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Environmental Impact Resulting from Unconfined Animal Production

Environmental Protection Technology Series

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ENVIRONMENTAL IMPACT RESULTING FROM UNCONFINED ANIMAL PRODUCTION

by

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FOREWORD

The Environmental Protection Agency was established to coordinate administration of the major Federal programs designed to protect the quality of our environment.

An important part of the Agency's endeavors to fulfill its mission involves the search for information about environmental problems, management techniques and new technologies through which optimum use of the nation's land and water resources can be assured. The primary and ultimate goal of these efforts is to protect the nation from the scourge of existing and potential pollution from all sources.

EPA's Office of Research and Development conducts this search through a nationwide network of research facilities.

As one of these facilities, the Robert S. Kerr Environmental Research Laboratory is responsible for the management of programs to: (a) investigate the nature, transport, fate and management of pollutants in groundwater; (b) develop and demonstrate methods for treating wastewaters with soil and other natural systems; (c) develop and demonstrate pollution control technologies for irrigation return flows; (d) develop and demonstrate pollution control technologies for animal production wastes; (e) develop and demonstrate technologies to prevent, control or abate pollution from the petroleum refining and petrochemical industries; and (f) develop and demonstrate technologies to manage pollution resulting from combinations of industrial wastewaters or industrial/municipal wastewaters.

This report is a contribution to the Agency's overall effort in fulfilling its mission to improve and protect the nation's environment for the benefit of the American public.

William C. Galegar

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ABSTRACT

This report outlines and evaluates current knowledge related to environmental problems resulting from unconfined animal production. Animal species directly addressed are cattle, sheep, and to a limited extent, hogs. Information for the report came from literature and current research reviews plus direct inputs from a group of 17 specialists in the subject field.

Unconfined animal production utilizes about 40% of U.S. land area, consists of hundreds of thousands of individual units, receives almost 50% of all livestock wastes, and is compatible with a high quality environment. Associated environmental problems are limited to those that affect surface water quality. These nonpoint source problems are not directly related to number of animals involved; they are intimately dependent on hydrogeological and management factors and are best described as results of the erosion/sediment phenomenon.

Unconfined animal production can cause changes in vegetative cover and soil physical properties that may result in increased rainfall runoff and pollutant transport to contiguous surface waters. The most common stream water quality change is elevated counts of indicator bacteria. Increased levels of inorganic (eroded mineral soil) and organic sediments with associated plant nutrients and oxygen demands may also result from certain high impact or problem areas where inadequate management and/or poor site conditions exist. These areas are usually only a small portion of the total production area and are readily identified by observation. The pollutant levels from the remainder of the production area are seldom discernible from background levels and, on an areal basis, are of the same magnitude as yields to land from rainwater and yields from relatively undisturbed lands. If other changes occur (such as to affect groundwater or air quality), they are either at such low levels as to be of no environmental consequence, or they are so site specific that they are not characteristic of unconfined animal production.

Prediction of increases in pollutant yields to receiving waters due to unconfined animal production is not possible with present state of the art technology. In principle, control is realized by locating high impact, problem areas according to hydrological dictates and by following good management practices. One major challenge is to demonstrate cost-effective routes toward achievement of various levels of control.

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SECTION I

FINDINGS AND CONCLUSIONS

Generally, unconfined animal production is both environmentally sound and compatible with a high quality environment. Documented cases of pollution resulting from production of livestock on pasture and rangeland are limited, indeed. Furthermore, all the available data indicate that neither the number nor the seriousness of environmental problems resulting from unconfined animal production is directly related to the number of animals involved or to the amount and characteristics of animal wastes generated. Rather, these nonpoint source problems are intimately dependent on hydrogeological and management factors, and are best described as results of the erosion/sediment phonemenon.

Unconfined animal production can cause changes in vegetative cover and soil physical properties that may result in increased rainfall runoff and pollutant transport to contiguous surface waters. The most common stream water quality change, and often the only change that can be definitively discerned, is elevated counts of indicator bacteria. Increased levels (concentrations) of inorganic (eroded mineral soil) and organic sediments with associated plant nutrients and oxygen demands may also result from certain high impact or problem areas -- where inadequate management and/or poor site conditions exist. These areas are usually only a small portion of the total production area and are readily identified by observation. The pollutant levels from the remainder of the production area are seldom discernible from background levels and, on an areal basis, are of the same magnitude as yields to land from rainwater and yields from relatively undisturbed lands. There is some evidence that pollutant yields (amounts rather than concentrations) increase in direct proportion to rainfall runoff from these non-problem areas. Seemingly, this is more generally the case when the stocking rate is relatively large. If other changes occur (such as to affect groundwater or air quality), they are either at such low levels as to be of no environmental consequence or they are so site specific that they are not characteristic of unconfined animal production.

Prediction of increases in pollutant yields to receiving waters due to unconfined animal production is not possible with present state of the art technology. As measured in receiving streams, these increases are not only usually small in value but extremely erratic in occurrence as well. As a first approximation, factors that govern erosion/sediment yields also are the factors that govern pollutant yields from unconfined livestock systems.

While organic materials entering surface waters from these systems may exert oxygen demands in water quality tests, the organics are usually relatively unavailable to organisms indigenous to the receiving waters and, thus, may not materially affect oxygen kinetics in receiving streams. Increased yields of chemical constituents such as nitrogen and phosphorus are generally so small that they are confounded in streams with background levels. The actual significance or meaning of elevated bacterial counts in this case is not clear. Bacterial indicators are reputed to be the most sensitive index of water quality impacts resulting from unconfined livestock. These organisms are properly used to designate the bacteriological safety of potable water. Their presence in water is accepted by public health authorities as an indication of fecal pollution. Whenever water is polluted with fecal waste, it poses a potential health hazard if used untreated for drinking or body contact recreational purposes. There is a dearth of documented cases of health problems correlated with bacterial indicators counts in water related to unconfined animal production systems, but this may be due solely to the lack of intensive and systematic research in this area.

While certain specific questions such as desired level of control and best methods to achieve water quality goals remain unresolved, the basic concepts, methods, processes, and procedures needed to reduce pollutant yields from unconfined animal production systems are available in principle. Since the pollutants are nonpoint in origin, control methodology is effected through changes in the production management system; i.e., by incorporating practices involved in controlled grazing, regulated animal congregation patterns, sustained forage production (establishment and protection of desired species), intensive erosion control, and proper land use.

Pasture and rangeland management practices leading to optimal forage production on a long-term sustaining basis, such as that resulting from maintaining correct stocking rates and forage production practices with erosion control, are also those practices which minimize environmental impacts. Still, less pollutants would reach streams if the operating philosophy of such production systems were broadened to include control or elimination of any problem areas. On the other hand, when exploitive production (poorly managed) is followed, unnecessary detrimental effects on surface water quality are likely to occur. These systems may require major modification/adaptation to meet environmental goals as well as to achieve other objectives which govern pasture and rangeland use.

One major challenge is to demonstrate cost-effective routes toward achievement of various levels of pollution control for unconfined animal production systems. Whether resources should be used to reduce pollutant yields from a given production system really requires an on-site evaluation of whether the pollutants have a real adverse effect on the quality of the receiving water and whether the yields can be significantly and definitively reduced. Certainly, control will be difficult and costly if control is defined as the ability to establish and enforce effluent standards. In cases where pollutants from livestock activity are not discernible from background levels, little or no change may be noted in stream quality even when significant efforts and resources are expended on control. However, if control is approached using well-planned management practices that include pollution control as an integral part rather than a laissez faire approach, the impact of unconfined animals will be well within acceptable limits and in keeping with the national water quality goals.

SECTION II

RECOMMENDATIONS

1. Exploitive range and pasture management practices such as overgrazing are to be discouraged due to the associated potential of increased rainfall runoff inputs to contiguous surface waters. Mechanisms should be developed so that intensive, well planned management practices that are supportive of long-term, sustained forage yields will be adopted. While no regulatory action seems justified to further reduce the environmental impact resulting from such well managed systems, the operating philosophy of these systems should be broadened to include pollution control for any high impact problem areas.

2. Multidisciplinary and multiagency review teams should be used to evaluate specific environmental problems resulting from unconfined animal production and to recommend changes in management practices to correct the problems. Their recommendations should be applied in concert with established regulatory procedures.

3. Regulatory programs should account for local (site specific) conditions. Regulated changes in management practices should be restricted to those documented to have measurable water quality benefits for receiving waters. Due to the low level of pollution associated with unconfined animal production, regulatory programs that would in general discourage or restrict livestock production on pasture and rangeland should be avoided.

4. When developing or modifying management practices for unconfined animal production systems to include environmental protection, logic and field observation suggest that consideration should be given to the following concepts:

   a) Install and maintain an effective and complete program of soil erosion control.

   b) Follow stocking rates and controlled utilization of forages (e.g., rotation, deferred, and seasonal grazing) that reduce erosion and waste accumulation. Reduce stocking rates in problem areas and at critical times or seasons. Stocking rates and grazing programs should be tailored to the soil vegetation, topography, hydrogeology, and microclimate of the particular site.

   c) Avoid animal stocking rates and other practices that create holding areas rather than grazing areas. Promote necessary animal congregation in areas that are hydrologically remote from streams and other major drainage channels. Periodically move bedground, shelter, salting, feeding, and/or watering areas to control waste accumulation, soil compaction, and erodible paths and areas.

d) Maintain to the extent ecologically feasible, highly productive forage and dense ground cover on the land to decrease volume and rate of runoff, to entrap and hold animal wastes, to utilize fertilizer nutrients, and to prevent erosion. Increase herbaceous cover in proximity of stream banks, downslope from animal congregational areas, and on other critical areas.

e) Where the number of animals per unit area or the characteristics of the site present pollution problems, appropriate drastic management alternatives/practices may include:

(1) Restrict animal access to critical areas. Use fencing to prevent livestock from entering highly erodible areas and critical stream or pond reaches and to prevent animals from wading in water. Provide summer shade (trees or artificial shelters) and insecticides to lessen the need for animals to enter water for relief from heat and insects. Block erodible paths with physical barriers and revegetate eroded paths. Move drinking facilities outside critical areas.

(2) Increase rate of fecal degradation and incorporation. Modify feed formulation and/or texture. Use tillage to break up, manipulate, and incorporate wastes in particular problem areas.

(3) Use land forming and diversions to modify drainage patterns.

Total stream fencing and other drastic controls will usually be both unnecessary and impractical except for a few problem areas within an operation.

5. In view of the many desirable characteristics of unconfined animal production compared with alternate livestock production techniques, adequate research, management, and educational resources should be allocated to:

a) Assess the importance and significance of increased levels of pollutants (indicator bacteria, plant nutrients, and oxygen demands) in surface waters (streams and impoundments), with consideration given to fate of the pollutants and uses of the waters.

b) Increase operational understanding, improve design, and demonstrate effective management practices of control concepts (through study of pilot/demonstration sites).

c) Demonstrate water quality benefits of control practices.

d) Demonstrate cost-effective routes for achieving various levels of environmental protection.

e) Ultimately develop models of the environmental impact resulting from unconfined animal production that can be used to help in the design of best management practices for each sub-part of the total system.

f) Develop technology and establish educational and assistance programs that encourage producers to adopt management practices that include environmental protection.

6. Several areas do not need additional research:

a) Studies of environmental problems associated with unconfined animal species other than cattle and sheep seem unjustified since there are such small numbers of these species in unconfined systems and it should be possible to design adequate controls for such systems by extrapolation from cattle and sheep systems.

b) Studies of pollution problems other than those associated with increased levels of sediments, nutrients, and bacteria in surface waters seem inappropriate. Studies of air and groundwater pollution, for example, could only be expected to yield inconclusive or negative results. Other potential hazards such as those associated with using insecticides and herbicides are not unique to unconfined animal production systems and, thus, should be covered in more general studies.

SECTION III

INTRODUCTION

SCOPE

This report outlines and evaluates current knowledge related to environmental effects of unconfined animal production. The difference between confined and unconfined animal production is that wastes generated in confined systems are subject to handling/diverting for conventional control or treatment while those in unconfined systems cannot be handled and, thus, must be controlled through the management scheme. Correspondingly, the contrast between confined and unconfined animal production systems is very similar to the differentiation between point and nonpoint sources of pollution where a nonpoint source is one whose specific point of generation and exact point of entry into the environment cannot be defined. All grazing systems--where livestock have free access to pasture, range, woodland, or cropland and utilize the associated forage/residue as a major feed source--are unconfined systems.

Animal species directly addressed in this report are cattle (both dairy on pasture and beef on pasture and range) and sheep (on pasture and range). Some consideration is given to goats, hogs, poultry, and horses. Commercial or farm production of these latter species in the U.S. either utilizes confined systems almost exclusively or, as in the case of goats, unconfined populations are relatively small and information specific to the environmental impacts they produce is unavailable.

Specific tasks set for this report included:

1. Characterize unconfined animal production/management systems.

2. Identify the associated environmental problems.

3. Evaluate the magnitude and seriousness of the problems.

4. Assemble and prepare recommendations for reduction or control of the pollution problems cited.

5. Identify gaps in present knowledge and suggest areas needing additional evaluation, control, and research.

Environmental concerns investigated in preparing the report included:

1. Surface water quality as affected by both runoff from grazing areas

and direct contact with animals (including pesticide problems).

2. Impact on soil and vegetation.

3. Accelerated erosion - streambank as well as general wind and water erosion.

4. Groundwater quality.

5. Air quality - odors and dust.

The report does not address each of these concerns directly. It deals only with those found to be problems.

The basic approach used to gather information for this report was to evaluate existing literature, collaborate with specialists in the field, and review ongoing research relating to nonpoint source pollution. Major efforts were made to find information that would fill in gaps in the information assembled early in the study and to make sure that the information gathered was not misinterpreted or extended beyond its limits of applicability. To help assure that this was the case, specialists in the subject field reviewed drafts of the report and made suggestions for improvements and additions. Their assistance in both identifying information and helping interpret it was of major importance in the conduct of the study.

An original intent was to present the information in this report by geographical/climatic regions. However, analysis of various regional compilations of information did not reveal unique results for the règions as first envisioned. Thus, the effort to organize the report along regional boundaries was abandoned.

CONTEXT

Unconfined animal production systems have characteristics similar to other nonpoint, potential pollution sources which historically have been considered as natural and generally uncontrollable. Sources of this type have included precipitation, drainage from urban areas, runoff from forests and grasslands, return irrigation flows, leachate from decaying vegetation, and wastes from wild animals. Generally, these nonpoint sources have been assumed to be small compared to such point sources as municipal and industrial waste discharges. More information on the characteristics and magnitude of the nonpoint sources has led to questions about the validity of this assumption. At least one-third of the pollutants entering United States waters have been estimated to come from nonpoint sources.

The emphasis of our national water pollution control policy is now on the amount of wastes that can be kept out of surface waters rather than on the amount of wastes that can be assimilated by the waters. A major goal of Public Law 92-500 is that the discharge of pollutants into navigable waters be eliminated by 1985. The law also sets as the national goal that wherever obtainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water be achieved by July 1, 1983. Thus, it is imperative that potential pollution sources be evaluated so that appropriate remedial measures and control technology may be formulated and applied as needed. This document is an analysis of the technical information on the environmental impact resulting from unconfined animal production systems.

SECTION IV

CHARACTERISTICS OF UNCONFINED ANIMAL PRODUCTION

While approximately 50% of all livestock wastes in the United States are estimated to be produced in confinement, about 75% of cattle, 85% of sheep, and 10% of hogs are in unconfined systems at any given time. Table 1 contains approximate numbers of animals being maintained in various production systems. Although specialization, labor reduction, and improved efficiency have caused a trend toward confined production systems, unconfined production is expected to continue to predominate, particularly in the beef and sheep industries.

TABLE 1. DISTRIBUTION OF LIVESTOCK

Type Animal	No. of Production Units*	No. of Animals∇	No. Confined△	No. Unconfined	Percent Unconfined
	Thousands				
Cattle and Calves		123 000	30 000	93 000	76
Beef Cattle	490	101 500	20 000	81 500	80
Dairy Cattle	220	21 000	10 000	11 000	52
Sheep and Lambs	50	12 700	2 000	10 700	84
Goats and Kids	10	1 300	200	1 100	85
Hogs and Pigs	260	55 000	50 000	5 000	9
Horses and Ponies θ	--	8 000	--	--	--

* From 1971 USDA census.

∇ From 1977 USDA inventory figures.

△ Based on USDA estimates of livestock on feed and the assumption that 6% of all breeding beef cattle are confined and that 50% of all dairy cows and replacement heifers are confined.

θ From registration of various breeds and Extension Service estimates.

About 40% (360×10^6 ha) of the land area of the United States is used for grazing livestock. Forages account for the production of more than 50% of the nation's milk, nearly 80% of the total feed for beef cattle, and 90% of the total feed for sheep. Less than 5% of swine feed comes from forages. While some forages are harvested and brought to confined livestock, the vast majority are grazed. Ensminger (1970) gives tables of stocking rates to insure sustained yield of forage for a wide variety of conditions, including soil and forage types. Table 2 gives ranges in suggested stocking rates for each of the ten generally recognized grazing regions. The procedures for determining the correct stocking rate for a given site are generally well understood and require input data regarding both site and management factors.

TABLE 2. RANGE OF STOCKING RATES BY GRAZING REGION (AFTER ENSMINGER 1970)

Region	Animal units/ha: Permanent Pasture	Animal units/ha: Temporary Pasture
Northeastern	1.5 to 3.0	2.0 to 4.0
East Central	2.0 to 3.0	2.0 to 5.0
Southeastern (and Deep) Southeastern)	2.0 to 6.0	2.0 to 6.0
Northern Great Plains	0.5 to 3.0	1.5 to 4.0
Southern Great Plains (Irrigated)	0.1 to 1.0 (2.0 to 10.0)	0.5 to 2.0 (1.0 to 4.0)
Northern Intermountain (Irrigated Only)	2.0 to 4.0	1.0 to 5.0
Southern Intermountain (Irrigated Only)	2.0 to 7.0	0.5 to 7.0
Northern Pacific Slope	1.0 to 5.0	0.5 to 5.0
Southern Pacific Slope (Irrigated Only)	2.0 to 3.0	2.0 to 5.0

Smaller value represents stocking rates for continuous grazing; higher value represents rotational grazing. One animal unit equals 1 mature horse or cow, 2 yearling horses or cattle, 4 nursing calves, 2.5 mature swine, 5 hogs raised to 100 kg, 7 mature sheep, or 14 lambs.

IMPACT ON SOIL AND VEGETATION

As grazing animals traverse ranges and pastures, the stresses applied to the soil beneath their hooves often exceed the strength of the soil. The high stresses result in chipping of dry soils, compaction of moist soils, and deformation of wet soils. Resistance to compaction or deformation is determined by the soil's texture, structure, porosity, and moisture content. Maximum compaction is most predominate at a moisture content between wilting point and field capacity. Soils with high porosity and wide particle size range are more susceptible to compaction than are other soils under the same pressure and moisture content (Heady 1975).

The effect of soil compaction is to alter pore volume and structure. These alterations increase the soil bulk density and decrease infiltration capacity, permeability to water, water storage capacity, aeration, root penetration, and forage production. Trampling by grazing animals may cause poorer water infiltration, as indicated by numerous studies. For example, Trimble and Weitzman (1951) measured average infiltration rates of 52 and 11 cm/h on ungrazed and grazed pastures, respectively. In a New Mexico study of grazing intensity-infiltration relationships, infiltration rates were determined to be 10.5, 5.5, and 2.1 cm/h on undergrazed, overgrazed, and depleted ranges, respectively (Flory 1936).

Reductions in infiltration rates on pastures and ranges due to grazing correlate with increases in runoff. A decrease in infiltration and increase in runoff on grazed lands may lead to more arid conditions than normal. For example, Hanson et al. (1970) found that the reduction in available moisture on heavily grazed South Dakota ranges averaged 2 cm a year, or about 8% of the annual precipitation available for plant production. A decrease in moisture available for forage production is usually accompanied by an increase in soil erosion.

Selective defoliation by grazing animals decreases the preferred forage species and allows the proliferation of less desirable species. Close grazing of desired plant species during critical stages of growth such as before seed maturation hinders their competitive capacity. Reduction of the leaf area of forages by close grazing reduces their photosynthetic abilities and may affect plant succession (Stoddart et al. 1975). Heady (1975) attributes the most prevalent cause of rangeland retrogression to overgrazing and other faulty management of livestock operations.

Pastured woodlands and shelterbelts serve dual purposes and can have amplified stresses imposed by grazing animals. If grazing is poorly managed, direct damage to trees from browsing and trampling by livestock is compounded with soil compaction, reduced infiltration rates, and denudation of mulch and vegetation. Young trees within reach of browsing animals often suffer from defoliation and removal of shoots and buds. Older established trees may be damaged by horning, rubbing, or similar activities, resulting in broken limbs or ruptured bark through which pathogens may enter.

The severity of the impact of grazing animals upon tree establishment and growth depends upon the kind of animal and its forage preferences, intensity of grazing, type of trees, age of the stand, and availability of alternative forage sources. For example, under proper management, tree losses due to browsing damages on ponderosa pine forests may be as little as 4 percent from sheep and less than 1 percent from cattle. Between tree types, deciduous trees usually are more susceptible to browsing than are conifers; hardwood forests under open-range conditions can be grazed with minimal tree damage if properly managed (Stoddard et al. 1975).

ANIMAL BEHAVIOR

Behavior patterns and preferences of livestock species tend to result in certain areas showing intense environmental stresses. These problem areas are usually only a small fraction of the total unconfined production site and are caused by uncontrolled animal behavior that leads to selective and overgrazing (of sites as well as plant species) and to animal congregation and waste elimination in or near water sources or other critical areas. The general behavior patterns of livestock follow ancestral instincts but may be influenced by management practices.

Ingestion Preferences

Anatomical differences of digestive systems and mouth parts affect the ingestive behavior of animals. Cattle have no upper incisors. They wrap their tongue around forage and cut it off with their lower teeth by jerking forward. Thus, cattle do not graze as closely as other animals but may uproot plants. They primarily graze grasses but will readily consume forbs and, to a lesser extent, browse from woody plants. In order of preference, cattle will consume grasses, forbs, and browse (depending on species composition), with the volume of grasses generally exceeding the combined total of the latter two. Within the grasses, cattle will select certain species if more than one is available. Thus, controlled grazing may be necessary to maintain desired species composition and ground cover.

Shrubs produce forage favored by sheep and goats that cattle and horses usually reject. Sheep and goats also feed on grasses, provided the forage is tender. Due to the cleft upper lip structure of the mouth parts, sheep and goats can graze plants close to the ground. Uncontrolled grazing by these species may result in denudation of the area.

Horses possess full sets of teeth and are very forage selective. Although monogastric animals, horses have a highly specialized area of the colon (the cecum) in which microorganisms break down forages. Horse pastures show definite areas of short, heavily grazed grasses and tall, mature ungrazed portions. While swine have full sets of teeth, their monogastric (simple stomach) nature limits their ability to utilize forages. As a result, swine are not generally provided grazing. Even though poultry have no teeth, they can graze. But, unlike other farm animals, they are not capable of digesting forages; thus, poultry are raised in confinement.

Site Preferences

Areas that will be most heavily utilized for grazing by the various livestock species are dependent upon topography, water distribution, vegetation, prevailing winds, and the kind of livestock. Cattle prefer accessible areas such as valley bottoms, saddles between drainages, areas around salt sources, and level mesas. They lightly graze areas away from water and areas with steep slopes if more preferred grazing grounds are available. Conversely, unherded sheep and goats tend to overutilize slopes and ridge tops. These areas serve as their preferred bedding, as well as grazing, grounds.

Elimination Behavior

When animals are confined in lots, essentially all rainfall and runoff come in direct contact with manure-covered surfaces. But in unconfined systems where animal density is less, the vast majority of runoff may show no fecal contamination. On the other hand, small portions of the total runoff, particularly that from animal congregation and waste elimination areas, may contain pollutant levels similar to runoff from manure-covered surfaces. Sweeten and Reddell (1976) reviewed the literature related to excreta loading rate, distribution, and "fouling" of vegetation. By assuming completely uniform spreading of manure by grazing cattle, thereby giving the highest estimate of areal coverage over a given time period, they calculated the percent of coverage for various grazing densities, as given in Table 3. From their study, the researchers reasoned that sustained high stocking rates on pastures tend to be self-limiting because of so-called "dung-fouling" of vegetation and that "dung-fouling" is a more natural and permanent constraint to limiting waste buildup on true grazing areas than any water pollution control regulation. However, even when physical features (such as pasture size and shape, water, trees, and fences) have no effect on animal eliminative behavior, excreta are not uniformly distributed throughout the production site. Petersen et al. (1956) observed that when dairy cows were not attracted by physical features, the distribution of excreta was approximated by a negative binomial distribution (i.e., non-uniform). Beyond this, physical features do attract unconfined animals and, thus, eliminative patterns of livestock tend to result in areas of both high and low density waste deposition.

Swine and horses tend to deposit fecal wastes in the same general areas time after time. Swine usually void their excreta in places away from sleeping areas, but may eliminate wastes near watering places. Cattle, sheep, and goats eliminate wastes without preference to location and generally do not exhibit any inclination to avoid contact with depositions, except cattle do show an oral or grazing-related avoidance.

TABLE 3. PASTURE AREA COVERED BY MANURE AS A FUNCTION OF STOCKING RATE (SWEETEN AND REDDELL 1976)

Waste Material	Area Covered, $m^2 hd^{-1} day^{-1}$	Area Covered, %/yr — Stocking Rate, m^2/kg liveweight: 0.2	2	20	200	2000
Feces	1.1	430	43	4	0.4	0.04
Urine	2.8	1080	108	11	1.1	0.11
Feces and Urine	3.9	1500	150	15	1.5	0.15

Assumes cattle weigh 450 kg/hd and uniform distribution of waste material. Values exceeding 100% indicate overlap of waste deposits.

As ruminants (pregastric fermentation of roughages), cattle on pasture or range generally graze about 8 hours and then retire to shade or shelter to ruminate approximately 8 hours. During the period of rumination and inactivity, cattle tend to congregate in and around watering areas, shade, or shelter. These areas are subject to waste accumulation and tend to become compacted and denuded as cattle repeatedly congregate in the same location. A similar situation exists with sheep and goats. In particular, sheep on pasture with shelters tend to eliminate larger amounts of wastes in the shelter areas.

BEEF SYSTEMS

Unconfined beef cattle production systems are divided into three unique categories -- cow-calf system, stocker system, and grass finishing system.

Cow-Calf System

The cow-calf system is the propagating unit of the beef chain. In this system, mature cows weighing 350-500 kg are maintained on pasture for the express purpose of producing a calf and raising that calf to a weight of approximately 250 kg at 8-10 months of age. About 70 million animals (42 million cows and replacement heifers, 26 million calves, and 2 million bulls) are in cow-calf systems. As noted by Dixon et al. (1977), the average number of animals per cow-calf operation varies with region:

Corn Belt and Southeast. 50

Northern Plains. 150

Intermountain, Southwest, and
High Plains 350

Animals in cow-calf systems roam unconfined throughout the year and graze for virtually all of their feed during the forage growing season. Main forage growing seasons vary from 4 months in northern-most states to 8-10 months in the southern states. In addition, winter forages are often used in the Southeastern and Pacific Slope regions, making year-round grazing and unconfined production a reality. In most rangeland areas, cattle are maintained during non-growing seasons on dormant vegetation and fed small amounts of supplemental concentrates. Hay is fed when snow or ice prevents grazing. In other regions, surplus forages are harvested during peak growing seasons and fed to the cattle during non-growing seasons.

In areas of heavy winter rains or wet snows and in areas of intense cold and high winds, winter lots with open sheds may be provided for the cattle. Some winter lots include small paved areas and larger adjacent areas. The cattle are turned into the larger areas for exercise when the ground is frozen or dry. In regions where the winters are relatively dry, open rolling land with trees for shelter is commonly used. A more confined area may be used in other management systems, and particularly so for cows with new-born calves.

Important characteristics of cow-calf systems from an environmental standpoint are:

a) Within a system that follows stocking rates and management practices that maximize long-term sustained forage production, only certain problem areas are likely to contribute increased pollutant loads and to warrant control beyond the good soil and water conservation practices that are characteristic of such systems. These problem areas are alluded to below and are readily recognized by observation.

b) During non-grazing periods of the day, cattle tend to congregate (around shaded watering areas or other places of shelter), and the areas of congregation tend to be constant.

c) Cattle tend to follow the same paths to and from grazing areas, water, and shelter. Ingress and egress points to ponds and streams are usually particularly heavily traveled.

d) Cattle are often grouped into smaller areas during winter (and droughts).

Stocker System

The stocker systems take the product of cow-calf system and provide a growing phase for calves between weaning and the time they are ready to go to a finishing system or be returned to the breeding herd. Major emphasis is placed on obtaining economical gains on forage. Of the 1977 beef inventory, approximately 17.5 million cattle (6.5 million replacement beef females plus 11 million steers and heifers not on feed) were in stocker systems.

Primary grazing regions of stocker management systems are the Southeastern and Pacific Slope regions which make maximum utilization of winter grazing capabilities as well as lush summer growth. In addition, small grain areas of the Southern Great Plains region (particularly Texas, Kansas, and Oklahoma) utilize stocker calves for grazing grain fields during winter months.

Cattle remain in stocker systems for periods of four to six months. Some systems utilize both summer and winter pastures for year-round stocker production. Stockers may be obtained in the fall and wintered on hay and other coarse roughages and grazed on spring and summer grasses. They may otherwise be obtained in late winter or spring, for spring and summer grazing only.

From an environmental standpoint, stocker systems are similar to cow-calf systems. Additional features to consider include:

a) While more animals are maintained per unit area, they are smaller in size. Liveweight per unit area is at first lower and subsequently similar to cow-calf systems.

b) Most stocker programs make use of temporary pastures. Excessive rain or snow and ice may make grazing impractical, creating need for stockers to be maintained in smaller areas and provided supplemental feed. Otherwise, the temporary nature of these programs is such that potential problem areas are not used throughout the year and have opportunity to recover, thereby lessening the potential environmental impact.

Grass Finishing System

Interest in grass finishing programs has periodically increased as a result of increased prices and competition for feed grains. A clear estimation of numbers of animals in this program is not available. It represents only a small fraction of animals on feed, however. In this program calves grown on a stocker system to a weight of 300-350 kg are finished to market weight (400-450 kg) and grade on good quality forages. One alternative is the "grain-on-grass" program where calves graze 120-150 days at a recommended grazing stocking rate (e.g., 8-10 hd/ha) and then are fed a limited ration of grain for an additional 60-90 days of grazing. During this "grain phase", stocking rates may be increased to those common to open feedlots (e.g., 12-15 hd/ha). In another alternative, cattle are maintained from a weight of 350 kg to market weight of 500 kg, receiving no grain but obtaining all feed from grazing. For short periods of time these finishing systems may also involve stocking rates approaching feedlot levels.

Adequate fertilization, pasture rotation under controlled conditions, and forage harvesting practices are characteristics of this system. Grass finishing systems are located primarily in the Southeastern and, to a limited extent, in the Pacific Slope regions where year-round grazing is possible.

DAIRY SYSTEMS

Dairy cattle systems range from completely unconfined to totally confined with semi-confined in between. The semi-confined dairy system involves maintenance of 20 to 25 mature (450 to 550 kg) females per ha (open feedlot densities). Green forage is cut daily and brought to the herd. In intensive dairying areas of the Northeastern, Northern Intermountain, Southern Pacific Slope and Southeastern regions, total confined and semi-confined systems represent 60 to 70% of all dairy systems, with equal representation by both systems.

Portions of all dairies, including unconfined systems, have areas that should be managed as confined systems. For example, loafing areas and parlor holding areas, whether surfaced and flushed or not, should generally be managed as point sources (wastes and/or runoff collected for control). Likewise, most dairies, including many confined systems, have areas that are characteristic of unconfined production. Dairy replacement calves for all systems are most often a part of the total dairy system and these animals are generally maintained on pasture.

Environmental impact considerations of dairy systems are the same as for cow-calf management systems, with the following additions:

a) Unavoidable high impact (problem) areas such as the approach paths to milking barns and loafing areas are common.

b) In the pasture or paddock area of semi-confined systems, where stocking rates equal those of open feedlots, only a small portion of total wastes generated by the animals may be deposited on the pasture; a major portion may be collected in the milking area and managed as point source wastes. Nevertheless, the pasture area may still be so heavily impacted that it requires controls appropriate to open feedlots (collection of runoff, etc.).

SHEEP SYSTEMS

Sheep are unique in that they can attain top meat grade (prime) on forages alone. Consequently, the majority of lamb production occurs in unconfined management systems. The unique systems of sheep production are range systems, farm flock systems, and lamb feeding systems. Environmental problems associated with these systems are similar to those for beef systems.

Range systems are designed to maximize utilization of available rangeland forage. This system is found primarily in the Great Plains and Intermountain regions. Range management systems are nomadic in that large herds move over vast areas following seasonal availability of forages. These herds move up mountainsides in summer as higher elevation forages become available and return in the fall to lower elevations where protection from winter weather can be effected. On summer ranges, ewes and their spring-born lambs are maintained together. Lambs are weaned in late summer or early fall, with heavier lambs being sent directly to slaughter and lighter lambs sent to confined or pasture finishing systems.

Farm flock systems predominate in the eastern U.S. This system differs from the range system in that improved pastures of legumes and/or grasses meet most of the nutrient requirements of the flock. As a result, farm flocks are usually maintained in small areas at high stocking rates. Rotational grazing is common.

In lamb feeding systems, 30 kg lambs are grazed at rates of 10-25 hd/ha, depending on the intensity of management of livestock and improved forages. In the Southeastern regions, grass-legume mixtures may provide the nutrients for production of 45-55 kg slaughter lambs at 4 to 6 months of age.

SWINE SYSTEMS

Swine management systems are generally classified according to the number of litters produced per year. Due to the monogastric nature of the swine digestive system, forages are not essential, although they may be advantageous if utilized properly. Swine production tends to center around grain production areas with approximately 80% of all hogs produced in the North Central states and Great Plains regions. The Southeastern regions account for 14% of total production. The remainder is divided evenly among other regions.

A frequently used management procedure is a 2-litter system in which each breeding female weans two 7-8 pig litters in 12 months. Although swine management systems involve total confinement to a large degree, many sow operations include pasture (rotated drylots) or drylots (permanently denuded areas) with stocking rates as low as 1000 kg/ha. Rates of 6000 kg/ha (30 to 36 sows weighing 200 kg or less, or 20 to 24 sows with 7-8 pig litters per ha) are more common. Hogging off grain fields, once very popular, is still practiced to a limited extent, but usually only for a short duration. Also, a very few feeder pigs are finished by feeding on pasture. Due to the efficiency of confinement feeding, most such unconfined finishing operations are temporary.

Environmental problems common to swine systems are similar to those for dairy systems. Additional features to consider include:

a) Hogs on pasture and drylots often have access to streams. Such access must be controlled if the environmental impact is to be minimized.

b) Even when pastures are rotated, much of the area may be heavily impacted and soon denuded. The entire pasture area is generally a problem area and requires control appropriate to confined systems/point sources.

c) Swine tend to uproot forages if not controlled and are attracted to streams and waterways for wallowing areas.

SECTION V

WATER QUALITY EFFECTS FROM UNCONFINED ANIMAL PRODUCTION

Excellent reviews of agricultural nonpoint sources of pollution, including consideration of unconfined animal production, have been prepared by Loehr (1974), Dixon et al. (1977), Sweeten and Reddell (1976), Dornbush et al. (1974), and USEPA (1973). Numerous other studies have reported information that is very helpful in assessing the character and extent of the effect of unconfined animal production on water quality. However, a word of caution is in order on the use of the reported information. Some otherwise potentially useful data are so confounded with regard to cause and effect (e.g., uncertainties imposed by incomplete descriptions of the systems) that their use must be guarded. Other information is of a speculative, general nature, often based on less than definitive data. Still other information concerns site specific problems and, thus, cannot be considered characteristic of unconfined animal production in general. And, as Loehr (1974) found, some is of limited usefulness because of its form: concentration of pollutant in water rather than yield of pollutant per unit of watershed area. With due regard then, the available information has been reviewed, screened, and, when appropriate, used to formulate the following discussion of the nature and extent of the problems.

BACKGROUND LEVELS OF POLLUTANTS

In assessing the environmental impact of unconfined animal production, the concept of "background (natural) levels" of pollutants is important. Known background levels of a particular pollutant for a particular site can serve as a point of reference for determining what environmental quality level might reasonably be acceptable and achievable in water quality management.

From a study of 12 agricultural watersheds, Robbins et al. (1971) found that distinguishing between pollutants from farm animal production units and natural pollutants in receiving streams is difficult or impossible. They concluded that control of pollutants from unconfined animal production units may be to no avail unless other pollutant sources that naturally occur in the watershed are controlled as well. They stressed that additional information and research on the types and yields of natural pollutants are needed to formulate meaningful water quality management programs.

Loehr (1974) summarized reported data concerning oxygen demands, nitrogen, and phosphorus transported in drainage from various land-uses and the amount of pollutants deposited on land by precipitation. Nitrogen and phosphorus yields from various sources are given in Table 4. These values vividly reveal that background levels of pollutants can be appreciable. Note that precipitation can deposit as much as 10 kg $ha^{-1}yr^{-1}$ total nitrogen and 0.06 kg $ha^{-1}yr^{-1}$ total phosphorus. Also note the yields of nitrogen and phosphorus from undisturbed forestland can be as much as 13 and 0.9 kg $ha^{-1}yr^{-1}$, respectively. Realistically, Loehr described undisturbed forestland and rangeland as natural situations and reasoned that the runoff from these lands contains only background levels of pollutants. Concentrations and yields of pollutants from these two nonpoint sources are of the same type and magnitude as those of precipitation.

TABLE 4. AREAL YIELD OF NITROGEN AND PHOSPHORUS (LOEHR 1974)

Source	Total N, kg $ha^{-1}yr^{-1}$	Total P, kg $ha^{-1}yr^{-1}$
Precipitation	5.6- 10	0.05-0.06
Forested Land	3- 13	0.03-0.9
Rangeland	0.65*	0.76
Cropland Runoff	0.1- 13	0.06-2.9
Urban Land Drainage	7- 9	1.1 -5.6
Cropland Receiving Manure	4- 13	0.8 -2.9
Feedlot Runoff	100-1600	10 -620

* value for NO_3-N

As suggested by Dixon et al. (1977), water quality data reported by Doty and Hookano (1974) from a study of three pristine watersheds in northern Utah are suitable for background or benchmark information. The watersheds had been protected from fire, domestic livestock, and timber cutting for 45 years. Table 5 gives ranges of some water quality characteristics reported. Comparison of such data as these with similar data from unconfined animal production sites allows a first evaluation of the importance of the production practice on water quality. In such comparisons, it is important to note that for most indices the order of magnitude of differences are to be considered significant rather than small differences in the values themselves.

PREDICTION OF POLLUTANT YIELD

An ultimate goal in pollution control technology is to have some form of model/method that will estimate pollutant losses from pollution sources. No such model exists for unconfined animal production systems. Once models of other nonpoint sources are developed, they will no doubt be modified to serve the need. Discussion of models for nonpoint sources is given by Donigian and Crawford (1976) and True (1976). Also, Sweeten and Reddell (1976) presented concepts based on information from McElroy et al. (1976) for estimating yield of nutrients and organic matter from nonpoint sources.

TABLE 5. WATER QUALITY FROM PRISTINE WATERSHEDS (DOTY AND HOOKANO 1974)

Parameter	Range of All Values	Range of Watershed Averages
pH	5.50- 8.00	6.98-7.13
Phosphorus, ppm	0 - 0.63	0.06-0.07
Nitrate, ppm	0.07- 0.70	0.34-0.37
Suspended Sediment, ppm	0.10-247.80	5.55-9.86
Total Coliform, cts/100 ml	1 -570	42 -72
Fecal Coliform, cts/100 ml	0 -183	2 -13
Fecal Streptococcus, cts/100 ml	0 -500	31 -60

Guidance for--and a view of the difficulties involved in--developing models for predicting pollutant yields from unconfined animal production units may be surmised from work by Robbins et al. (1971). The two-year study was designed to determine the pollutant loads in runoff from farm animal production areas and to evaluate factors governing the timing, amount, and concentration of pollutant discharges. Generalized findings related to the present discussion follow:

1. Concentrations of pollutants in land runoff increase with runoff intensity and are proportional to flowrate. But, the value of the proportionality varies throughout the runoff event and even more so between events. Thus, determination of pollutant yield requires measurement of both pollutant concentration and flowrate throughout the entire runoff event.

2. High correlations exist between most pollution indices other than bacteriological indicators, both for a given runoff event and between events. Relationships between such indices as chemical oxygen demand and phosphorus levels generally hold constant enough for modeling purposes. This suggests that with the measurement of one key index such as phosphorus content, the concentration of other pollutants in the stream can be estimated. However, bacteriological indicator organisms are poorly correlated with other pollutant indices except for a given runoff event and at a given sampling site. Bacteriological counts are highly dependent on temperature (bacterial activity increases with temperature) and may exhibit either a die-off or an aftergrowth with time (or flow distance). While correlations between various bacteriological indicator organisms are often high, they are also erratic and change with both season (temperature) and time (flow distance). Thus, estimations of either the level of bacteriological activity or the ratios between indicator

organisms are not reliable; these values must be determined by measurement.

3. Pollutant yields are not related to number of animals involved and, therefore, they are not related to either the amount or the characteristics of animal wastes involved. Rather, yields are intimately related to hydrogeological and management factors. The process is less of an animal waste problem than a soil and water conservation problem. Mainly, it is an erosion/sediment transport phenomenon. For example, the researchers found a yield of five times as much phosphorus per animal from a site with a high rate of erosion as from a site with less erosion, when no differentiation of pollutant source was made (all phosphorus reaching the streams was attributed to animal activity). Models must be built around a sound accounting of these watershed and management factors, including the changes watersheds undergo with time.

4. The increases in pollutant concentration in receiving waters caused by an unconfined animal production system, particularly when pollutants from problem areas are controlled, are generally so small compared to and so completely confounded with background or other pollutants, that the contribution from the system is impossible to definitively establish. At a given time during a runoff event, pollutant inputs may be only from natural or other non-livestock related sources in the watershed, while at other times inputs from unconfined animal activities may also be included. In most cases, it is not possible to differentiate between sources.

Again, the movement of pollutants from unconfined animal production units to receiving waters is governed by numerous, complex, and variable hydrogeological and management factors which are yet to be codified. In lieu of a model that will estimate pollutant yields, an understanding of the erosion/sediment process plus a review of pollution studies (research results) related to unconfined animal production should be helpful in assessing the environmental impact resulting from these systems. Since the erosion/sediment process is so fundamental to pollutant yields resulting from unconfined animal production activities, one is encouraged to review the subject in detail.

SEDIMENT

Sediment is both a pollutant and a carrier of pollutants from unconfined animal production systems. As a first approximation, factors that govern erosion and sediment yields are the same factors that control pollutant yields from unconfined animal production systems. Robbins et al. (1971) pointed to the need for good soil and water conservation practices to minimize the movement of pollutants from animal production units into streams. Excellent, detailed, and thorough reviews and discussions of erosion, erosion models, and sediment yields as related to agricultural nonpoint sources have been prepared by USEPA (1973), Stewart et al. (1975), and Sweeten and Reddell (1976).

Sediment yield to streams and lakes exceeds 2 t $ha^{-1}yr^{-1}$ on the average for the total U.S. land area. On-site erosion is estimated to be twice this value, or more than 4 t $ha^{-1}yr^{-1}$ for a U.S. total yield of 3.6×10^9 t/yr. According to Froehlich (1976), the smallest levels of sediment loss are from certain undisturbed forestlands in the Rocky Mountains where sediment reaching certain high elevation streams may range up to 0.36 t $ha^{-1}yr^{-1}$. Other examples of background sediment yields are 0.59, 0.90, and 1.10 t $ha^{-1}yr^{-1}$ from three neighboring watersheds in western Oregon. Well stocked southern pine forests may yield 0.7-1.1 t $ha^{-1}yr^{-1}$. In southwestern forests with low precipitation, yet high intensity storms, sediment yields may be 1.1-1.4 t $ha^{-1}yr^{-1}$.

Background sediment yields may be compared with yields from cropland. Cropland has been credited with responsibility for 50% or 0.9 x 10^9 t/yr of the 1.8 x 10^9 t/yr total sediment delivered to U.S. streams and lakes. As noted by Sweeten and Reddell (1976), 70% of the nation's cropland yields more than 6.7 t $ha^{-1}yr^{-1}$. Representative values for on-site erosion from several sources as reported by USEPA (1973) are given in Table 6. Here, grassland includes pasture and rangeland. While the erosion rate from grassland is 10 times that from forestland, it is considerably less than the average rate for all land of 4 t $ha^{-1}yr^{-1}$ and it represents the average background or natural rate for grassland ecosystems.

TABLE 6. REPRESENTATIVE RATES OF ON-SITE EROSION FROM VARIOUS LAND USES (USEPA 1973)

Land Use	Rate t $ha^{-1}yr^{-1}$	Relative Rate, Forest = 1	Total, t/yr	Relative Total Forest = 1
Forest	0.085	1	16.8	1
Grassland	0.85	10	185	11
Cropland	17	200	2840	168
Harvested Forest	42	500	187	11
Construction	170	2000	100	6

Sediment yields are very erratic (Froehlich, 1976). The largest annual sediment loads for a given stream are often 20 times greater than the smallest sediment load and can generally be correlated with those years of greatest runoff. Large differences in sediment yield can exist on adjacent streams discharging at the same rate. And, even in the same stream, suspended sediment concentration can vary 10-fold at a given discharge rate, depending on many factors.

Most sediment from a watershed may come from a relatively few small areas needing corrective attention. Stewart et al. (1975) listed conditions indicative of high sediment yield potential that can usually be identified by observation. Overgrazing, and resultant loss of groundcover can greatly increase the erodibility of pasture and rangeland.

CASE STUDIES

Important results have been obtained from studies concerning the pollution potential of unconfined animal production operations. Early work by Meiman and Kunkle (1967) revealed that bacteriological indicators provided a more sensitive evaluation of grazing than did suspended sediment or turbidity. Of three indicator groups--fecal coliform (FC), total coliform (TC), and fecal streptococci (FS)--FC and TC were the most sensitive in detecting the grazing impact, with FC being the best. Ratios of FC/FS ranged from less than 1 to 4.5 on natural areas and less than 1 to 44 on impacted areas. Bacteriological concentrations in the stream were related to overland flow, stream discharge, and season of the year. Maximum concentrations were obtained during periods of lower storm runoff flows and warmer water temperatures.

Additional work by the researchers (Kunkle and Meiman 1968 and Kunkle 1970) essentially verified the fact that increased levels of bacteriological indicator organisms occur in streams draining grazing operations. The researchers studied sites where animals did and did not have direct access to streams and found no detectable differences from a bacteriological contamination standpoint. Also, their work underscores the fact that predicting the level of bacteriological indicator counts resulting from unconfined animals is inaccurate and difficult, if not impossible. As indicated above, their conclusions could not be more specific than to relate that hydrological and watershed characteristics are of great importance in bacteriological yields, and greater counts are common to warmer weather.

Smeins (1976) studied the effect of various rangeland livestock grazing management programs on the quantity and quality of surface runoff. He tentatively concluded that nitrogen and phosphorus yields from pastures are greater from a "heavy continuous grazing system" than from a "four-pasture deferred rotation grazing system". This conclusion was made on the basis of increased runoff caused by overgrazing and drastically reduced--to less than half--infiltration rates under the continuous grazing program, rather than to discernible differences in runoff quality. The concentrations of pollutants in runoff were low. Nutrient losses appeared to be related to sediment loss rather than to animal waste contributions. Generally, less sediment loss occurred on the better vegetated watersheds. The findings emphasize that grazing management systems influence water quality through erosion/sediment control, that pollutant yields are directly proportional to runoff amounts, and that grazing may decrease infiltration rates and, thereby, increase runoff and pollutant yields.

Schreiber and Renard (1976) studied the chemical quality of runoff from grazed and ungrazed rangelands. Nitrate, phosphorus, sodium, and potassium concentrations were found to be higher in runoff from the grazed watershed; but lower concentrations of calcium, carbonates, and magnesium and lower pH and electrical conductivity values were exhibited. The researchers noted that the concentrations of the pollutants in runoff were low (near background levels). Although comparison between the grazed and ungrazed watersheds indicated these slight differences in runoff water quality, the researchers also noted that the differences may have been caused by differences in soil and vegetation (hydrogeological) characteristics.

Colthrap and Darling (1975) studied three mountain streams to determine the impacts of grazing cattle and sheep on rangeland watersheds. Results of chemical and physical analyses were inconclusive. Turbidity, pH, nitrate, and phosphate values were generally not affected by grazing. Statistically, stream temperature was a more frequent indicator of grazing than these variables, indicating that grazing had no definitive impact on the physical and chemical parameters. The bacteriological results of the study did, however, indicate that grazing cattle and sheep significantly increased the total coliform, fecal coliform, and fecal streptococci counts in streams draining grazed areas. Examples of results are presented in Table 7 and reveal that the increased bacterial activity resulting from grazing was not large enough to remove the values beyond the range of background or natural levels that might otherwise be anticipated for such an ecosystem void of livestock. Counts reached relative maximums during snowmelt runoff, absolute maximum levels during grazing periods, and minimums in winter months.

TABLE 7. BACTERIOLOGICAL QUALITY BY LAND USE (COLTHARP AND DARLING 1975)

Watershed	Bacteriological Quality, cts/100 ml		
Land Use	Total Coliform	Fecal Coliform	Fecal Streptococci
Grazed	24	88	325
Grazed	103	38	101
Ungrazed	18	4	27

These bacteriological findings agree with a Laycock and Conrad (1967) study in Colorado which investigated rangeland adjacent to a stream. They also substantiate a USDA (1976) study in Idaho which showed that bacteriological counts increase in streams when cattle are introduced to graze, remain high until the cattle are removed, and, according to the researchers, are flushed into streams for as long as three weeks after cattle are removed.

Milne (1976) evaluated the impact of a livestock wintering operation on a mountain stream. Within a 3.6 km stream segment, 1200 sheep, 350 cows, 50 heifers and 85 hogs were held in partial confinement (corrals and pastures) with access to the stream. Also, a 200-head cattle feedlot lay alongside the stream. From the four-year stream monitoring program, he concluded that the livestock wintering operation had negligible effect on chemical properties of the stream. For example, the concentration of nutrients in the creek passing by the wintering operation increased from 0.007 to 0.019 ppm nitrate nitrogen and from 0.007 to 0.027 ppm orthophosphorus.

Bacteriological counts were significantly increased at the location of greatest livestock activity when compared to counts taken upstream. The average total coliform and fecal streptococci counts per 100 ml of stream water before entering the wintering area were 7.08 and 17.62, respectively. Just downstream from the wintering area, the respective average counts were 1431.27 and 996.92 per 100 ml. However, these high bacterial densities were shortlived, with marked reduction within 5 km downstream. Bacteriological analyses were deemed more suitable (more sensitive) than chemical analyses for evaluating livestock nonpoint inputs.

A study conducted by Greathouse et al. (1971) near Lake City, Michigan found no difference in nitrogen and phosphorus concentration as a result of wintering and pasturing cattle along rivers and streams. Similarly Campbell et al. (1977) found no significant water quality impacts from production of beef cows and calves on Florida flatwood soils and at stocking rates greater than those for regular pasture systems.

After reviewing the information relevant to nonpoint pollution from cattle wintering sites, Dixon et al. (1977) concluded that cow-calf operations involving a rangeland operation with confined wintering (to pasture stocking densities) most probably will contribute little to the nutrient and chemical load of a stream. The operation very likely could contribute to microorganism contamination of the stream, however. The researchers also reasoned that consideration of microorganisms as a pollutant from range-type wintering operations might be overemphasized because they may be the only discernible pollutants from the operation. They concluded that the concentration and quality of pollutants from cattle wintering areas are not known.

Dornbush et al. (1974) evaluated runoff quality from seven agricultural land-use areas, including a 6.3 ha summer pasture. The study yielded values of the bacteriological quality of runoff water, pesticides carried in runoff, and physical and chemical characteristics of land surface drainage. Bacteriological indicator organisms in runoff exceeded drinking water supply criteria 50 percent of the time for fields with heavy ground cover (including the pasture) and from 50 to 100 percent for fields with minimum cover (including cropland). It is significant that no bacteriological effect directly attributable to pastured animals was discernible. The researchers realistically concluded that the runoff was probably not a potential health hazard.

Also, the level of pesticides present in runoff seemed quite low and the majority of concentrations were below analytical limits. Values of the yield of other pollutants are given in Table 8 and indicate that pastureland contributes less than cultivated fields but more than permanent grasslands. The researchers noted that even these low pollutant yields may have important implications regarding lake eutrophication.

Sewell and Alphin (1972) studied problem areas associated with unconfined animal production systems. They took grab samples at 24 test sites involving cropland, ungrazed woodland, barnyards, and heavily-grazed pastures. Results from four test sites which exemplify water quality resulting from suspected problem sites and unimpacted sites are given in Table 9. Average BOD values were found to be least in runoff samples from ungrazed woodlands and normally-grazed pasturelands and greatest from heavily-grazed areas within pastures, animal resting areas, and heavily-used farm ponds. Also, BOD values tended to be greater in farm ponds than in flowing streams. Nitrate-nitrogen averages in surface runoff from two (problem) sites on a heavily-grazed dairy pasture system exceeded those from all other sites, including those of an aerobic lagoon and drainage from cultivated lands. The mean orthophosphate, total coliform, and fecal coliform levels from the problem areas in the dairy pasture were exceeded only by those of aerobic lagoon waters. Based on data from all the test sites, the researchers concluded that while bacterial counts and chemical concentrations of surface receiving waters depend upon land use activities and is increased by livestock operations, the most important factors affecting the measured levels of these parameters are the location of the sampling points with reference to the source, the dilution of the pollutants, and the time during the runoff cycle at which samples are taken. Their work vividly illustrates that problem areas within unconfined systems may result in substantial input of pollutants to contiguous surface waters.

TABLE 8. POLLUTANT YIELD BY LAND USE (DORNBUSH ET AL. 1974)

Pollutant	Yield, $kg\ ha^{-1}\ yr^{-1}$ Cultivated	Pasture	Grassland
Total Residue	334	58.2	32.4
Suspended Solids	286	11.8	4
Total Phosphorus	0.30	0.25	0.1
Nitrate-Nitrogen	0.37	0.40	0.24
Total Kjeldahl Nitrogen	0.91	1.12	0.73
Chemical Oxygen Demand	48	28	13

TABLE 9. WATER QUALITY BY LAND USE (SEWELL AND ALPHIN 1972)

Land Use	BOD_5 (ppm)	DO (ppm)	NO_3-N (ppm)	PO_4-P (ppm)	Total Coliform, cts/100 ml
Ungrazed Woodland	2.5	8.6	0.05	0.05	1500
Heavily-Grazed Pasture	13.8	6.1	4.5	7.1	330000
Farm Pond in Pasture	10.0	7.9	0.20	0.05	600
Farm Pond in Woodland	3.1	7.6	0.12	0.02	1500

As indicated by the work of Sewell and Alphin (1972) and as pointed out by Dornbush et al. (1974), small increases in pollutant yields may have important implications when the receiving waters are impounded. In a study of farm pond water quality, Dickey and Mitchell (1975) found BOD values of pond water in livestock watersheds exceeding 20 ppm while the average BOD value of pond water for grassed watersheds free of animals was 0.77 ppm. The average level of phosphate in pond water where animals had direct access was 5.82 ppm, or 32.3 times the average value for grassland watersheds. Pond water on the pastureland reached a maximum nitrate nitrogen level of 22.0 ppm.

A more intensive study of pond water quality by Willrich (1961) gave evidence that generally indicates that grazing of grassed watersheds does not materially affect the nitrate concentration in pond water. Heavily-grazed watersheds, as contrasted to watersheds which were predominantly cultivated or in meadow, did not cause a higher nitrate nitrogen level in the pond water in his study. He also reported similar results from other studies.

Janzen et al. (1974) sampled streams above, adjacent to, and below 22 dairies. While the study tested waste handling techniques (lagooning, dry disposal, and liquid manure spreading) rather than solely the effect of unconfined production, the results exemplify the environmental impacts to be expected from unconfined dairies when the contributions from problem areas are included. Fecal coliform counts exceeded 1000 cts/100 ml for 90% of all stream samples, including samples from all but three sites above the animal production units. Statistically, 42% of the farms studied contributed in varying amounts to a reduction in stream water quality on the basis of bacteriological activity (26%), dissolved oxygen (14%), pH (19%), and/or oxygen demand (9%). Overall, increased nitrate nitrogen (from about 2.3 to about 3.8 ppm) and phosphate (from about 2.4 to about 3.7 ppm) levels existed between upstream and adjacent sampling sites. Average concentrations of both of these indices were about 2.9 ppm at sampling points 50 to 600 m below the dairies.

Of the 12 animal agricultural watersheds examined by Robbins et al. (1971), two exemplified solely unconfined production units: a beef pasture (site Z) and a hog drylot (site K). They also studied a watershed (site E) that received hog wastes by spreading in addition to that from sows on drylot. A watershed (site F) free of domestic animal wastes was used to determine background levels of pollutants. Results from study of these land runoff sites are summarized in Table 10. For comparison, the Table includes results from three watersheds (sites D, H, and J) that included direct waste discharges to streams.

The pollution loads in the land runoff streams followed a general increase with time from winter to summer. Bacteriological counts were very responsive to temperature. During runoff events, average bacteriological quality of all streams, including the stream draining control site F, far exceeded any known maximum allowable for body contact. Nutrient contents in streams were always, including periods of base flow, well in excess of that needed for algal growth. Phosphorus entering the streams was mainly orthophosphate and, thus, was immediately available to plants. Wastes that reached the streams were relatively well oxidized.

Considering the level of pollutants measured in the stream draining control site F, much of the pollutants observed in the other land runoff streams could be attributed to natural sources. For example, a comparison of nitrogen

TABLE 10. POLLUTION LOADS IN ANIMAL AGRICULTURAL STREAMS (ROBBINS ET AL. 1971)

Variable		Site F	Site E	Site K	Site Z	Site D	Site H	Site J
No. of animals, 450 kg liveweight		0^{Δ}	50^{Θ}	20^{∇}	21^{ϕ}	25^{Ω}	$75^{\times}$	$155^{\dagger}$
Watershed area, ha		30	14	20	10	16	28	6
Fecal Coliform	mean 10^3 cts/100 ml	10	190	350	30	2700	2300	8600
	10^{12} cts ha^{-1} yr^{-1}	0.30	4.6	7.4	0.5	160	46	650
	10^{12} cts $animal^{-1}$ yr^{-1}	--	1.3	7.4	0.2	100	17	26
BOD_5	mean ppm	2.0	4.7	6.4	9.8	73	17	170
	kg ha^{-1} yr^{-1}	6	11	13	17	430	34	1260
	kg $animal^{-1}$ yr^{-1}	--	3	13	8	276	13	51
Nitrogen-N	mean ppm	1.2	1.1	1.4	1.2	13	7	19
	kg ha^{-1} yr^{-1}	4.5	9.3	3.4	4.5	78	20	160
	kg $animal^{-1}$ yr^{-1}	--	2.6	3.6	2.0	50	6	6
Phosphorus-PO_4	mean ppm	0.2	1.2	1.9	1.1	6.9	4.6	18
	kg ha^{-1} yr^{-1}	0.6	3.0	3.8	2.0	40.9	9.2	140
	kg $animal^{-1}$ yr^{-1}	--	0.8	3.9	1.0	26.5	3.4	5.6

Δ Free of domestic animals
Θ 200 sows on 1.2 ha of drylots plus wastes from 300 confined hogs spread on 2 ha
∇ 200 hogs on 2.5 ha of drylots
ϕ 35 beef animals on 6 ha of pasture
Ω 150 sows on 4 ha of drylots plus direct discharge from 100 confined hogs
$\times$ Dairy cows on 22 ha of pasture and washwater from milking area flowed directly into stream
$\dagger$ Dairy cows on 5 ha of pasture and washwater from milking area flowed directly into stream

yields per unit watershed area from the sites (F vs. E, K and Z) suggests that no increase occurred due to animal activity. (The researchers attributed the increase nitrogen yield from site E to the hog wastes spread in the watershed, increasing the nitrate nitrogen content of the groundwater and base flow in the stream, rather than to the sow drylot operation.)

The results from the beef pasture (site Z) suggests that grazing cattle can be maintained without materially affecting stream quality. The pasture area in this case was free of observable problem areas except possibly a small area where the cattle entered the stream for watering purposes. And, the increased levels of pollutants from sites E and K over those from control site F exemplify contributions to be expected from problem sites (swine drylots in these cases). These results suggest the need to concentrate control efforts on any problem areas within the total production system.

The results in Table 10 for sites D, H, and J show the effects of dumping fresh wastes directly into streams and are to be compared in orders of magnitude with pollutant yields from land runoff sources. The calculated amounts of pollutants (natural plus swine or dairy) carried by the streams draining these sites compared to the estimated amounts of animal waste pollutants produced in the watersheds were 375, 875 and 1340 percent of FC; 56, 6 and 23 percent of BOD_5; 67, 10 and 10 percent of N; and 49, 23 and 30 percent of P for sites D, H and J, respectively. Again, the phosphorus carried by the stream draining site D amounted to 49% of the estimated phosphorus excreted by the hogs at site D. The exceptionally high values of FC carried by the streams with direct waste inputs suggest that an aftergrowth of bacteria occurred in the short 500 m reaches of the streams between the discharge and sampling points. The aftergrowth was limited to warmer weather, and most FC bacteria died off before reaching the sampling points during the winter period.

While these direct discharge operations involved only small numbers of animals and were only a portion of production systems that included largely unconfined animals, their pollutant contributions were several orders of magnitude greater than those from the land runoff areas. These results vividly emphasize the need to consider any such operations separately as point sources rather than including them as part of otherwise nonpoint systems.

SECTION VI

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

This report outlines and evaluates current knowledge related to environmental effects of unconfined animal production. Animal species directly addressed include cattle, sheep, and hogs. All available date indicate that pollutant yields from pasture and rangeland operations are not directly related to the number of animals or amount of wastes involved. Rather, these nonpoint source problems are intimately related to hydrogeological and management factors and are best described as the results of the erosion/sediment phenomenon.

Unconfined livestock production can cause changes in vegetative cover and soil physical properties that may result in increased rainfall runoff and pollutant transport to surface waters. The most common stream water quality result is elevated counts of indicator bacteria. Increased levels of inorganic and organic sediments with associated plant nutrients and oxygen demands may result from problem areas. These areas are usually only a small portion of the total production system and are readily identified by observation. Generally the pollutant levels from the remainder of the production site are not discernible from background levels. If other changes, such as those affecting groundwater quality, occur, they are of no environmental consequence.

A major challenge remaining is to demonstrate cost-effective routes toward achievement of various levels of pollution control from unconfined animal production.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Animal Husbandry Livestock Range grasses Pasture Water Pollution Agricultural Wastes	Nonpoint pollution source Unconfined animal production Water pollution sources Agricultural land runoff Animal Wastes	43 Ø 68 D 98 B

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