quality planning coordination.

Planning for rangeland treatment practices must be initiated well in advance of work plan schedules. Planning includes preparation of management plans in conjunction with other uses, arrangements for nonuse or other site protection, job design and specifications. The Range Seeding Equipment Handbook (USDA, USDI 1965) describes most of the specialized equipment currently used to accomplish rangeland treatment practices.

Good planning is imperative in order to meet total rangeland improvement construction needs. All plans should be checked before work is done to assure adequate protection of watershed values and coordination with other resources and uses. Constructed improvements should be field checked to assure compliance with standards and plans. The rangeland rehabilitation program is an integral part of resource management. Rangeland development work is directed by coordinating requirements of multiple-use management (USDA, Forest Service 1968).

Selected References

Rauzi, Lang, and Becker (1962) found in Wyoming on sandy loam soils that pitting shortgrass ranges did increase infiltration rates, even after five years following pitting. They fould during a second 30-minute period of one-hour test, that the test plots on the pitted pastures absorbed almost twice as much water as did the test plots on the pastures treated with the Wyoming range seeder, and almost four times as much as the pastures moderately grazed or as those treated with the sod drill. Rauzi (1956) also reported higher water infiltration on pitted rangeland in Wyoming.

Branson, Miller and McQueen (1966) discussed implements and general procedures used in pitting. They found pitting in Wyoming to be of limited value on course textured soils. They cited work that indicated the practice in some areas may have less value on some fine textured soils. Life of pits vary from less than six years to more than ten years. Consequently, the effectiveness and application of pitting depends to a large extent on the specific soil and site characteristics.

Branson et al., (1966) also found contour furrowing to be the second most productive treatment for increasing perennial grass yields on some sites used in evaluating various mechanical treatments in the Western United States. Broadbase furrows where earth was pushed down drainage to form a series of low dikes 45 to 60 centimeter height (1.5 to 2 feet) produced the highest yields of perennial grass. This treatment was applied to areas having medium to course textured soils, annual precipitation about 22.5 centimeters (9 inches) with native vegetation of saltbush converted to wheatgrass and Russian wild rye. Contour furrowing advantages outweight the disadvantages according to personal experience of Montana rancher Frank Sparks as reported by Sparks (1977) and Ell (1977). An inch of topsoil is built up every 50 years through decomposition of some plants turned over by the plowing. This concept is supported by Hormay (1970) and other scientists that soil is renewable and will regenerate if destroyed, but this process may take hundreds, if not thousands, of years. Land productivity depends on soil fertility. On rangelands, fertility is lost mainly through erosion. It is maintained by keeping a maximum protective cover of vegetation and organic litter on the soil.

Contour trenches sampled by Branson, Miller, and McQueen (1966) ranged from 1.5 feet (48cm) to 2.5 feet (76cm) deep when constructed. They found the treatment to have limited effectiveness in improving grass procustion but to be effective in reducing runoff and sediment. The major objective of the treatment was to contain all water and sediment on site and reduce erosion.

Ripping, chiseling, subsoiling and deep plowing are terms applied to similar treatments. The objective of the treatment is to fracture the soil, especially the subsoil, which may have a restrictive layer that inhibits root penetration, water infiltration, percolation and storage. Implements used for the treatment are discussed and evaluated by Branson et al., (1966) and Gifford (1975).

Hickey and Dortignac (1964) assessed runoff and erosion from ripping during a three year study in New Mexico on soils derived from shale. For untreated areas, surface runoff was as high as 89 percent of storm rainfall and annual erosion as high as 4,640 kilograms per hectar. With ripping (50 to 90 cm depth, 2.1 m apart) surface runoff was reduced 96 percent and erosion 85 percent the first year after treatment. Three years after treatment reductions were 85 percent for runoff and 31 percent for erosion. However, attempts to seed forage species during three successive years were largely unsuccessful under these circumstances which would limit the feasibility of applying the treatment on shale-derived soils. Auger ripping was the only mechanical treatment that actually decreased perennail grass production in the evalutaion of several types of treatment by Branson et al., (1966). On some of their plots runoff decreased annually. These results suggest under these circunstances that surface soil, not subsoil, modifications are essential for complete success in retaining water and sediment and also increasing forage production. Erosion and runoff varied with aspect and topographic position.

In a study on silt loam soils in Southern Idaho, Gifford (1972) and Gifford and Busby (1974) conducted intensive infiltrometer studies on a plowed big sagebrush site over a four-year period. Results of the study indicated there was a natural decay in the absorbtive capacity of surface soils with plowing. The apparent result of grazing (no grazing for two years following plowing and seeding) was not to reduce the minimal infiltration capacities measured on the respective site, but rather to eliminate seasonal trends so that infiltration rates were at the low end of the scale throughout the year. Grazing on the sites did not increase sediment production potentials beyond the increases expected as a result of mechanical disturbances associated with plowing.

Aro (1971) evaluated chaining (for conversion to grassland) and other conversion techniques applied to pinyon-juniper vegetation on public lands in Colorado, Utah, Arizona and New Mexico. Burning of debris was found to be the most effective in terms of conversion to grass. Dozing of trees into windrows, followed by seeding of grasses in the cleared area was the best mechanical approach examined, but requires careful site selection and economic evaluations. This is particularly the case for areas susceptible to soil erosion with potential water quality impacts. Aro suggested the technique should only be used on soils sufficiently free of rocks to allow drilling of grass seed. Slopes should not exceed 15 percent.

Gifford (1975) completed a comprehensive literature review of impacts of pinyon-juniper manipulations on watershed values related to infiltration, runoff, and water quality impacts. Suudies completed to date indicate that infiltration rates have only been slightly affected when comparing chained sites to the undisturded woodland. Course textured soils probably account for much of this. If there is a decrease in infiltration rates due to chaining activities, the decrease will probably occur on chained-with-windrowing treatments, this being the result of rather severe mechanical disturbance of surface soils during the windrowing process. The mechanical disturbance may actually increase permeability of surface soils but infiltration at the soil-air interface is decreased. Because of the variabliity on pinyon-juniper site characteristics, it is difficult to pinpoint exactly those factors that consistently influence infiltration rates. The impact of grazing on inflitration rates appears accumulative (up to some undefined point), and effects of even a single grazing season can be detected. Complete protection for four years of a grazing site in sandy loam soils restored infiltration capacities to a maximum. Burning of debris appears to depress infiltration rates. Given a runoff event due to high intensity rainfall, least runoff may be expected from sites chained with debris-left-in-place, followed very closely by the natural woodland and also sites which have simply been sprayed to kill the vegetation. Greatest runoff will occur on sites chained with debris windrowed. Where water yield is important, spraying (but not tree removal) is most effective in the Utah juniper type. At higher elevations in Arizona where alligator juniper is found, tree removal may result in a slight increase in water yield. Where only select areas of watersheds are treated or where tree densities are low, increases in water yield should not be expected. Indications are that sediment discharges have not increased on pinyon-juniper sites due to vegetation manipulation practices. An exception to this is the increased quantity of sediment produced from debris-windrowed sites during high intensity thunderstorms in Utah. Factors influencing sediment yields at given points on a pinyon-juniper site are variable from site to site. Minimum sediment yields (equal to that from undisturbed woodland) may be expected where surface soil disturbance is minimized (as with spraying a herbicide) or where debris is left in place on a chaining project; chemical aspects of water from pinyon-juniper sites indicate good quality water suitable for irrigation, public water supply, and for aquatic life. Potential public health hazards of livestock grazing on semiarid open range on gentle slopes appears to be minimal. Given a runoff event, during the first year from burned debris-in-place sites may contain increased amounts of phosphorus and potassium, but not calcium, sodium or nitrate-nitrogen.

Hibbert, Davis and Scholl (1974) published a report on the chaparral conversion potential in Arizona. Chaparral control methods that have proven effective in Arizon are not plowing, prescribed burning, chemicals (herbicides), and chemicals (herbicides) in combination with the others. Stream water from treated watersheds shows moderate to low contamination by herbicides. Over the long run, conversion should reduce erosion by reducing or eliminating the heavy erosion cycle set off by periodic wildfires in unmanaged chaparral. On areas favorable for treatment, conversion to grass reduces fire hazard and substantially increases water yield and forage for livestock. If treatment areas are kept small and interspersed with native chaparral, protective cover and browse for game animals will always be available nearby, and the edge effect created by the openings will enhance the overall environment for wildlife.

Chaparrall in Arizona is used far below its potential (Cable 1975). Conversions to grass can greatly increase water and grass production, and improve wildlife habitat. Management options include conversion to grass, maintaining shrubs in a sprout stage, changing shrub composition, reseeding, and using goats to harvest shrub forage.

Fisser (1968) found herbage production increased on both arid and mesic sites in Wyoming following the sagebruch and grazing control treatment wil the greatest increase occurring on the mesic site. Average annual soil temperature was greatest at the arid site and was warmest in the shrub-dominated areas at both sites. Soil moisture accumulation during the spring period was greatest at the mesic site from 24 to 60 inches below the soil surface and the greatest values occurred in the shrub controlled grassland area.

Conclusions from the Cornfield Wash Watershed study in New Mexico and the Boco Mountain Watershed study in Colorado were reported by Shown (1971). Amount of vegetation plus mulch cover was found to explain 79 percent of the variance in sediment yield for a set of eight small watersheds that represented the full range of hydrologic, geologic, and biotic conditions in the Cornfield Wash area of New Mexico. Vegetation amounts appear to be the result of the intergrated effects of slopes, soil types, and drainage densities. Because these same variables also affect runoff and sediment yield, a high degree of correlation existed between vegetation cover and runoff and sediment yield. The Cornfield Wash watersheds are essentially grass-covered, but have patches and stringers of shrubs. Sheet and rill erosion is most evident in the parts of the watersheds covered by big sagebrush and juniper, but because these types usually covered less than 10 percent of the watersheds, their effect on runoff and sediment yield at the reservoirs appeared to be monor. A short record at the Boco Mountain watersheds in Colorado indicated that sediment yield was greatly reduced when big sagebrush cover was converted to beardless bluebunch wheatgrass cover. This was attributed to a significant increase in vegetation plus mulch cover on the grassed watersheds which reduced runoff during the April-to-October period, and which appeared to retard overland flow, decrease soil detachment, and decrease rilling.

Further conclusions were reported by Shown, Lusby and Branson (1972) from the Boco Mountain Study. At the Boco Mountain watersheds in western Colorado big sagebrush appeared to use slightly more soil water than beardless bluebunch wheatgrass. The sagegrush extracted water from deeper in the soil and from the fractured shale beneath the soil and also extracted water from the soil to a lower soil water potential, thus removing slightly more water than the beardless bluebunch wheatgrass. The waterpotential data coupled with root data also suggested that slightly more water was removed by evaporation from the soils of the sagebrush watersheds which likely was related to the barren interspaces being about 3 times larger in the sagebrush than in the grass. The beardless bluebunch wheatgrass used the soil moisture resource more efficiently than the big sagebrush as about 300 pounds per acre more usable forage was produced annually. The grass provided about one-fourth greater vegetation cover and the smaller interspaces among the grass plants protected the soil from erosion better than the sagebrush.

The status of our knowledge with the ecology and management of southwestern semidesert grass-shrub ranges was presented by Martin (1975). Mesquite control was proven beneficeal throughout almost all the semidesert area. Several mechanical and chemical control methods have been developed; each is peculiarly suited to certain situations. The average rancher with a mesquite-infested range can supply forage for additional cattle much more cheaply by controlling mesquite than by purchasing additional land. The value of controlling creosotebush, cactus, burroweed, and snakeweed is much less clear. Acceptable procedures for seeding have been developed for ranges with annual precipitation of 13 inches or more. The success of seeding of drier ranges is less certain, but can be enhanced greatly by pitting to increase infiltration. New seedings must be protected from grazing for at least one growing season; protection for two seasons is recommended.

Earth structures, diversion dams and gully plugs with water spreaders were construced on mountain meadows in Nevada to collect sediment and raise the water table (Eckert 1975). An effective dam can (collect sediment and) raise the water table. After a channel is cut, an effective dam is necessary to raise the water table to a level required by mesic, productive meadow species. The height of water table maintained will influence the productivity of native and introduced species.

Resource conservation areas have been developed by BLM in all the western states to demonstrate the effectiveness of management planning for rangeland developments, treatments and implementation of allotment management plans. One such large scale program is the Vale Project in Oregon. The Vale rangeland rehabilitation program was analyzed by Heady and Bartholome (1977). The report discusses the initiation, execution, and outcome of an 11-year program of range rehabilitation on public lands in southeastern Oregon. Initiated primarily to benefit the livestock industry, the investment of $10 million in range improvements also profoundly affected other multiple-uses. The analysis of this large and successful program should serve as a useful guide for monitoring other range programs.

Design and construction specifications for rangeland improvement practices, treatments and epuipment are included in the Soil Conservation Service's National Engineering Handbook (1966), the paper by Branson et al., (1966), Bureau of Land Management Watershed Conservation and Development and Engineering Manuals (1968), Forest Service Structural Range Improvement and Engineering Handbook (1968), and the USDA-USDI Range Seeding Equipment Handbook (1965). Principles and practices for range development and improvement are covered by Valentine (1971) as well as in the above handbooks and manuals.

Summary Features of Mechanical Rangeland Treatments and Water Quality Relationship

a. The major objective of most mechanical rangeland treatments is to improve vegetation production by increasing moisture storage and reducing soil erosion. This objective is usually consistent with minimizing water quality impacts on a long term basis or after improved vegetation establishment.

b. The fact that certain mechanical rangeland treatment practices increase soil moisture availability has been well documented. The impacts of some of the practices have been to reduce runoff and possibly reduce erosion, however, exact quantitative data is lacking.

:. The most consistent beneficial response to mechanical rangeland :reatment in terms of vegetation production and reduction of runoff and :rosion in cited research occurred on medium (very fine sandy loam, loam, ;ilt loam and silt) to fine (sandy clay, silty clay, and clay) textured ;oils.

l. With severe soil disturbance resulting from many mechanical rangeland :reatments, it is essential that sites be conducive to vegetation establish- ient with seed after the treatment if completed. Since the life of most iechanical rangeland treatments is relatively short, it is essential to iinimize water quality impacts from sediment that a desirable vegetation :over be established and maintained.

:. Soil characteristics (texture, structure, consistency and moisture iolding capacity), climate, type of vegetation, and implements used are the)rincipal variables that determine water quality impacts of any treatment. \n understanding of these variables is essential to evaluate the potential iechanical rangeland treatment for or to minimize the water quality impacts 'rom any mechanical rangeland treatment.

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Prescribed Burning

Overview

An important and sometimes controlling factor affecting plant succession in much of the western United States has been fire. As a result, prescribed burning can be used as a natural and effective management tool. The use of this practice varies considerable in the eleven western states. It has not been tried in some areas and has not reached its maximum potential in others. This is because of recently developed fear, misunderstanding and bias toward fire, as well as a general lack of knowledge of the effects of fire on vegetation, the animal life it supports, and water quality. Factors associated with human population densities and distribution patterns have also affected the use of fire. In California for instance, (Bush, 1978) indicated that high liability insurance rates have significantly reduced the frequency of burning.

The concept of fire management is becoming increasingly apparent and in may realms is replacing the restrictive "fire control" approach. Because of this increased emphasis, prescribed burning is being recognized as an efficient range management tool and is being utilized by land management agencies and private land owners to obtain management objectives.

The effectiveness of burning as a technique for improving rangeland conditions has frequently been demonstrated and documented. Beneficial vegetative changes have been noted and recovery rates studied. Big sagebrush and grass vegetative types have been successfully restored to more productive rangeland using prescribed burning practices. More thorough discussions of burning as a range management practice is included in (Dillion, 1967), (Pechaenec, et al., 1944 and 1965), and (Wright, et at., 1965).

Prescribed burning also impacts wildlife habitat. Some wildlife species may benefit, others will not. (McGowan, 1978) indicated that fire can open monocultures and produce patchy vegetation mix with the newly developing vegetation being quite nutritious and palatable to wildlife. Large burns that destory vegetational diversity and are reseeded to provide a large monoculture will be deleterious to wildlife.

The impacts of water quality as a result of prescribed burning have not been well documented, and a significant lack of information is apparent. (Gifford, 1975) pointed out that there is limited documented information available related to the hydrologic impact of burning as a management tool for rangeland resources. Collection of water quality data has been extremely limited and interpretations have restricted value.

Although the documented affects of fire on water quality are not extensive, it is possible to make some reasonable predictions as to the impacts under identified conditions. These predictions are based on the experience of rangeland managers, existing soil, vegetation and runoff studies and documented observations following natural and prescribed burns.

(Gifford, 1975) stated that fire will influence infiltration by changing variables upon which infiltration seems dependent such as characteristics of accumulated litter, soil surface area, structure, porosity, apparent liquid-solid contact angle, and solute concentration of the infiltration water.

Following burning, soil movement is usually related to the intensity of the fire (Wright et al., 1976). Intense fires increase runoff and may increase erosion (Connaughton, 1935; Holland, 1953; Rowe, 1955; Hussain et al., 1969), whereas low intensity fires leave some litter on the soil surface and have little or no effect on surface runoff and erosion (Biswall and Schultz, 1957; Agee, 1973). Thus it appears that cover is by far the most important variable related to soil erosion (Packer, 1951; Bailey and Copeland, 1961; Orr, 1970).

Slope is also a critical factor. Wright et al., 1976 indicated that erosion, runoff, and water quality were unaffected on level areas, but there were adverse effects on moderate and steep slopes. With such a wide variety of conditions in the western states the results from studies on the effects of burning on water quality have been quite variable. (Gifford et al., June 1976) did not find significant changes in potential sediment production during a grazing and burning study in Utah. A high natural variability existed among the study locations and it was concluded that any changes in potential sediment production due to grazing or burning were masked by this natural variability. Second year trends, however, indicated an increase in potential sediment production.

The movement of nutrients to the aquatic system has received limited study. Even more unclear is the impact such movement may have on water quality. In certain instances, particularly where water impoundments or lakes may be involved, the impacts could be significant.

Stored nutrients are released when vegetation is burned and it is possible for these nutrients to be transported from the site by erosion and overland flow. Gifford et al. measured phosphorous and potassium in overland flow following burning on chained with debris-left-in-place sites. They found significant increases in phosphorus and potassium. Wright et al. concluded that nutrient and organic matter losses due to erosion following burning, were relatively low in porportion to the amount available in the upper 6 inches of the soil profile.

The significant water quality impacts from burning would generally come from poorly exacuted burns which through increased runoff and erosion result in sediment delivery to water bodies. The degree of pollution would depend upon the quantity of sediment and the quantity of nutrient and pesticides the sediment may be carrying.

Prescribed burning is in many cases beneficial to water quality by reducing the long-term potential for erosion and sedimentation. This is accomplished when prescribed burning in conjunction with other range management techniques results in changes in type and density of vegetation that provides greater erosion protection than was originally present. The degree to which this benefit is being achieved is quite variable and not well documented.

In summary, prescribed burning could have both adverse and beneficial impacts on water quality. In order to control the adverse impacts and derive maximum water quality benefits the following guidelines are suggested:

- All burns must be carried out in accordance with a burning plan which has been developed to achieve minumum disruption of cover, balanced with achieving disired vegetatve changes.

- Prescribed burning plans should establish the objectives, priorities, and technical procedures to be used in carrying out the burn and should conseder the following site and watershed characteristics: litter accumulations, availablity of fuel, soil type, stability and moisture content, susceptabilty of soil to water repellency, annual precipitation, slope exposure and steepness, vegetation, recovery potential, and location of the area in relation to streams and lakes. Other factors are season of year and wind conditions. Each of these factors affect the results of burning in a unique manner and vary greatly depending upon their interaction with other factors and climatic conditions.

- Burning plans should consider location of critical wildlife habitat and distance from aquatic habitat systems.

- Burning plans must address the risk of wildfire ignited from the prescribed burn areas and contain measures to minimize this risk. Wildfire conditions have potential for severe watershed damage and quality impairment.

- Each of the factors previously mentioned justify a detailed discussion, but it is the rangeland manager that must understand the effects of each factor on the burn and prepare a plan that will achieve both rangeland and water quality objectives.

- State and Federal land management agencies with assistance from researchers and ranchers have developed prescribed burning plans to a reasonable high level. Persons wishing to practice prescribed burns who have limited experience with the techniques involved should request technical assistance from the appropriate agency.

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Use of Chemicals

Overview

There are number of chemicals used for a variety of purposes in range management. Some of the major uses are for fertilization, pest control, and predator control. The various chemical compounds available for use, the efficacy, and types of chemicals that should be used for various practices are beyond the scope if this document. The discussion here is intended only to provide general information related to use of chemicals and some rules of thumb for protecting the environment if chemicals must be used on range management.

Pesticides and fertilizers enter water bodies by several means: (1) erosion, (2) runoff water, (3) escape of chemicals during application, (4) volatilization and redeposition of chemicals, and (5) accidents and incorrect container disposal. An obvious but fundamental means of reducing potential water pollution from pesticides is correct usage. It is essential that users follow recommended application techniques and not exceed precribed dosages for specific pest problems and plant and soil needs for fertilizers, Washington State University (1971).

The major route of pesticides to waterways is via soil erosion. Because of the tight binding characteristics of pesticide residues and some fertilizers, especially phosphorus, in many instances pollution of water by these chemicals occurs throught the transport of soil particles to which the residues are attached. Since most pesticides adhere readily to soil, any range practice that is likely to cause erosion in areas where chemicals are used is also likely to facilitate entry of the chemical materials into lakes and streams. Limiting the use of chemicals on erosion-prone soil will reduce the pollution potential, EPA (1973).

Nonpersistent pesticides pose only short-term problems from erosion or runoff. Persistent pesticides are a more serious threat to waterways from water and wind erosion. Persistence depends primarily on the structure and properties of the compound and, to a lesser degree, on location in or on the soil complex. There is wide variation in persistence amoung different pesticides. The amount of pesticides entering water bodies is influenced by the method of application and solubility and volatility of the chemicals. Chemicals incorporated into the soil, rather than left on the surface of soil or plants, are less subject to movement by runoff water and to evaporation. Most chemicals used in range management are applied in liquid form as a spray or in solid form as a dust or granule. Most methods of application are imperfect in that some of the chemicals reach nontarget organisms. The major reasons are lateral displacement (i.e., wind drift) and volatilization. Where this process occurs, the chemical material may enter open bodies of water directly, or after fallout and washout from nontarget areas.

Insecticides used to control livestock pests may be applied by various means, such as feed additives, backrubs, sprays, pour-ons, liquid dips or barn fumigation. Pesticide exposure to the environment is minimal with these type applications with correct use. With the exception of dumping or accidental spillage, the potential for water pollution is very limited.

Container Disposal

Pesticides can enter the environment through careless or improper disposal of containers and unused materials. If these items are deposited or burned, pollution may result through washout or fallout. The Federal Insecticide, Fungicide and Rodenticide Act as amended in 1972 (Public Law 92-516) directed EPA to issue procedures and regulations governing the disposal of pesticide containers. Regulations for acceptance and recommended procedures for disposal and storage of pesticides and pesticide containers were published May 1, 1974 (Federal Registar, Volume 39, Number 85). The regulations should be reviewed prior to disposal of pesticide containers and residue.

Some key features of the rules and regulations are:

· As a general guideline, the owner of excess pesticides should first exhaust the two following avenues before undertaking final disposal:

  o Use for the purposes originally intended, at the prescribed dosage rates, providing these are currently legal under all Federal, State, and local laws and regulations.

  o Return to the manufacturer or distributor for potential re-labeling, recovery of resources, or reprocessing into other materials. Transportation must be in accordance with all currently applicable U.S. Department of Transportation regulations.

· To provide documentation of actual situations, all accidents or incidents involving the storage or disposal of pesticides, pesticide containers, or pesticide-related wates should be reported to the appropriate EPA or State Office for pesticide regulation.

No person should dispose of or store (or recieve for disposal or storage) any pesticide container or pesticide container residue:

a. In a manner inconsistent with its label or labeling.

b. So as to cause or allow open dumping of pesticides or pesticide containers.

c. So as to cause or allow open burning of pesticides or pesticide containers; except, the open burning by the user of small quantities of combustible containers formerly containing organic or metallo-organic pesticides, except organic mercury, lead, cadmium, or arsenic compounds, is acceptable when allowed by State and local regulations.

d. So as to cause or allow water dumping or ocean dumping, except in conformance with regulations.

e. So as to violate any applicable Federal or State pollution control standard.

The following general guidelines from the Washington State Pest Control Handbook (1971) if followed will go a long way toward minimizing water quality impacts of chemicals used in range management:

- Do not use pesticides unless there is a definite need for insect, disease or plant control

- Be sure you have a problem that pesticides can correct. Apply them as specific treatments, not as general remedies.

- Use them only on crops or plants that are being attacked by the insect or disease or that are to be suppressed. Do not apply them to other plants.

- Do not apply more spray or dust than needed. A thorough, light application is more effective than a heavy, spotty one.

- Avoid the need to dispose of pesticides by making up only the amount of spray you need.

- Do not flush surplus pesticides down the drain into sewage or septic tank systems, for relatively small amounts of material:

    -- Select a disposal site on your property where you can dig a hole at least 18 inches deep.

    -- Make sure the site is on level ground and not close to streams, wells, ditches, or other water supplies. It should not be near the garden or the roots of trees, shrubs, or grass, Avoid areas where children or pets might dig or play. Also avoid gravelly soil.

    -- Pour the pesticide in the hole. Rinse the container three or four times and pour the rinse water in the hole. Wear neoprene-coated gloves. Cover the pesticide with at least 18 inches of soil.

    -- Wash off the gloves with soap and water; then wash your hands with soap and water.

    -- Keep from having to dispose of pesticides by buying no more than you need for the planned pest control job.

There are a number of good references available related to safe use of chemicals in the environment. Some of these are Washington State University (1971), Oregon and Washington State Universities (1973), Gratkowski and Stewart (1973), USDA and EPA (1975) and EPA (1977). In addition to references, State Agriculture Departments, Extension Services, local county agents and Soil Conservation offices also have information on appropriate chemicals and their safe use for range management practices.

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The report is a State of the Art Reference of methods, procedures and practices for including water quality considerations in livestock grazing management activities. The document identifies existing and potential hazards to water quality, practices or methods suitable for preventing or minimizing water quality impacts, and alternatives for the assessment of a rangeland watershed's total runoff and pollution production.

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